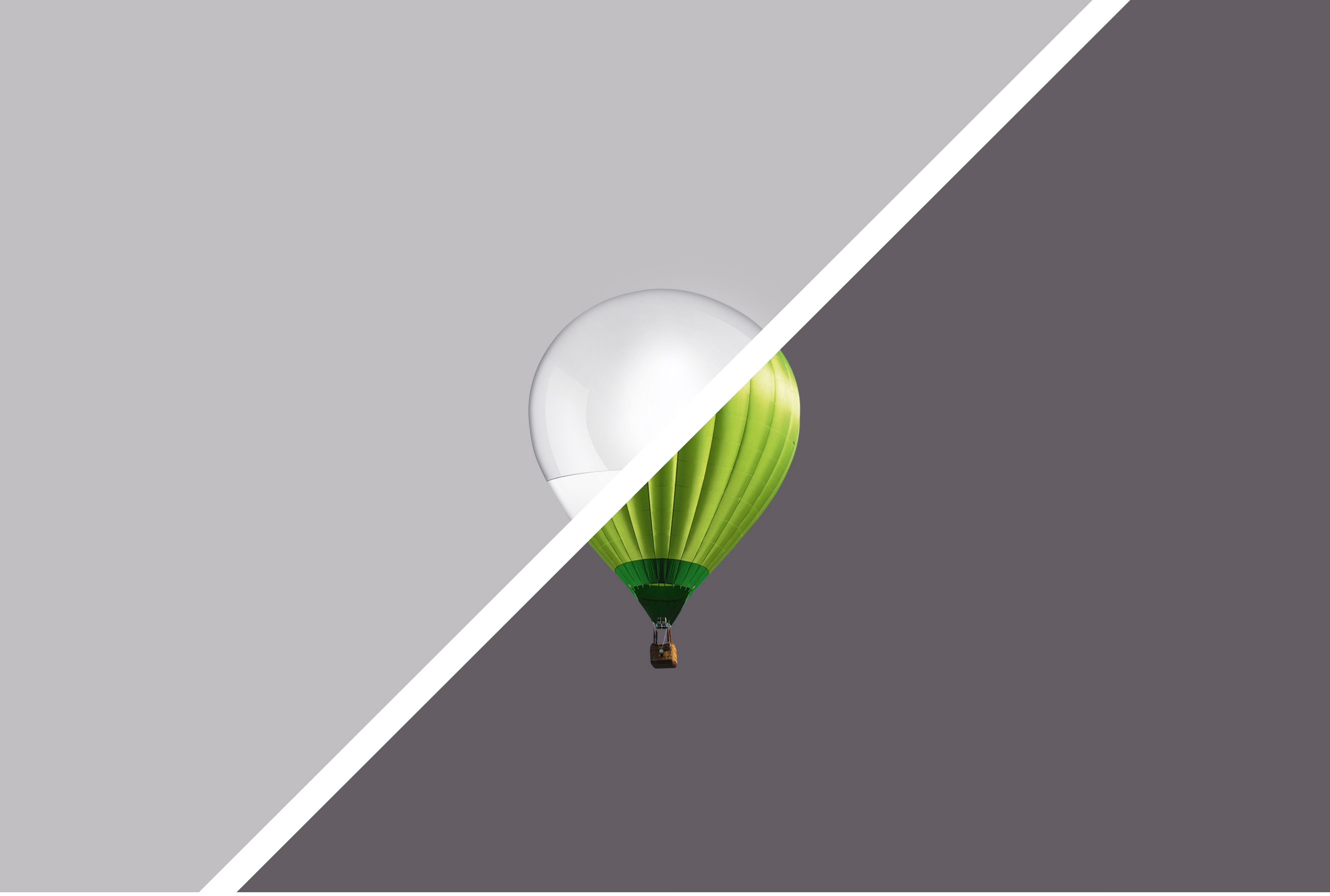
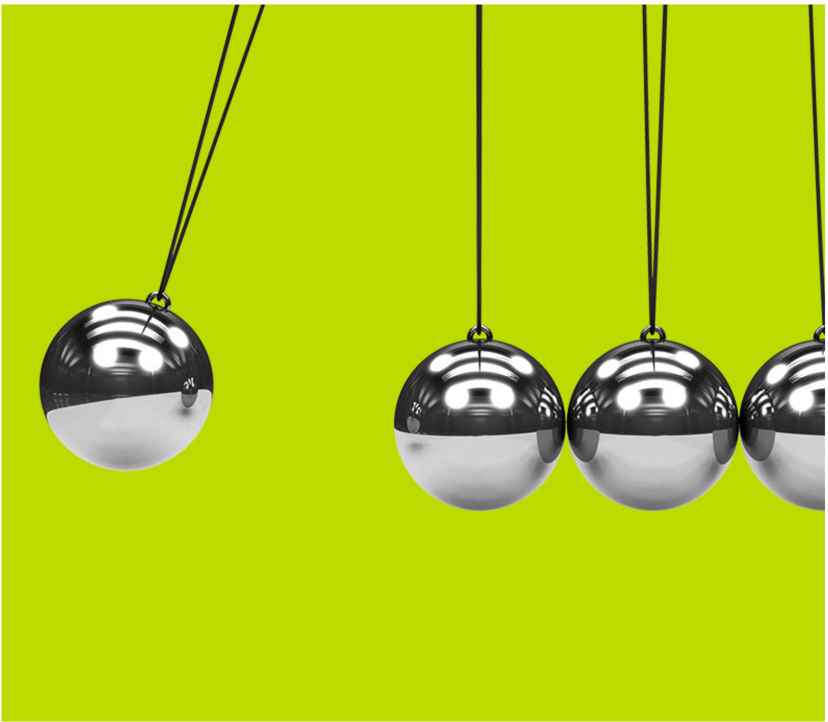


Blockchain Technology in the Energy Ecosystem

An explorative study on the disruptive power of blockchain technology in the Dutch energy ecosystem

Amber Voets



Blockchain Technology in the Energy Ecosystem

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Preface

Almost six years ago, a shy, eighteen year old girl came to Delft to follow her dream. She wanted to become an architect. Well, a lot can change in six years.

When finishing my Bachelor in Architectural Engineering, I realised that my dreams had changed and decided that it was time for something different. Being in a challenging and innovative environment such as the TU Delft made me realise my interests are much broader, and that innovation particularly fascinates me. This is why I made the choice to start the Master Management of Technology. A choice of which I am still truly happy to have made. A topic that is of particular interest to me, is the transition which the energy industry is currently undergoing. That is how I got into contact with Enpuls, and we decided to perform a research to explore the disruptiveness of blockchain technology in the energy industry. This document is the end product of six months of research at Enpuls and the Delft University of Technology, and the end product of six years of hard work, learning, and above all, a lot of fun.

This report is intended for anyone willing to explore blockchain technology, and particularly, the use of blockchain technology in the energy industry. Because both blockchain technology as well as the energy industry are quite complex topics, one of the goals of this research was to be able to discuss both topics in an understandable language. The reader with more than basic knowledge on one or both of these topics could therefore sometimes perceive our content as more elaborate than necessary.

Without the support of Enpuls, and especially my supervisor Frank van Rossum, this research project would not have been possible. Thank you for your warm welcome, for making me part of the Enpuls team, for your motivation, for sharing your knowledge, and introducing me to the people that have been very important for my research.

I would like to thank my first supervisor, Mark de Reuver, for his enthusiasm when we first discussed this research project and his continuous and direct supervision during the past months. During our meetings, you kept challenging me to get the most out of my work. Although I have to admit that this was difficult and a bit frustrating sometimes, in the end, I am proud of the result. I would also like to thank the two other members of my graduation committee, Paulien Herder and Emile Chappin. Thank you for the pleasant meetings, and for the valuable insights and talks which helped me to improve my research.

Furthermore, I would like to thank the ten experts who found the time to be part of my research project. I am still amazed by your enthusiasm and your willingness to share your widespread knowledge and ideas concerning the energy industry and blockchain. I would also like to thank all the other people who cleared their busy schedules to have a talk with me.

Last but not least, I would like to thank my family and friends for supporting me during this journey. I especially owe a big thank you to my mom and dad, Jasmijn, Bob, and Jeroen. Thank you for the distractions when I needed them, and for your endless support and believe in me.

Amber Voets
Delft, August 2017

Summary

Today's energy system has originally been developed based on central energy production and a passive consumer, whose interests have to be represented by the energy suppliers and distribution system operators. However, the industry is quickly changing. The share of renewable energy is growing, and consumers are increasingly involved in the production of energy. As a result, the share of intermittent energy sources increases and so does the need for flexibility in the energy industry. Therefore, it is questioned whether the current system in the energy industry still fits with today's developments.

To allow for flexible demand and supply of energy, digital technology for communication between computers or devices and electricity providers and consumers will become necessary. This will help to balance production and consumption at each time resolution, without high costs and unnecessary bothering of consumers. Blockchain is a technology that could potentially serve as a solution for a new energy industry system. Blockchain enables direct and reliable transactions of assets, between every party willing to do so, without the need for an intermediary or central party in control.

Often, blockchain is viewed from a technology-based perspective, in which blockchain is seen as a new technology that can be adopted by firms in different ways, which leads to a new round of technological competition. In this study we use another, less used perspective, namely the new institutional economics perspective. From this perspective, blockchain is viewed as an 'institutional technology', because it has the ability to coordinate people in, for example, making economic transactions, since it enables new types of contracts and markets. This way, blockchain can compete with organisations and markets. As a result, the application of blockchain could lead to disintermediation and decentralisation of the system. Hence, as the current energy industry system consists of many intermediary roles, blockchain technology could change the industry and lead to the removal, change, and emergence of new roles, relationships, and interdependencies that will fundamentally differ from the current system. Therefore, it is assumed that the application of blockchain in the energy industry could potentially result in a completely new configuration for the energy ecosystem.

The goal of this study is to explore whether there might be different ways to organise the energy ecosystem with blockchain as the enabling technology. Because there are a lot of uncertainties, a qualitative and explorative perspective is needed. The objective that has been formulated for this research is:

To develop future scenarios on ecosystem configuration within the Dutch energy industry to explore the disruptive power of blockchain technology

The main research question that will be answered in this research is:

What are possible consequences of the implementation of blockchain as institutional technology on the business ecosystem configuration of the Dutch energy industry?

Business ecosystems are used as a lens to view the energy industry system in the Netherlands. We use the following definition of business ecosystems for our research: *A business ecosystem is a networked system of different types of actors that are tied to each other through relationships, and interact both cooperatively and competitively.* We have formulated a theoretical framework based on the business ecosystems concept to describe and analyse the ecosystem of the Dutch energy industry.

We have formulated four future scenarios on ecosystem configurations for the Dutch energy ecosystem. Scenario planning was found to be an appropriate method for this project, because of the existing uncertainty regarding both the development of the transition in the energy industry, as well as the development of blockchain technology. Because of the exploratory nature of this study, the intuitive logics approach has been used. We used the eight-step approach by Schwartz (1991) to derive the five stages of this research project:

1. Problem definition. Define the aim and the boundaries of the study and generate a clear understanding and overview of the context of the study.
2. Identify the key drivers. Identify and analyse trends which both directly and indirectly influence the context of the study, and determine the most important and uncertain trends.
3. Select the scenario logic. Define the scenario framework based on the two most important and uncertain trends, to structure the development of the scenarios.
4. Formulate the scenario narratives. Describe the principles for each of the scenarios, using qualitative storylines and the most important trends from stages 2.
5. Assess the implications. Assess the implications or potential impacts of the scenarios, using qualitative storylines and images.

For stage 1, we specified the focal issue of this project as *'the potential and disruptive impact of blockchain technology for the energy industry, with the main focus on changes in the configuration of the corresponding ecosystem'*. Furthermore, a thorough literature study on blockchain technology has been carried out, and the business ecosystem for the Dutch energy industry has been modelled based on our theoretical framework, to generate a clear understanding of the context of our study. For stage 2, we used an external trend list from Enexis. We analysed this trend list critically, using criteria to determine the relevance of the trends for our project, and the STEEP analysis tool to categorise the trends. Based on this analysis, the trends have been re-clustered into twelve trends. Thereafter, the twelve trends have been analysed based on their impact on the ecosystem, the uncertainty of their development path, and the impact they have on the development of the other trends, using an impact and uncertainty analysis through an expert survey, and a cross-impact matrix. In stage 3, we selected the two most important and uncertain trends to construct our scenario framework, based on the results of stage 2. The trends *'acceleration of technological breakthroughs'* and *'increase in decentralised energy production'* were found to be the two most important and uncertain trends. We plotted these two trends on a 2x2 matrix, which has been used as scenario framework for the following stage. This resulted in the following four scenarios:

1. *Power Play* – Central energy production and incremental technological developments
2. *Power to the Devices* – Central energy production and radical technological developments
3. *Power to the People* – Decentral energy production and incremental technological developments
4. *Land of Plenty* – Decentral energy production and radical technological developments

For stages 4 and 5, we used a combination of a focus group and expert interviews. During the focus group session, a group of ten experts was asked to discuss possible future scenarios for the Dutch energy industry using the scenario framework constructed in stage 3. The assumptions developed during the focus group, and the knowledge generated in stage 1 were used to formulate the scenario narratives. Thereafter, five expert interviews were held to validate and enrich the scenarios and the implications of the scenarios, in an iterative process. After each interview, the scenario narratives were adjusted before they were send to the next expert. Afterwards, we analysed and described the implications for the energy ecosystem based on our theoretical framework.

Based on the results of our scenarios, we are able to answer our main research question:

What are possible consequences of the implementation of blockchain as institutional technology on the business ecosystem configuration of the Dutch energy industry?

We found four main consequences of the implementation of blockchain technology as institutional technology on the business ecosystem configuration of the Dutch energy industry. First of all, in each of the four scenarios, we saw that the implementation of blockchain technology affected the business ecosystem configuration of the Dutch energy industry. Secondly, in each of the four scenarios, the same functions within the energy ecosystem change or are replaced as a direct result of the implementation of blockchain technology. The functions of the supplier, the data facilitator, the market operator, the mobility service provider, and the independent service provider are directly replaced by an application based on blockchain technology. Thirdly, in each of the four scenarios the other roles and functions change or are replaced as an indirect result of the implementation of blockchain technology. The impact on the functions of the transmission system operator, the distribution system operator, the producer, the decentral producer, and the charge point operator is different per scenario. These functions are mainly affected due to technological and/or political developments, which are facilitated by blockchain technology and applications built on blockchain technology. Lastly, for the structure of the energy ecosystem, we saw that in each of the four scenarios the density of the ecosystem became higher, the centrality lower, the number of cliques decreased, and the diversity of roles within the ecosystem also decreased. Hence, the implementation of blockchain technology leads to decentralisation, and the removal of intermediaries in the energy ecosystem. As a result, the energy ecosystem will become more robust, flexible, secure, and efficient.

To conclude, we argue that the energy industry should recognise blockchain as an institutional technology. We acknowledge the fact that there still is a long way to go before blockchain can and will be used the way we presented in this study. There are still a lot of uncertainties, issues, and inconveniences that need to be solved. However, when we focus on the possibilities which blockchain could theoretically provide, we argue that blockchain has the potential to disrupt the energy ecosystem. In all of our four scenarios, the business ecosystem configuration for the energy industry changed due to the implementation of blockchain technology, and the energy ecosystem decentralised. But above all, in all of the four scenarios, blockchain is a potential competitor of organisations and markets within the energy industry. Therefore, we argue that blockchain is not solely a technology with the potential to lead to efficiency gains. Instead, blockchain is a technology with the potential to change the entire business ecosystem of the energy industry. As a result, the future of multiple functions in the current energy ecosystem becomes questionable.

The contributions of this research project are of both scientific, as well as practical value. First of all, we have studied blockchain technology from a new institutional perspective, instead of a technology based perspective. This way, we have provided a different perspective on the use of blockchain technology in the energy industry than most articles which have recently been published on blockchain technology. Instead of just focussing on supportive blockchain solutions for the energy industry, we have focussed on larger possibilities of this technology for the energy industry, with bigger consequences for the members of the ecosystem. Second, through our scenarios we have provided new ideas of how blockchain can be used in the energy industry. Our research has pointed out that blockchain technology has the potential to change the configuration of the energy ecosystem, and the potential to provide a solution for the challenges in today's energy transition. With the scenarios we have given an insight in the extremes towards which the energy industry could potentially move. The scenarios provide a starting point for future scientific research on the organisation of the energy industry. For current members of the ecosystem, the scenarios provide a comprehensible representation of possible future directions to which the energy industry could move. Hence, the scenarios will help these organisations to consider their future business strategy. Third, our model of the energy ecosystem provides a new way to look at the energy industry, presenting important actors, relationships, and flows, which are not included in the frequently used energy value chain. Thereby, it provides an extensive model to analyse the energy industry, which could be of both scientific as well as practical use as it gives an insight in the (sometimes inefficient) flows of exchange processes within the industry. Lastly, for Enpuls this research project provides valuable input to determine their opinion about blockchain technology, and the value of blockchain technology for the energy industry. It helps Enpuls to set direction for new research projects and new innovations and cases. Furthermore, the scenarios and the main conclusion of this research project help Enpuls to open the eyes of the rigid energy sector in their mission to drive for change and stimulate the energy transition.

This research has several limitations. First of all, scenario planning was used as methodology. This method is used to explore the extremes for the energy industry, but the resulting scenarios are not predictions of the future. The scenario narratives are based on expectations voiced by experts, and could be seen as extrapolations of current developments. However, the scenario narratives described are not forecasts: they are possible future worlds and are therefore fictional. Secondly, opinions and judgements are crucial in all scenario planning approaches, because scenarios attempt to say something about environmental changes we know little about. Hence, the outcome of scenarios are based on the level of knowledge and experience of the participants in the scenario planning process. To derive valuable input for our scenarios and enrich our results, we have included expert judgements in several stages of the process. A survey has been send out for the impact and uncertainty analysis, a focus group has been organized, and expert interviews have been held. Because specific knowledge was needed for these components, most experts used are active in the same industry (the energy industry, the field of blockchain technology, or a combination of both). Hence, a certain amount of bias could not be ruled out. For example, it is very well possible that the participants are overly optimistic about developments in the energy industry or the developments in blockchain technology than others would be. Third, the choice for the key driver for change ‘incremental vs. radical technological developments’ as axis for our scenario framework was questioned by a few of the participants during the focus group. Additionally, the axis appeared to be difficult to understand for some of the participants. Looking back at the process, there are other possible axes thinkable. Lastly, the scenarios derived in this research are based on the functionalities blockchain theoretically could provide, but are not yet possible in practice. Hence, they are based on the assumption that blockchain technology has been developed further, and has overcome its inconveniences. As a result, technological and regulatory constraints have not been taken into account.

At last, we provide several recommendations for future research. First, we recommend to further explore the different scenarios we have provided in our research. The scenarios should be studied in more detail to test the viability of the scenarios. Additionally, the scenarios could be modelled quantitatively and be used for simulation models. Furthermore, the scenarios constructed for this research project should be used for research on future business models for current energy ecosystem members. Second, the blockchain cases provide new insights for research on the use of blockchain technology in the energy industry. The cases should be studied in more detail to be able to determine the viability, which functionalities should be included into the blockchains, how the applications should be modelled and should work, what the interface of blockchain applications should look like, etc. Furthermore, it should be studied which regulatory changes are needed before a particular blockchain case could be realised. Third, the ecosystem developed for this research project to provide a new perspective to view the energy industry provides a starting point for future research on business ecosystems in energy industries. This model could be extended to increase the usability. Lastly, we recommend future research on scenario planning. Especially in changing and complex environments like the energy industry, this methodology could be a useful method for scholars. We suggest that more research should be done to structure the scenario planning process and to create a consistent methodology.

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ACM	Autoriteit Consument & Markt (translation: Authority Consumer & Market)
AI	Artificial Intelligence
CIA	Cross-Impact Analysis
CIM	Cross-Impact Matrix
CPO	Charge Point Operator
DAO	Decentralised Autonomous Organisation
DSO	Distribution System Operator
EDSN	Energy Data Services Nederland (translation: Dutch Energy Data Services)
ENTSO-E	European Network of Transmission System Operators for Electricity
EV	Electric Vehicle
IoT	Internet of Things
MSP	Mobility Service Provider
NEDU	Nederlandse Energie Data Uitwisseling (translation: Dutch EnergyDataExchange)
ODA	Onafhankelijke Diensten Aanbieder (translation: Independent Service Provider)
PV	Programma Verantwoordelijke (translation: programme responsible party)
SMEs	Small and Medium Enterprises
STEEP	Social, Technological, Economic, Environmental, and Political
TCE	Transaction Cost Economics
TIA	Trend-Impact Analysis
TSO	Transmission System Operator

Glossary

Aggregator	A party offering consumers help to save energy and/or energy costs through flexible procurement of energy and/or return of energy.
Blockchain technology	The underlying technology of blockchain applications.
Consumer	The end-user of electricity. A consumer can either be a small consumer (households and small and medium firms) or a large consumer (large (industrial) firms).
Charge Point Operator (CPO)	A party responsible for the charging points for EVs.
Data Facilitator	A central organisation for administrative links between different market roles.
Distribution System Operator (DSO)	The party responsible for the regional energy grids, which transport electricity from the transmission network to the end-consumer.
Dominator	A business ecosystem member role. Dominator organisations are the organisations which eliminate other firms in the ecosystem.
Ecosystem	A networked system of different types of actors that are tied to each other through relationships, and interact both cooperatively and competitively.
Hybrid Blockchain	A blockchain which is permissioned, but not fully centralised. Often there is a consortium of organisations or institutions controlling this blockchain.
Independent Service Provider (ODA)	A party which is certified to request smart metering data from data facilitator EDSN to visualise this data at request of the consumer.
Ledger	A record of ownership.
Link	A representation of a relationship between members of an ecosystem.
Keystone	A business ecosystem member role. Keystone organisations provide a set of common assets that other organisations use to build their own offerings.
Market Operator	A party providing a platform for the trade of energy in the day-ahead market, the intraday market and the balance market.
Miner	A special kind of node in a blockchain network, which participates in the verification process.
Mobility Service Provider (MSP)	A party selling mobility products and services, like a charging subscription, and a charging card for EV drivers.
Netting Agreement	A prosumer can return self-generated energy to the energy system in the case of a surplus. The energy will be deducted from the energy bill.
Niche player	A business ecosystem member role. Niche players are the organisations that have specialised themselves in a particular domain of the ecosystem.
Node (blockchain)	A computer, connected to a blockchain network.
Node (ecosystem)	A representation of a member of an ecosystem.
Permissioned Blockchain	A blockchain which requires a participant to have certain credentials to have access to the blockchain and to be able to interact.

Permissionless Blockchain	A blockchain to which anyone can have access to and interact in the blockchain network. Anyone can read the blockchain, send transactions, and participate in the consensus process. Also called a public blockchain.
Producer	The owners of the power plants at which electricity is generated.
Programme Responsibility (PV)	Requires programme responsible parties to notify the TSO of the electricity volume they will supply to, or take from the system, each fifteen minutes, one day ahead.
Prosumer	A consumers that both buys energy, as well as produces energy.
Scenario	A possible future world, based on assumptions and expectations.
Scenario planning	A structured method to derive possible future worlds, based on key drivers for change.
Smart contract	A code for a programmed contractual agreement between parties.
Supplier	A party that produces electricity and sells the electricity produced to their end-consumers, or a party that buys electricity from electricity producers and sells it to their end-consumers (retailer).
Transmission System Operator (TSO)	The party responsible for the national high-voltage grid.

1. Introduction

1.1 Context

Three important pillars of the Dutch energy industry system are reliability, affordability and sustainability. For a reliable energy system it is of utmost importance that demand and supply are balanced at any moment, and the capacity to transport energy through the system is sufficient. To be able to balance demand and supply, a system of different markets has been developed and the Distribution System Operators (DSOs) and the Transmission System Operator (TSO) have been made responsible for the stability of the energy infrastructure. The central thought in this energy system is that that the DSOs and the TSO always have to make sure to have enough capacity to be able to meet demand (Donker, Huygen, Westerga, Weterings, & Bracht, 2015).

Electricity itself is traded in different electricity markets: the long-term market, the day-ahead market, the intra-day market, and the balance market. In these markets, electricity producers sell their electricity to users. Because the electricity sold cannot yet be stored on large-scale, electricity has to be produced at the time of use. In order to be sure that the demanded amounts of electricity can be supplied and distributed, the different electricity markets have been established. The current system assumes a passive consumer, whose interests have to be represented by the energy provider and DSOs (FUSE, 2017), because the electricity markets are all centrally organised, and not open for small users like households and small/medium organisations (Donker et al., 2015).

However, the industry system is quickly changing as new technologies to produce or store energy arise, and consumer behaviour starts to change. Consumers change from being passive consumers to being active consumers or even prosumers. These developments have led to new trends being present in the Dutch energy industry. Firstly, there is an increase in renewable energy sources (Donker et al., 2015). Goals have been set to reduce greenhouse gas emissions, and technological developments allow for increasing sustainable ways to generate energy, and quickly decreasing prices for sustainable energy technology (FUSE, 2017). The growth in the amount renewables goes hand in hand with an increase in intermittent energy sources, like wind and solar energy. As a result, the challenge to balance demand and supply, every time and everywhere, has grown, as wind and solar energy depend on the availability of wind and sunlight respectively. Secondly, there is an increase the initiatives to generate energy locally and regionally. This results in an increase in decentral energy supply (Donker et al., 2015). Today's energy system was originally developed based on central energy production, hence, the flexibility in the energy industry system which is needed for these trends has not been incorporated in the system. Therefore, the current energy system does not fit with today's developments anymore (Donker et al., 2015; FUSE, 2017; Matilla et al., 2016; Hellström, Tsvetkova, Gustafsson, & Wikström, 2015). To allow for flexible demand and supply of energy, digital technology for communication between computers or devices and electricity providers and consumers will become necessary. First, this is needed to be able to secure the balance of production and consumption of energy for each time resolution. Second, this will avoid high costs and unnecessary bothering of consumers (Matilla et al., 2016; FUSE, 2017; de Reuver, van der Lei, & Lukszo, 2016). A potential technology that is currently on its rise is blockchain technology. Blockchain technology enables direct and reliable transactions of assets between every party willing to do so, without the need for an intermediary or a central party in total control over the process. As such, blockchain technology could potentially change the current energy system and lead to completely new roles, relationships and interdependencies that will fundamentally differ from the current system.

1.1.1 Blockchain Technology

In 2008, an article under the pseudonym Satoshi Nakamoto appeared, introducing a new cryptocurrency called the Bitcoin. The technology behind this cryptocurrency, blockchain technology, allowed for “electronic transactions without relying on trust” (Nakamoto, 2008, pp. 8). In order to prevent double-spending, they proposed a peer-to-peer network, using proof-of-work to store a public history of transactions. If honest nodes, meaning honest users, control the majority of CPU power, they say it becomes computationally impractical for an attacker to change the transactions (Nakamoto, 2008), hence the system can be considered tamper-proof.

Iansiti and Lakhani (2017) provide five principles underlying the blockchain technology:

1. Distributed database:
   Each party has access to the entire blockchain database and its full history, and there is no single partly controlling the data or information in the blockchain. No intermediary is needed to verify the records of transaction partners.
2. Peer-to-peer transmission:
   There is no central node needed for communication, communication takes place directly between peers. Each node stores and forwards data to all of the other nodes in the network.
3. Transparency with pseudonymity:
   Every transaction and its value are visible for everyone with access to the system. Each node can choose to remain anonymous with their unique character that identifies them as a user, or to provide their identity to other users.
4. Irreversibility of records:
   Once a transaction is entered in the database, it cannot be changed because they are linked to every transaction that took place before.
5. Computational logic:
   Blockchain transactions can be tied to computational logic. This means that the transactions can be programmed, and that users can develop algorithms and rules to automatically trigger transactions between the users.

Although blockchain still is a relatively young technology, which has not yet reached maturity, it shows great potential. Therefore, it is important for organisations to clearly asses the consequences the introduction of blockchain could have on their existing business models. The bitcoin cryptocurrency, based on blockchain technology, at first woke up the financial industry, but now the use of blockchain technology in other industries, including the energy industry, is widely being explored. Established organisations active in the energy industry have to take into account the trends regarding renewable energy sources, decentralised energy generation and increased (autonomous) mobility, as young start-ups are waiting to jump in with revolutionary new ideas.

1.1.2 A Changing Industry

Often, blockchain is viewed from a technology-based perspective, in which blockchain is a new technology that can be adopted by firms in different ways, which leads to a new round of technological competition. When looking at blockchain from an economic perspective, blockchain can be seen as an institutional technology, because it has the ability to coordinate people in, for example, making economic transactions, since it enables new types of contracts and markets. This way, blockchain can compete with organisations and markets (Davidson, De Filippi, & Potts, 2016a, 2016b; Macdonald, Allen, & Potts, 2016). This means that blockchain technology has the potential to disrupt society, because it "enables direct and reliable transactions of valuable and scarce assets over the internet between any two parties willing to do so" (Matilla et al., 2016, pp. 3) and it could provide efficiency gains as it eliminates the need for a trusted intermediary. In an industry like the energy industry, in which the current system does not fit with current developments in the industry, blockchain technology could lead to changing, and even new roles, different relationships, and different interdependencies. For this reason, it is assumed that blockchain technology could potentially result in a completely different industry system, or to put differently, a completely new configuration of today's ecosystem in the energy industry.

1.2 Research Focus

From previous sections, it can be concluded that the way the energy industry system has been constructed does not match the current developments in the energy industry, including the two major trends of the growing availability of renewable energy sources, and the increasing amount of locally or regionally produced energy. Blockchain technology has the potential to change the energy industry system and to facilitate the decentralisation of the industry system. However, as this technology is still immature, only a few possible, incremental applications of blockchain technology in the energy industry have been developed. As a result, the possible impact on the configuration of the ecosystem is still unknown. Because there is still a lot of uncertainty around the potential of blockchain technology, a study in this area of research has an explorative nature. In this research, large consumers have not been included, because the process for large consumers is more streamlined, with less intermediary parties. This is in contradiction with the retail market, which is a complex system with more intermediaries. Therefore, the focus of this research will be on the energy retail market.

1.2.1 Problem Statement

From a practical point of view, it is clear that there is a need for a change in the current energy system. The trends occurring in the energy industry, an increase in renewable energy sources and an increase in decentral generated energy, put pressure on the current energy industry system. These developments require a level of flexibility which the energy industry system is currently not capable of, because the energy industry system was initially designed on the basis of centrally generated energy and passive consumers. As a result, it is questioned whether the current energy system still fits. Renewables like wind and solar energy, and initiatives for locally generated energy give consumers the opportunity to be their own producers of energy and shake up the future role of energy producers, energy providers and network operators. According to Hekkert (2016, pp. 5) "we are locked-in in our current energy system, our current policy paradigms, and innovation paradigms". He calls for attention on how to break through this lock-in, and he encourages the sector to experiment, because "only through the use of experiments we will be able to see if the interaction between technology, people and rules will work or not" (Hekkert, 2016, pp. 6). When experimenting, it is important to look at the ecosystem of the energy industry as a whole, instead of looking just at underlying business models (Hellström et al., 2015). Because business models mostly only say something about one particular organisation or type of organisation.

Secondly, with blockchain technology, new possibilities to construct industries are emerging. Several organisations are currently developing blockchain solutions for the energy industry and some of the ideas are even already being developed into real projects or pilots, like Block-Charge, Power-peers, and the Brooklyn Microgrid (PwC, 2016). Although these ideas seem to be promising, the implementation of blockchain remains a relatively incremental change, focussed only on a small part of the ecosystem. As a result, although it is claimed by some that "blockchain will revolutionize business and redefine companies and economies" (Iansiti & Lakhani, 2017, pp. 4), the real disruptive power of blockchain in the energy industry is not known.

Following this line of reasoning, blockchain technology has the potential to create completely new ecosystems that fundamentally differ from the current ecosystem of the energy industry. A focus on the ecosystem as a whole, and an understanding of how the configuration of the ecosystem could change when blockchain technology is implemented, is however lacking. Within this research we will address the implications of blockchain technology on the possible configuration of the ecosystem for the Dutch energy industry to close this knowledge gap.

1.3 Research Objective and Research Questions

From both the practical as well as the scientific problem statements, one can conclude that new technologies and initiatives have the potential to completely change the ecosystem around the energy industry. The implementation of blockchain technology could change or replace activities within the current energy ecosystem and could thereby change or replace the roles of the organisations which are currently active within the ecosystem. As a result, the ecosystem configuration could completely change. Because the renewable energy sources and local initiatives are just starting to reach the larger public, and much is still unknown around the possibilities of blockchain solutions, a qualitative and explorative perspective is needed to study these developments and the impact of these developments on the ecosystem configuration. Although this study will have a qualitative and explorative character, the results of this research can in the future be analysed or modelled quantitatively.

The goal of this study is to explore whether there might be different ways to organise the energy ecosystem with blockchain as the enabling technology. Therefore, the following research objective has been formulated:

The objective of this research is to develop future scenarios on ecosystem configuration within the Dutch energy industry to explore the disruptive power of blockchain technology.

The main research question that followed from this objective is:

What are possible consequences of the implementation of blockchain as institutional technology on the business ecosystem configuration of the Dutch energy industry?

In order to be able to answer the main research question, the following five sub questions have been formulated. Each sub question will briefly be discussed.

SQ1: What are business ecosystems and how can business ecosystem configurations be analysed?

Business ecosystems will be used as a 'lens' to view the energy industry system in the Netherlands. Important for this study is to analyse which parties are involved in the system, which roles they fulfil, and what relationships and interdependencies there exist. The mutual relationships and interdependencies between the different roles and activities within the ecosystem will be called the configuration of the business ecosystem. To be able to analyse the ecosystem around the energy system, first a clear theoretical and conceptual framework on business ecosystems and how to analyse business ecosystems is needed.

SQ2: What is blockchain technology, how does it work, and what are the possibilities this technology brings forth for the energy sector?

A clear understanding of blockchain technology, its functioning and its possibilities are needed to explore potential blockchain solutions for the energy system, and which activities and roles in the energy system it could change, or even eliminate, and in what way.

SQ3: How is the ecosystem around the energy industry system in the Netherlands currently arranged?

Based on the first sub question, the ecosystem around the energy system in the Netherlands will be described. This information is needed to be able to explore activities and roles blockchain technology could have an impact on.

SQ4: What are possible scenarios for the ecosystem configuration of the Dutch energy industry system, when blockchain is implemented as an institutional technology?

Based on the outputs from previous sub questions, possible future scenarios for the Dutch energy industry system can be formulated. This will help us to derive possible future business ecosystems.

SQ5: Based on the evaluation of the possible future scenarios for the ecosystem configuration of the Dutch energy industry system, what is the potential of blockchain technology?

Lastly, the scenarios defined in sub question four have to be analysed and evaluated to explore the potential of blockchain technology on the current roles and activities in the business ecosystem for the Dutch energy industry.

1.4 Research Framework

Based on the previously discussed sub questions, the following research framework has been developed (see Figure 1). The first sub question is used to describe the theoretical background of this study. This contains the theory on business ecosystems and business ecosystem configurations. The second and third sub questions describe the domain of blockchain, as well as the domain the current energy system. Through the last two sub questions, questions four and five, the scenarios for a future ecosystem of the energy sector will be developed and evaluated to be able to answer the main question of this research.

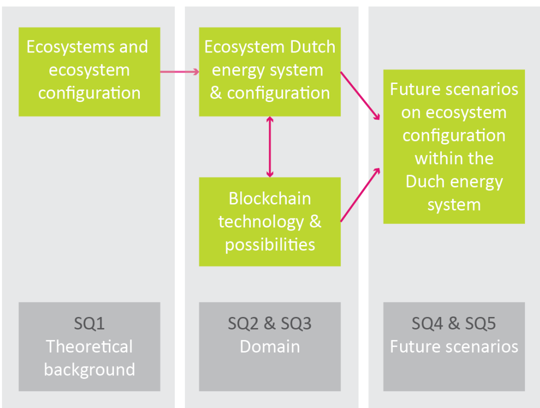

Figure 1: Research Framework

1.4.1 Research Outline

A visual representation of the thesis outline is given in Figure 2. This chapter, chapter 1, provided the objective and research questions for this research project, based on the problem statement. Chapter 2 will provide a description of the ecosystem theory and the approach on how to describe and analyse the current ecosystem of the energy sector based on this theory. The result of this chapter is a theoretical framework for this research project. This framework will be used in the domain studies (chapters 4 and 5), and in the development of the scenarios and the implications of the scenarios (chapter 7). Chapter 3 specifies the research design for this study. This chapter includes the introduction and explanation of the methodology and data collection strategy used.

Chapters 4 and 5 are used to gain a clear understanding of the domains of blockchain technology and the energy industry. In chapter 4 the blockchain technology domain is analysed to provide an overview of blockchain technology, the possibilities, and the current state of blockchain applications in the energy industry. Chapter 5 provides an analysis of the current energy industry system domain. The theoretical framework from chapter 2 is used to develop a model of the current business ecosystem in the Dutch energy industry. These two chapters together provide the input for the sixth and seventh chapter in which future scenarios for the Dutch energy industry system will be developed.

Chapter 6 provides the results of the scenario planning process, prior the development of the scenario narratives. This chapter is followed by chapter 7 in which the scenario narratives and the implications of the scenarios on the configuration of the energy ecosystem are described. Lastly, chapter 8 provides the conclusions of this research project, and will reflect on the process and outcomes of this study. Additionally, this chapter includes recommendations for future research and the use of the results of this explorative study.

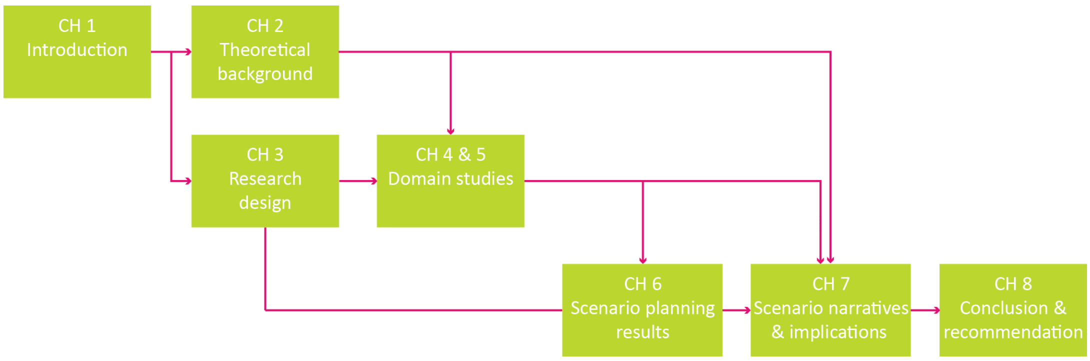

Figure 2: Research outline

2.

Theoretical Framework

In the previous chapter, the research objective and research questions of this study were formulated. The goal of this chapter is to develop a theoretical framework to analyse and explain changes in the configuration of the energy ecosystem, and provide and answer to the first sub question: *What are business ecosystems and how can ecosystem configurations be analysed?* The theoretical framework will provide guidelines to analyse and compare the different ecosystems in the scenarios that will be formulated later on in this report.

First, in section 2.1 we will explain our choice for business ecosystems as the conceptualisation for the energy industry system. This section starts with the formulation of criteria which the conceptualisation has to meet. Thereafter, three main inter-organisational network concepts will be discussed. Based on the criteria, the best suitable inter-organisational network concept for this study will be chosen.

Second, because the objective of this research is to develop future scenarios on *ecosystem configuration,* sections 2.2 and 2.3 will describe the concepts we understand as part of ecosystem configurations. Following the main research question of this study, we distinguish two important levels that together comprise the configuration of an ecosystem. The first level is the actor level, the second level is the network level. Section 2.2 is focussed on the actor level and will elaborate on concepts to describe and analyse actors and the relationships between actors. Section 2.3 is focussed on the network level and will discuss several characteristics that help to describe the structure of an ecosystem.

Third, we need to understand why blockchain has the potential to disrupt the current energy industry system. Therefore, section 2.4 will discuss the new institutional approach of transaction cost economics.

Lastly, based on the previously described concepts and theories, a theoretical framework will be developed to guide the scenario development process, and structure the description and analysis of the ecosystems and ecosystem configurations of the scenarios.

2.1 Inter-organisational Network Concepts

The focus of this research is on the disruptive power of blockchain on the Dutch Energy industry system. Therefore, to view the energy industry system as a whole we need an inter-organisational network concept. There are different inter-organisational network concepts to analyse a system of actors. Often used conceptualisations are business ecosystems, Porter's Value Chain, and value networks. To be able to choose a concept that suits our research, we first need to set up the criteria the inter-organisational network concept has to meet.

First, we need to define the focus of our inter-organisational network concept. Generally, the focus of inter-organisational network research can have two different directions, 1) the view of the individual firm or organisation in the network, which is called the ego-centric perspective, and 2) the view of the network level, which is called the socio-centric perspective (Barnes, 1972; Provan, Fish, & Sydow, 2007). Because the focus of this research is not on the network from the perspective of one specific organisation, but rather the network as a whole, a concept is needed that allows for a socio-centric perspective.

Second, the aim of this study is to develop future scenarios for the Dutch energy industry system. Because we do not know yet what form the networked systems in these scenarios will take at this point in time, we need a concept that allows for some flexibility. With this we mean we do not want a concept with clear guidelines or narrow characteristics that will restrict the possible configurations of the networks.

Lastly, in the current energy industry system there are players that compete with each other, but at the same time have to cooperate. Hence, the last criterion is that we need a conceptualisation of a networked system in which cooperation and competition can both exist.

The following sub-section will provide a brief discussion on the concepts and theories of business ecosystems, value chains and value networks. Based on the three criteria described above we will discuss which of these concepts fits best with the objective of this study.

2.1.1 Business Ecosystems

A business ecosystem can be seen as a perspective or lens to look at a company's environment, or at an industry as a whole. The natural ecosystem has been used as an analogy to describe many different processes and structures. In most cases, these analogies served as a tool to understand a particular system. Instead of looking just at the direct network of a company, the ecosystem metaphor in the business environment reaches further (Peltoniemi & Vuori, 2004). Rothschild was the first to introduce the biological ecosystem as an analogy for the economy: "Key phenomena observed in nature – competition, specialisation, cooperation, exploitation, learning, growth, and several others – are also central to business life." (1990, pp. xi). A few years later, Moore was the first to view a company as a member of a business ecosystem, rather than just as a part of a particular industry. According to his ideas, the business ecosystem crosses various industries and consists of participants that develop capabilities around a new innovation together. The members of a business ecosystem work both cooperatively as well as competitively in order to "support new products, satisfy customer needs, and eventually incorporate the next round of innovations." (Moore, 1993, pp. 76). Later, in his book *The death of Competition*, Moore (1996, pp. 26) gave a slightly more elaborate definition of a business ecosystem when he said that a business ecosystem is "an economic community supported by a foundation of interacting organisations and individuals – the organisms of the business world. This economic community produces goods and services of value to customers, who are themselves members of the ecosystem." Furthermore, in Moore's view the ecosystem consists of suppliers, lead producers, competitors, and other stakeholders. He adds that the business ecosystem does not necessarily stop at the boundaries of a traditional industry, it can cover multiple industries or sectors together. From this we can conclude that business ecosystems do not have clear-cut boundaries, and that an important characteristic of business ecosystems is that both competition as well as cooperation can be present at the same time.

Business ecosystems are sometimes also seen as a new organisational approach (Anggraeni, Hartigh, & Zegveld, 2007). Because we want to conceptualise a networked system, we rather use ecosystems as a metaphor than an organisational form. Besides the ecosystem metaphor for the economy and for the business environment, the natural ecosystem has been used as a metaphor for other fields. Following the ecosystem analogies of the economic ecosystem and the social ecosystem, an alternative description of business ecosystems has been provided: "… a dynamic structure which consists of an interconnected population of organisations. These organisations can be small firms, large corporations, universities research centres, public sector organisations, and other parties which influence the system" (Peltoniemi & Vuori, 2004, pp. 13). Important in this description of business ecosystems is the notion of interconnectedness between the organisations in the ecosystem. Because of the interconnectedness, the failure of one firm can lead to the failure of other members within the ecosystem. Some scholars argue that this means that there is a shared fate among the members of a business ecosystem (Peltoniemi, 2006), we argue that this is not necessarily the case for all ecosystems.

Others scholars emphasize the network in their description of business ecosystems. They say business ecosystems consist of large and loosely coupled networks of different entities that interact with each other (Iansiti & Levien, 2004a) or define ecosystems as "a networked system that contains a set of objects (e.g. actors, nodes, etc.) that are tied to each other." (Basole, 2009b, pp. 3). These last two descriptions of business ecosystems give a broad meaning to the concept of business ecosystems that allows for a flexible use of the concept.

2.1.2 Value Chains and Value Networks

An alternative approach to conceptualise a networked system is the value network approach. The value network approach has been developed from the value chain approach. Porter (1985) defined the firm's value chain to diagnose a firm's competitive advantage. The value chain includes the different activities within a firm that create value. In his value chain, Porter distinguishes primary activities and support activities. The primary activities consist of inbound logistics, operations, outbound logistics, marketing and sales, and services. They directly relate to the development or delivery of a product or service. The support activities on the other hand span the whole firm. They consist of firm infrastructure, human resource management, technology development and procurement (Porter, 1985). The value chain of one firm is linked to the value chains of supplying firms, and buying or distribution firms. The overall system can be seen as a chain of interlinked value chains of firms consisting of primary activities that lead to the final product of value for the consumer (Stabell & Fjeldstad, 1998). Although value chains are applicable for the analysis of the activities of one firm, when analysing a complete industry system, Porter's value chain is not suitable as it focuses on activities inside the organisation rather than the relations in the network.

Whereas a value chain implies the linear, sequential flow of goods, information, et cetera., a value network refers to multidimensional connectedness, or a web like structure (Peltoniemi, 2004). Also, the focus in value chains is limited to tangible assets, while the exchange of intangible assets, like knowledge, skills, expertise, etc., is not taken into account (Allee, 2000). Two types of value networks can be identified in the literature, namely internal value networks and external-facing value networks. The internal value networks are more focussed on the relationships between individuals within organisational groups or departments and the relationships between these various groups. External-facing value networks on the other hand, focus on the relationships between the organisation and its suppliers, investors, business partners and customers (Allee, 2008). For the purpose of this study, the external-facing focus of value networks would be of interest.

Several definitions of value networks can be found in literature. One definition of value networks is clearly focussed on the exchange of both tangible and intangible assets: "any set of roles and interactions in which people engage in both tangible and intangible exchanges to achieve economic or social good" (Allee, 2008, pp. 6). Other descriptions of value networks that were found in literature are more focussed on the relationships between the actors in a network: "a series of dyadic and triadic relationships that have been designed to generate customer value and build sustainable competitive advantage to the creator and manager" (Campbell & Wilson, 1996, pp. 3), and "a dynamic network of customer/supplier partnerships and information flows" (Bovel & Martha, 2000).

From these descriptions on the meaning of value networks, it becomes clear that besides a focus on intangible assets, the focus on relationships is of great importance in value networks. This explains why positive network externalities can increase the value perception of customers. Generally seen, if one customer is added to the network, this directly affects the value created through the network for other customers. However, this also brings forth challenges. A new product or service generally has few initial users, while at the same time the costs are most of the time the highest in this phase.

Value networks have a few explicit characteristics that can be identified in the literature. For example, it becomes clear that each member in a value network has its tasks that are strictly defined by the network. Furthermore, the value network has a co-operative structure, meaning that the members of the value network usually do not compete with each other. Only when the members of the network are chosen there can be competition between (potential) members. Besides the co-operative structure of a value network, there is generally one actor that is larger than the other actors in the value network. Because of its bigger size, small suppliers can become completely dependent on this actor, making the larger actor a dominant actor able to control (parts of) the network (Peltoniemi, 2004). Hence, a value network is usually controlled by one central actor.

2.1.3 Conclusion

In this part, the concepts of business ecosystems, value chains and value networks have been discussed. Based on the criteria that have been set up for the selection of an inter-organisational network concept, it is clear that the concept of value chains is not suitable because of its ego-centric focus. The two other conceptualisations, the business ecosystem and the value network, can be applied from a socio-centric perspective.

Both business ecosystems as well as value networks can be seen as networks of entities that interact with each other. Relationships and interdependencies between the entities of such a network are central concepts in both conceptualisations. Following the descriptions of business ecosystems and value networks mentioned above, the main difference between business ecosystems and value networks is the fact that actors in value networks cooperate to create value for customers and the network as a whole, while actors in business ecosystems can also have a competitive relationship. In value networks the different actors explicitly work together to reach a shared goal, and some authors add that value networks rely on a mediating technology. Furthermore, a value network differs from a business ecosystem with regard to control. In a value network there is mostly one actor that is much larger than the other actors, which has control over the network due to dependency of the smaller actors on the large actor. In business ecosystems control is most of the time decentralised due to mutual interdependencies (Peltoniemi, 2004).

In the energy industry system, interactions between different organisations or entities are not solely limited to collaboration, competition between the different actors can also exist. Additionally, with regard to control, in future scenarios it is possible that control is exercised by one actor but in this stage it is equally possible that control is divided over multiple actors. Hence, the ecosystem is more flexible in possible relationships, dependencies, actors, et cetera. Where the value network has several characteristics that limit the flexible use of this conceptualisation, the characteristics of the business ecosystem conceptualisation increase its flexible use. Therefore, based on the criteria that have been set up, we argue that the concept of business ecosystems is the most applicable inter-organisational network concept for this study. Based on the theory discussed above, the definition of a business ecosystem that will be used for this research is:

"A business ecosystem is a networked system of different types of actors that are tied to each other through relationships, and interact both cooperatively and competitively."

From this definition of a business ecosystem, a few concepts stand out: 1) the actors, 2) the relationships between actors, and 3) the networked system. Therefore, the ecosystem members and the structure of the networked system will be discussed in the following parts. Throughout this report, the terms business ecosystem and ecosystem will both be used interchangeably.

2.2 Ecosystem Members

As the inter-organisational network concept has been established, we need to be able to describe and analyse the possible changes in the configurations of the ecosystem for the Dutch energy industry system. Therefore, this section will focus on the members of a business ecosystem. A business ecosystem consists of actors that interact with each other. These actors can be seen as the members of the ecosystem. Actors can be individuals, groups of individuals, organisations, parts of organisations, groups of organisations and institutions. As mentioned before, the members of an ecosystem can be part of different networks, different value chains, and even from different industries. Each actor has specific activities, or functions, and resources. The actors are connected through relationships which are mostly developed through exchange processes. The network of each actor gives the actor access to other actors' resources (Hakansson & Johanson, 2002). Besides their activities, functions and resources, we can also ascribe a particular role to the actors of an ecosystem (Iansiti & Levien, 2004b).

2.2.1 Actors and Relationships

In this sub-section, we will discuss three different approaches to look at actors and relationships in networks. The first approach aims to visualise actors and their relationships in ecosystems. The second approach uses business models to describe a business ecosystem. The last approach uses Network Value Analysis (NVA) to identify where value in a network is created.

A first approach to describe or analyse the actors and relationships of an ecosystem is to visualise them (Basole, 2009a). Nodes and links are often used as elements to represent actors and their relationships in a network or ecosystem. The nodes are the actors, players, or entities within the ecosystem. The nodes have a label (the name of the actor), belong to a type or class (for example be 'supplier', or 'partner'), and contain an attribute (this can be the segment, the company size, revenue and geospatial position of the node). The links are the ties, connections or relationships between the different nodes. The attributes of the links are the strength of the relationship, the duration of the relationship, or the value exchanged. Additionally, the links can be directed or undirected (Basole, 2009a).

A second approach to describe the members of an ecosystem is to use the actors' business models. According to this perspective, the relationships between actors consist of offering and revenue. The actor's offering is the value that is created and proposed by the actor and its co-operators. Revenue can be described as the value the actor receives from its customers. These relationships between actors are in this approach described as the value creation structure of an ecosystem, which can be a chain, a network, or a mixture of both of these structures. Because the position and necessity of an actor in an ecosystem is determined by the actor's resources, capabilities, offering and financial performance, the position and necessity of an actor in the ecosystem can change (Kinnunen, Sahlman, Harkonen, & Haapasalo, 2013).

The last approach is the use of Network Value Analysis (NVA) to analyse business ecosystems. NVA helps to identify the value created in a network through the identification of participants of the network and the linkages, or relationships, between them. These linkages are sometimes called *network influences.* The following types of linkages can be identified (Peppard & Rylander, 2006; Tichy, Tushman, & Fombrun, 1979):

1. Exchange of goods and services
2. Affective and liking
3. Information and ideas
4. Influence and power

Having discussed these three approaches, we argue that the three approaches are complementary. Each of the approaches discusses a different way to describe and analyse the actors and their relationships within an ecosystem. The first approach visualises the actors and relations in the ecosystem. The second approach explains that the relations between actors are based on offerings and revenue. The third approach categorises the offerings and revenues in four categories. Because we argue that the three approaches support each other, we will combine the approaches to be able to derive a complete view on the actors and their relationships. We will do so by using the first approach to visualise the ecosystem through its actors and relations, and use the second and third approach to analyse the relations.

2.2.2 Member Roles

A business ecosystem is populated by different species, like the natural ecosystem. These species all have their own characteristics and consist of a number of agents. The agents share the characteristics of the specie, but can be different from each other (Hartigh, Tol, Wei, Visscher, & Zhao, 2005). This subparagraph will discuss the different role typologies actors can take on in a business ecosystem. Based on these discussions we can derive concepts to describe and analyse the members of the energy ecosystem and the relationships between them.

Iansiti and Levien (2004) have identified 3 primary roles or strategies to which the members of a business ecosystem can be categorised: *keystones, dominators, and niche players*. The fundamental role of keystone organisations is that they "... provide a stable and predictable set of common assets ... that other organisations use to build their own offerings" (Iansiti & Levien, 2004b, pp. 6). Hence, although they only make up a small part of the business ecosystem, they play a system wide role. Additionally, keystones can promote niche creation within the ecosystem by offering new, innovative technologies to different third party organisations. In this way, keystones are able to ensure their own survival and profitability. An effective keystone strategy, consists of creating values first, and then sharing this value with the other members of the ecosystem. Examples of keystones are Microsoft Corporation and Wal-Mart. Both effectively provided platforms that made the creation of new products by other parties easier and more efficient, encouraging niche creation, and eventually improving the health of the ecosystem (Iansiti & Levien, 2004a).

Next to the keystones, two types of dominators can be distinguished: a physical dominator and a value dominator. Where keystones improve the health of the ecosystem, dominators usually only harm the ecosystem. They are in fact the firms that eliminate other firms in the ecosystem (Iansiti & Levien, 2004a). The physical dominator aims to directly own a large part of the business ecosystem. Once a physical dominator becomes responsible for most of the value creation on its own, this means that the dominator will provide most of the products and services the customers need (Iansiti & Levien, 2004a), leaving little space for other organisations to create substitutes or even complementary products (Iansiti & Levien, 2004a). On the other hand, the value dominator has much less direct control over the ecosystem. The value dominator creates little value for the ecosystem, it mainly extracts as much value as possible from the ecosystem. In the end, the value extraction will lead to the collapse of the ecosystem and the value dominator (Iansiti & Levien, 2004b). An example of a dominator was IBM, who did not open up its platform to third party organisations in the era of the minicomputer (Iansiti & Levien, 2004a).

The largest part of the ecosystem generally consists of organisations following the niche strategy. These organisations try to develop capabilities that will differentiate them from the other organisations in the network.

Often, the niche players leverage complementary resources from keystones or other niche players which enables them to fully focus on their own specialisation domain, improving their efficiency and productivity. The leveraging of tools, technologies and standards from keystones could even be called critical to the success of a niche player (Iansiti & Levien, 2004a). As a result, a niche player is naturally dependent on other organisations within the ecosystem. Eventually, many niche players will find themselves in conflict with other niche players, keystones, or most likely, dominators. Only continuous innovations in their specialisation will make them successful in these conflicts (Iansiti & Levien, 2004b). The role division described by Iansitie and Levien is not static, niche players can for example develop into keystones in their current ecosystem, or become a keystone in their own ecosystem.

2.2.3 Conclusion

In this section we have discussed three approaches to describe actors and relationships in an ecosystem. The ecosystem consists of actors interacting with each other, and connected through relationships that are most of the time based on exchange processes. From the first approach it followed that ecosystem can be visualised using nodes, which are the actors, players or entities in the ecosystem, and links, which represent the relationships or connections between the nodes. The second and third approach made clear that relations between actors are based on exchange processes that can be categorised into the exchange of: 1) goods and services, 2) affective and liking, 3) information and ideas, and 4) influence and power.

Besides their activity/function and types of relationships, actors can also be characterised by the role they play within the ecosystem. Five types of roles can be identified, namely the keystone, the dominator, the niche players, bridge players and gatekeepers. The keystones are represented by organisations that provide a set of common assets that other organisations use to build their own offerings. The dominators can either be a physical dominator or a value dominator. The physical dominators goal is to own a large part of the business ecosystem to be able to provide most of the products and services for the consumers. The value dominator has less control, creates little value for the ecosystem and mainly just extracts value from the ecosystem. The niche players form the largest part of the ecosystem. These are the organisations that have specialised themselves in a particular domain of the ecosystem. The niche players are naturally dependent on other members of the ecosystem.

For each possible scenario one or more ecosystems have to be described, analysed and compared. For each ecosystem it is important to identify the members of the ecosystem. Therefore, in the scenario formulation phase, the members of the ecosystems will be characterised based on their activities or functions, their relationships with other members of the ecosystem using the combination of the three approaches described in sub-section 2.1.1, and the role they take within the ecosystem described in sub-section 2.2.2.

2.3 Ecosystem Structure

Following the main research question, this section is focused on the network level of the ecosystem configuration. Frequently studied at the network level is the network structure. Therefore, to study the network structure we rely on the method of Social Network Analysis.

2.3.1 Network Properties

Typical properties of a network structure are the network density, centralisation, and cliques (Provan et al., 2007). Because our main research question emphasises the change of roles and relations, we add diversity to this list of network properties.

Density – The density of a network says something about the overall connectedness of a network. It is the amount of ties, or relationships, in a network, relative to the total amount of ties possible in the network (Otte & Rousseau, 2002; Provan et al., 2007). The more ties relative to the total possible ties, the higher the density of a network.

(De)centrality – Networks are often associated with decentralisation, however, even in networks a certain degree of centrality can exist. Sometimes some organisations are considerably more centrally linked to other organisations than others. In more decentralised networks the connectedness of organisations is more equally divided among the network (Provan et al., 2007). A distinction can be made between local and global centrality. A locally central actor has many connections with other actors in its direct environment. A globally central actor is positioned at short distances from other actors. With distance the number of nodes between two actors is meant. Additionally, it is possible to examine the centrality of a network as a whole. This describes the extent to which cohesion in the network is organised around particular actors. (Scott, 1991).

Cliques – Cliques are closely knit subgroups of actors in a network. Each of the actors in a clique is connected to every other actor in the clique. Each subgroup consists of three nodes or more (Otte & Rousseau, 2002).

Diversity – A business ecosystem can consist of many different organisations, or many different species. Diversity of ecosystems can be discussed in many different ways but in this study we refer to the variety in different roles and functions, and different types of relations.

2.3.2 Conclusion

A network can be analysed from an ego-centric or a socio-centric perspective. Because this study is focused on the whole ecosystem of the Dutch energy industry, and not on the ecosystem around a particular organisation in the Dutch energy industry system, this research has a clear socio-centric perspective. To analyse the structure of the different ecosystems that will be developed in the scenarios, different concepts of social network analysis will be used. The concepts used in this study are:

1. Network density
2. Network (de)centrality
3. Cliques
4. Network diversity

In a social network analysis, the density, centrality and cliques of a network are often mathematically determined. For the purpose study however, we will use these terms to qualitatively describe and explain the network structure. The analysis of the network structure in terms of density, centrality, cliques and diversity will provide insight in the changes in ecosystem configurations.

2.4 Transaction Cost Economics

Up to this point, we have discussed how changes in the energy ecosystem can be described. In this section, we will discuss how changes in the energy ecosystem (due to blockchain) can be explained. The New Institutional approach of transaction cost economics (TCE) can provide insight into this. The main question TCE asks is why some transactions take place in the market and some in organisations. The same question can be asked for blockchain: why do (or might) some transactions take place in blockchains, rather than in organisations or markets? (Davidson et al., 2016b). This approach is clearly different from the neoclassical approach of economising blockchain technology. From the neoclassical perspective, technological improvements lead to lower production costs (Davidson et al., 2016a). Although it is possible that blockchain will lead to lower production costs, this will probably be a result of organisational efficiency gains. Therefore, our thought is that the new institutional approach to blockchain fits best with the purpose of this study.

Transaction costs can be seen as the costs of buying goods from an external organisation, rather than producing them in-house (Williamson, 1979), or more general, the cost of coordinating economic activities. According to

TCE, organisations and markets are institutions for economic coordination. Because actors seek to economise on transaction costs, an efficient mix of institutions will be shaped. The main reason why transaction costs exist is to control or protect against opportunism through a hierarchical organisation (Davidson et al., 2016b). Williamson (1985, pp. 47) defines opportunism as "self-interest seeking with guile", or more specifically "the incomplete or distorted disclosure of information especially to calculated efforts to mislead, distort, disguise obfuscate, or otherwise confuse". Transaction costs mainly arise from uncertainty, from the cost of writing contracts, and from the cost of enforcing contracts as the utmost reason for opportunism is the intent or ability of organisations to exploit trust. If transactions are made fully rational, at no cost, there is no need for trust. However, in the real world information is almost never perfect. Highly trusted transaction recorders, or ledgers, are needed to lead to a low transaction cost economy. To create high trust, the ledgers needs to be centralised and strong. In essence, this results in the need for high-quality central government institutions or large centralised aggregating organisations, which come at cost mainly because of its largeness and centrality (Davidson et al., 2016a).

Blockchains are trustless, decentralised ledgers. Essentially, they facilitate transactions. In this way, they enable new types of contracts and markets. Blockchain technology has the ability to organise the need for trust in a different way, because contracts are agreed upon based on consensus through the network and transparency. From this point of view, blockchain technology can provide an instrument to control opportunism by eliminating the need for trust, which will drive down transaction costs. What differentiates blockchain technology from other ledger technologies is that blockchain is an enabler for decentralisation. Decentralisation makes a system more robust, flexible, secure and efficient. This makes blockchain technology as an institutional technology a potential competitor of organisations or markets (Davidson et al., 2016a).

2.5 Conclusion

The first part of this chapter was focussed on concepts to describe that help to describe the energy industry system and changes in the energy industry system in future scenarios. This chapter started with a selection of an inter-organisational network concept to that will help to describe the energy industry system as a whole, and potential future configurations of the energy industry system. We defined three criteria the inter-organisational network concept has to meet: 1) the concept needs to allow for a socio-centric perspective, 2) the concept needs to allow for some flexibilities, and 3) the concept recognizes both cooperation and competition. Based on these three criteria the concepts of business ecosystems, value chains and value networks have been discussed. The concept of business ecosystems was found to be the most appropriate for the purpose of this study as it met all three predefined criteria. The definition of a business ecosystem that will be used for this research is:

"A business ecosystem is a networked system of different types of actors that are tied to each other through relationships, and interact both cooperatively and competitively."

This answers the first part of the first sub question, namely *"what are business ecosystems?"* For the second part of the sub question, *"how can ecosystem configurations be analysed?"* sections 2.2 and 2.3 focussed on the description actors in ecosystems and their relationships with other actors in the ecosystem, and network structure respectively. Together, these parts describe the components that describe the configuration of an ecosystem. It was found that ecosystems can be visualised by visualising actors and relationships using nodes (representing the actors) and links (representing the relationships). The actors can be described based on their activities/functions in the ecosystem, and on the role they play. Three different member roles have been identified:

1. Keystones
2. Dominators
3. Niche players

The relations between the members of an ecosystem are most of the time based on exchange processes. Typical exchange processes are the exchange of:

1. Goods and services
2. Affective and liking
3. Information and ideas
4. Influence and power

To analyse the ecosystem structure, different concepts of social network analysis can be used. Social network analysis uses the unique properties of a network to describe the structure of a network. The properties that will be used for this study are:

1. Network density
2. (De)centrality
3. Cliques
4. Diversity

In social network analysis, the density, centrality and cliques of a network are often mathematically determined. For this study, we will use these terms to qualitatively describe the network structure to provide insight in the changes in ecosystem configurations.

The second part of this chapter discussed how changes in the energy ecosystem, due to blockchain, can be explained, or, why blockchain technology has the potential to disrupt the energy ecosystem. The institutional approach of transaction cost economics provided insight by explaining blockchain as an institutional technology that lowers transaction costs. According to TCE transaction costs mainly arise from uncertainty, from the cost of writing contracts, and from the cost of enforcing contracts as the biggest reason for opportunism is the intent or ability of organisations to exploit trust. Because blockchain technology has the ability to eliminate the need for trust because contracts are agreed upon based on consensus through the network and transparency, blockchain technology can provide an instrument to control opportunism. This will drive down transaction costs. Additionally, blockchain is an enabler for decentralisation. Decentralisation makes a system more robust, flexible, secure and efficient. This makes blockchain technology as an institutional technology a potential competitor of organisations or markets.

Therefore, in this research project, the impact of blockchain as an institutional technology on the energy industry will be studied. The potential impact will be studied through the analysis of potential changes in the configuration of the ecosystem in the Dutch energy industry. In the following chapter, the method used to identify the potential impact on the ecosystem will be elaborated.

3.

Research Design

In previous chapters, the objective and research questions for this project were specified, and a theoretical framework has been constructed. Before we start our research to derive an answer to our main research question, it is necessary to specify and structure our research design. In this chapter, we will elaborate on the methodology and tools used for this study.

First, in section 3.1 we discuss the overall research approach used for this research, namely scenario planning. Secondly, we derive the specific scenario planning design based on the intuitive logic approach in section 3.2. Lastly, the strategy defining the methods used to collect information will be discussed in section 3.3.

3.1 Scenario Planning

To be able to derive a useful approach for this research project, it is important to introduce the approach of scenario planning and explain why it is used. First, we present an overview of the methodology of scenario planning and explain why this method is useful for our research project (section 3.1.1). Secondly, we further specify our methodology by selecting a specific approach to scenario planning (section 3.1.2). Lastly, we will elaborate on the main limitations of this methodology (section 3.1.3).

3.1.1 Why Scenario Planning?

From chapter 1, we have learned that there is a need for change in the current energy industry system. Blockchain technology is identified as a technology that could potentially compete with organisations or markets. As a result, blockchain has the potential to change the energy industry ecosystem. However, because blockchain is mostly viewed from a technological perspective, it remains rather unclear what the impact of this technology on the industry as a whole could be. A frequently used approach to construct *probable futures* in business planning are forecasts. However, forecasts rely on the assumption that the world of tomorrow will be much like the world of today. As a result, when major changes occur, and forecasts are needed the most, they will fail because forecasts do not (or cannot) anticipate on major shifts. Hence, when the level of uncertainty increases, other planning methods are needed which include potential risks and possibilities to identify multiple possible futures (Huss, 1988; Lindgren & Bandhold, 2003; Wack, 1985). Therefore, when there is a lot of uncertainty about a future business environment, scenario planning is used to study *possible future worlds* to explore future business environments.

According to Huss (1988, pp. 378), "A scenario is a narrative description of a consistent set of factors which define in a probabilistic sense alternative sets of future business conditions". *The core idea of scenario planning is to* _identify possible futures, rather than to focus on a precise prediction of one future_. Scenarios include the most important uncertainties within a system (Peterson, Cumming, & Carpenter, 2003). This makes scenario planning "the methodical thinking of the unthinkable" (van der Heiden, 2005, pp. 219), which provides "… a paradigmatic way of strategic thinking that acknowledges uncertainty with all the consequences this entails." (van der Heiden, 2005, pp. 19). This is also what sets scenarios apart from visions. A vision is a desired future, or a future to strive for. Scenarios on the other hand, provide an answer to the questions of "what can, or could, happen if …?". In this study we want to answer the question "what can, or could, happen in the energy industry if blockchain is implemented as an institutional technology?".

Scenario planning can be used for different purposes. Generally, scenarios are developed for exploration or for decision support. When scenarios are used for exploration, the goal is mostly to learn, drive for change, or to generate new ideas. When scenarios are used as decision support, scenarios are often used for planning or strategy development, or for the evaluation of existing business concepts, strategies, or products (Lindgren & Bandhold, 2003; Notten, Rotmans, Asselt, & Rothman, 2003; van der Heijden, 2005). Stakeholders and experts are often included in scenario planning. They are used to get valuable input, include different and new perspectives, and increase the support for the final scenarios. This is important as the purpose of scenarios is either for exploration or for decision making (Bradfield, Wright, Burt, Cairns, & Van Der Heijden, 2005; Peterson et al., 2003; Ratcliffe, 2000; Rounsevell & Metzger, 2010).

Because scenario planning is used for different purposes, there are also many different types of scenarios. First, a scenario can either be descriptive or normative. In descriptive scenarios, the future is often studied using extrapolation of current trends. In practice these scenarios often are extrapolative as well as explorative. Normative scenarios are goal directed and designed to achieve desired targets. Second, scenarios can differ on the scope of their topic: scenarios can either be on a problem specific topic, or be more global. Third, scenarios can be for one specific sector, or for multiple sectors. And lastly, the level of aggregation (micro, meso, or macro) can be different for scenarios (Amer, Daim, & Jetter, 2013; Notten et al., 2003).

For industries, scenarios are used "to identify plausible future states of an industry and differences between them, to examine how these distinct industry states might evolve, and to determine what an organisation would have to do to win within each industrial future" (Fahey and Randell 1998 in Ratcliffe, 2000, pp 134). We are at the start of a transition in the energy industry, therefore there is still a lot of uncertainty of how this transition will develop. Additionally we want to explore how the still immature technology of blockchain could be used in this industry, and what effects the implementation of this technology could have on the energy industry ecosystem. The uncertainty within the industry, together with the uncertainty of the development of blockchain, makes scenario planning a useful method to explore future configurations of the ecosystem with the implementation of blockchain technology.

3.1.2 Selecting a Scenario Planning Approach

Scenario development methods range from being very simplistic to highly complicated, and can be based on qualitative or quantitative approaches and data. Generally, three methodological approaches can be distinguished for scenario planning: 1) intuitive logics, 2) probabilistic modified trends methodology, and 3) the French School (also: La prospective) (Amer et al., 2013; Bradfield et al., 2005; Rounsevell & Metzger, 2010).

Intuitive Logic

The first approach, intuitive logic, does not rely on a mathematical algorithm. It is used to develop flexible and consequent scenarios. Because of its qualitative nature this approach strongly relies on the knowledge, skills, commitment and credibility of the scenario development team members (Amer et al., 2013). Qualitative scenarios are often used to analyse complex situations, with many uncertainties, and when not all relevant information can be quantified (Notten et al., 2003). Examples of intuitive scenario development methods are the methods proposed by Schwartz, van der Heiden, Schoemaker and the Stanford Research Institute International. The intuitive logics model is mostly related to descriptive or exploratory scenarios (Rounsevell & Metzger, 2010).

Probabilistic Modified Trends

The second approach, probabilistic modified trends methodology, is of quantitative nature and consists of two methodologies: the Trend-Impact Analysis (TIA) and Cross-Impact Analysis (CIA). Both methodologies try to analyse changes in the probability of occurrence of events that might lead to other results than the simple extrapolation of historical data when combined with judgements and narratives (Bradfield et al., 2005). Both methodologies rely on time-series data in combination with judgements, but where TIA is used to identify the expected impact of a future event on a trend, CIA is used to study interdependencies of events.

The French School

The last approach is the French School. This approach uses both qualitative as well as quantitative tools. It is sometimes described as a combination of the intuitive logic approach and the probabilistic modified trends methodology (Amer et al., 2013; Bradfield et al., 2005). The French School is mostly used to identify the different pathways that lead to the same desired outcome. Therefore, the French school is mostly used to derive normative scenarios (Rounsevell & Metzger, 2010).

The nature of our study is explorative, because we want to know what *can* or *could* happen in the energy industry, when blockchain is applied as institutional technology. Hence, we need an approach to derive descriptive scenarios. For exploratory scenarios, the intuitive logic approach is often used, because it describes plausible, but alternative development pathways which can be analysed and compared. Additionally, because we want to assess possible futures for the Dutch energy industry, which is currently undergoing a major transition, there exists a high level of uncertainty. This makes the use of a qualitative method in this stage more useful than a quantitative method, because quantitative methods tend to become less reliable as uncertainty rises. Hence, we use the qualitative approach of intuitive logics because this enhances the explorative nature of this research.

3.1.3 Limitations

Although scenario planning is generally seen as a valuable tool to provide insight in various future pathways, this method has some limitations that need to be acknowledged. One of the most prominent limitations is the subjective character of scenario planning. Opinions and judgements are crucial in all scenario planning approaches, because scenarios attempt to say something about environmental changes we know little about. Hence, the outcome of scenarios are based on the level of knowledge and experience of the participants in the scenario planning process. Therefore, it is important to be transparent in the expression of assumptions and choices, and include a diverse group of experts/stakeholders (Rounsevell & Metzger, 2010).

Secondly, contrary to other scientific methods, the outcomes of scenario planning are difficult to validate, because there exists no empirical data against which the scenarios can be tested, as scenarios describe worlds that could exist in the future. As a result, the credibility of scenario narratives can be questioned (Rounsevell & Metzger, 2010). Additionally, scenario planning is often used in practice, but relatively little academic research has been carried out on its performance and underlying theories. This is mainly because the scenario planning technique has been developed from practice and experience. As a result, academics share the concerns about how we know if we have 'the right' scenarios, and how we go from scenarios to decisions (Schoemaker, 2004). It is therefore important to keep in mind that scenarios are not developed to create exact images of the future. Instead, scenarios should be seen as the boundaries of a framework of possible futures.

3.2 Scenario Planning Design

The methodology used for this study is based on the eight step methodology by Schwartz (1991), which is part of the intuitive logic approach. The methodology Schwartz has developed is the most common scenario planning methodology (Bishop, Hines, & Collins, 2007; Rounsevell & Metzger, 2010). At the core of this methodology is the formulation of a scenario framework, which is known as the Global Business Network (GBN) matrix. The goal is to identify the two driving forces with the highest impact and highest uncertainty and plot these on two axes to create a 2x2 matrix. Generally, researchers agree that a number of 3-5 scenarios is appropriate for a scenario planning project (Amer et al., 2013). The framework used in this research project gives the guidance and structure needed to create four mutually exclusive scenarios. See Figure 3 for an example of a 2x2 scenario matrix.

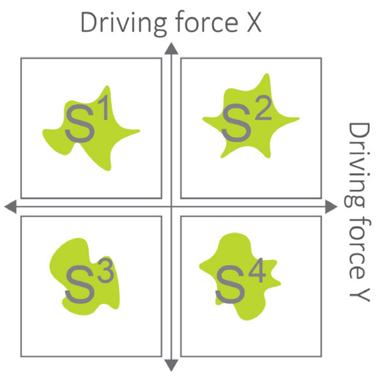

Figure 3: 2x2 Scenario framework

Schwartz identified the following steps in the scenario planning process:

1. Identify focal issue or decision
2. Key forces in the local environment
3. Driving forces
4. Rank by importance and uncertainty
5. Selecting scenario logics
6. Fleshing out the scenarios
7. Implications
8. Selection of leading indicators and signposts

   (Schwartz, 1991, pp. 226-233)

We identified five stages from these eight steps (see Figure 4):

1. Problem definition. Define the aim and the boundaries of the study and generate a clear understanding and overview of the context of the study.
2. Identify the key drivers. Identify and analyse trends which both directly and indirectly influence the context of the study, and determine the most important and uncertain trends.
3. Select the scenario logic. Define the scenario framework based on the two most important and uncertain trends, to structure the development of the scenarios.
4. Formulate the scenario narratives. Describe the principles for each of the scenarios, using qualitative storylines and the most important trends from stage 2.
5. Assess the implications. Assess the implications or potential impacts of the scenarios, using qualitative storylines and images.

Step eigth of the methodology by Schwartz is not included in our five stages, because this concerns the implementation phase of the scenarios, which is out of the scope of this research.

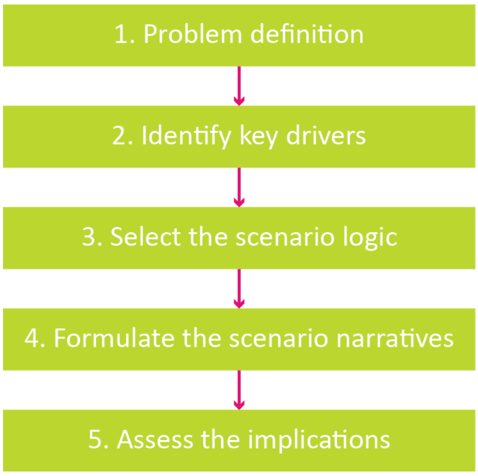

Figure 4: Five scenario planning stages

3.3 Data Collection

In this section, the strategy used to collect the data for the five stages described above will be discussed. Various tools exist to support a scenario planning process. Like the three approaches described in sub-section 3.1.2, these tools also range from very simplistic to highly complicated, and from purely qualitative to partly quantitative (Amer et al., 2013; Bishop et al., 2007; Lindgren & Bandhold, 2003).

Part of the data needed for stage 1 has already been discussed in chapter 1, the introduction. In our objective we stated that we want to develop future scenarios on ecosystem configuration within the Dutch energy industry to explore the disruptive power of blockchain technology. We do so, because we want to learn and drive for change: we want to *learn* about the possible impact of blockchain as institutional technology on the energy ecosystem, to *drive for change* in an industry that does not fit anymore with today's developments. The focus of this research is on the processes, roles, and functions, directly related to the energy value change for small consumers, as stated in our problem statement. Therefore, the strategic questions that have been formulated for the scenario planning process are:

1. What could the Dutch energy ecosystem look like in the future?
2. What is the potential disruptive impact of blockchain technology on the Dutch energy ecosystem, with the focus on the disappearance, change, and emergence of roles and functions?

Scenarios are mostly developed with a time horizon of 10-15 years, hence the scenarios will be formulated for the year 2030.

The following sub-sections elaborate on the data collection strategies and tools used for the remaining stages of the scenario planning method chosen for this research project.

3.3.1 Desk Research

To better understand the potential of blockchain technology in the energy industry, a clear understanding of both domains is needed as part of stage 1 (van der Heijden, 2005). The theoretical framework developed in chapter 2, is used to analyse both domains. An understanding of blockchain technology allows to better understand how blockchain could be used as an institutional technology. An understanding of the current situation within the energy ecosystem allows to identify where in the ecosystem blockchain could be used as an institutional technology. Additionally, a clear understanding of the current situation in the energy ecosystem allows to assess the impact of blockchain technology in each of the four scenarios that have been formulated. Therefore, it was necessary to conduct a thorough desk research into the domains of both blockchain technology as well as the energy ecosystem. Although scientific literature and grey literature was needed for the study of both domains, the different nature of both domains required different approaches. For the study of the blockchain technology domain, four types of documents were used, including:

1. Scientific literature in the form of books, articles, and master theses
2. Grey literature in the form of company reports
3. Personal blogs

Because blockchain technology is a relatively immature technology, not much scientific literature is available yet. Therefore, non-scientific literature, in the form of company reports and expert blogs were used to complement the information found in scientific literature. Through a review of the literature available, an overview of blockchain technology itself, an overview of the characteristics and possibilities of blockchain, and an overview of current blockchain projects were derived. First of all, the knowledge derived from this part of the study is used as input the second stage, the exploration and analysis of trends. Secondly, the knowledge gained from this desk research is used to enrich the scenario narratives in the fourth phase and assess the implications of the scenarios in the fifth phase.

For the study of the energy industry domain, the following information was used:

1. Scientific literature in the form of articles
2. Grey literature in the form of company reports and reports by research institutions
3. Company/institution websites
4. The theoretical framework formulated in chapter 2

First of all, scientific and non-scientific literature was used to generate an understanding of the different actors and processes within the energy industry. The energy value chain formed the basis for this research as will be explained in chapter 4. Secondly, the theoretical framework formulated in chapter 2 was used to create a model of the current ecosystem of the Dutch energy industry. Additionally, several experts were consulted to validate our model of the ecosystem and to complement the ecosystem with new information not covered by the literature. Hence, an iterative process took place to further develop the model of the ecosystem. The model and knowledge gained from this desk research are used in the second phase to explore and analyse trends, and in the fifth phase, to assess the implications of the scenarios.

3.3.2 External Trend Database

Scenario planning is an intuitive process, but scenarios "… must be based on a thorough research into present and past conditions and future developments and trends" (Lindgren & Bandhold, 2003, pp. 45). The present and past conditions have been identified in stage 1. The second stage concerns the exploration and analysis of relevant trends and developments. This stage forms the basis for the selection of our scenario framework in stage 3. The first step is to construct a list of trends and developments. The trends and developments should be relevant for this study, and should concern social, technological, economic, environmental, and political forces (Schwartz, 1991). To gather this data, two strategies could be used:

1. We could derive a list of trends ourselves, individually and/or using a project team. Frequently used methods to derive trends and developments are brainstorming techniques, STEEP factors analysis, research, interviews, discussions, and workshops with experts (Bradfield et al., 2005).
2. We could search for an external database of trends and developments in the energy industry.

In the early stages of this study, it was found that a scenario planning project had been conducted within the Enexis Holding, of which Enpuls is part of. In 2015, a project team of Enexis BV. conducted study similar to our research, to explore how the energy supply in the Netherlands could develop towards 2030. To gather external trends and developments they used a desk research in combination with expert interviews and expert workshops. For their desk research, a number of 34 'trend documents' were selected to identify important trends, using open coding techniques. Examples of trend documents are reports by PWC, the Dutch institutions ECN, Energie-Nederland, and Netbeheer Nederland, Deloitte, the Harvard Business Review, TenneT, and KPN.

For the interviews, a sample of 20 experts were selected. The experts operated in the energy market and closely related markets, such as advisory or educational institutes, energy suppliers, and construction companies. The interviews were semi-structured. Additionally, two expert workshops were held. The first workshop was held with the board of directors of Enexis. The second workshop was held with the project team itself, each of which were the manager of a different department within Enexis, such as customer relations, smart grid operations, etc. The goal of the interviews and the workshops was to identify additional trends and developments. During the expert workshops, brainstorming techniques were used to identify additional trends and developments. In total, a list of 909 trends was compiled. To be able to cluster the trends, the trends were labelled based on the STEEP categories (Social, Technological, Economic, Environmental, and Political) and on their relevance (high, medium, and low). Based on these labels, the trends were clustered during a second workshop with the project team. The result of this workshop was a list of 29 trend clusters that were used as input for the further steps during the scenario planning process.

The focus of the study done by the Enexis project team fits with the focus of this research, namely, an explorative study on the future of the Dutch energy ecosystem. As a result, the focus during the identification of trends and developments in the study by Enexis is similar to our focus in our in this phase. Additionally, because the study has been conducted in 2015, we argue that the trends and developments identified by Enexis are recent and therefore relevant for our research. Furthermore, the project team has used multiple methods to derive this extensive list of trends and developments and to cluster the trends and developments. The methods used are all methods which are frequently used in scenario planning, such as brainstorming techniques, interviews, expert workshops and a Delphi workshop with the project team. Additionally, the members of the project team were all managers of different relevant departments within Enexis. Hence, the project team consisted of experts on different relevant fields of the energy industry.

To conclude, the project team has performed a thorough research to collect a list of trends and developments. They converged from an extensive list of 909 trends to a list of 29 key trends and developments for the energy industry. Based on the focus of the database of trends, the combination of multiple often used tools in scenario planning, and the use of reliable and relevant input of trend documents and experts, the relevance and reliability of this database of trends and developments is considered to be high. Hence, we argue that this database provides relevant and reliable input for our research. Additionally, it would be inefficient to redo this process. If we would derive a list of trends and developments ourselves, it will likely result in a similar list of trends and developments. We therefore choose to use the 29 trend clusters as input for the further stages of our scenario planning process.

3.3.3 Trend Analysis

The second part of stage 2 concerns the analysis of trends to identify the most important trends. The goal of this analysis is to find the two trends that are most important and most uncertain. These two trends will then be used to construct the scenario framework for the development of the scenario narratives. To find the most important trends, the trends need to be ranked on the basis of two criteria:

1. The degree of impact
    a. on the focal issue, and
    b. on the other trends, and
2. The uncertainty surrounding the trends

First of all, trends have to have a big impact, because only then the trends will lead to changes. Secondly, there has to be uncertainty surrounding the trends, because predetermined trends will be the same in all scenarios (Schwartz, 1991). For the analysis of the trends, three different types of analyses were used.

First of all, because it is difficult for the human brain to memorise and handle large amounts of information consciously, trends are often clustered to reduce the information complexity (Lindgren & Bandhold, 2003). We consider a number of 29 trend clusters still as a lot of information to cope with at once, therefore we decided to perform an analysis in an attempt to reduce the number of trend clusters. Our main goal for this analysis is to increase the manageability of the trend list derived by Enexis for the following steps of the scenario planning process. A combination of the STEEP methodology and four criteria were used to analyse the trends based on their relevance, and to categorise and re-cluster the trends. STEEP stands for Social, Technological, Economic, Environmental, and Political forces. The STEEP methodology was used, because it is a frequently used technique in this phase of scenario planning, which helps to structure the trends and developments. This step was a necessary and important step to keep the following analyses manageable and focussed, and critically review the external data input.

Secondly, the trends needed to be analysed upon their uncertainty and importance. A combination of two tools is used to identify a trends impact on the ecosystem, as well as the impact of each trend on the other trends. This combination allows to identify the most important trends, in a structured and traceable manner, with the inclusion of expert judgements. Expert judgements are often used to identify the uncertainty and impact of qualitative trends. Therefore, to determine the uncertainty and the impact of the selected trends on the ecosystem, an impact and uncertainty analysis was carried out through a survey amongst experts. To determine the impact of the trend list on itself, a Cross-Impact Matrix (CIM) is used. A CIM is a useful method to systematically study the interactions of a set of data upon itself to identify key trends. A CIM allows to track the decisions made by the scenario developers with greater rigor (Amer et al., 2013; Lindgren & Bandhold, 2003; Ratcliffe, 2000).

The impact and uncertainty analysis is carried out amongst a sample of experts (N=30). The experts are asked to judge each trend on its impact on the energy ecosystem and its uncertainty. A Likert scale of *very small (0)* to *very high (5)* has been used to assess both the impact of each trend cluster as well as its uncertainty. The survey was carried out with the use of the tool SurveyMonkey. Because all respondents were Dutch, the survey has been written in the Dutch language. The respondents were selected from the professional network of Enpuls/Enexis. The respondents included employees from Enpuls/Enexis (explorers, managers, developers, innovators, architects and strategy advisors) and the participant of the focus group, which will be discussed in sub-section 3.3.4. The participants of the focus group consisted of experts from energy related companies or research institutions, and blockchain experts. A survey was chosen for this analysis, because it allowed to include expert judgement in the selection process of the most important and uncertain trends, to create a reliable and valuable scenario framework. Because the survey was carried out individually, the respondents were not influenced by other opinions. The advantage of this, is that everyone's opinion is heard, and valued the same. The risk of this method, is that the arguments behind the experts' choices are not taken into account. As a result, well-founded judgements are valued the same as less well-founded judgements. However, we reduced this risk through the selection of the sample of respondents. First of all, all respondents are experts in their field of work. Secondly, the sample size also reduced this risk. Additionally, because the participants of the focus group were also included into the sample of this survey, the participants supported the scenario framework that was used for the workshop. As a result, not much time was lost on discussions about a relevant scenario framework during the workshop.

Thereafter, a CIM has been used to structurally determine the mutual dependency of the clusters. The cross-impact is determined by the extent to which a trend cluster affects the other trend clusters. Put differently: the trend clusters with the highest impact and the lowest dependency, hence the biggest driver for change, can be identified. A cross-impact analysis, is often carried out in an informal way, by a small team. So was the case in this study. Generally, the following results can be derived from a CIM:

1. A trend cluster with *high impact* and *low dependency* can be seen as a key uncertainty, or a key driver for change.
2. A trend cluster with *low impact* and *low dependency* can be seen as an autonomous trend cluster.
3. A trend cluster with *low impact* and *high dependency* can be seen as a dependent trend cluster.
4. A trend cluster with *high impact* and *high dependency* can be seen as a linking pin with other trend clusters.

The results of both the survey, as well as the CIM, are used to determine the axes for the scenario framework.

3.3.4 Focus Group

In stage 4, the scenario narratives need to be developed. The scenario narratives form the describing component of the scenarios. The purpose of these narratives, or storylines, is to open eyes, to provoke, to stimulate, and to envision what the world could look like in the future. It is important that the narratives are creative, rigor, internally coherent, and plausible. Scenario narratives are mostly written storylines, but can also take the form of images, films, simulation models, and conceptual trend maps. Translating the scenarios into storylines makes them easy to memorise (Rounsevell & Metzger, 2010). In the intuitive logics methodology, the output of the scenario planning process take the form of qualitative, written narratives (Amer et al., 2013; Bradfield et al., 2005). Hence, following the methodology used for this research project, the output of our scenario planning process will take the form of written scenario narratives. The written storylines will be accompanied with an analysis and visual representations of the corresponding ecosystems.

As has been mentioned before in section 3.1.1, it is important to include stakeholders and/or experts in the scenario planning process. Therefore, the judgement of experts has been used to determine the key trends for the construction of the scenario framework. To formulate the scenario narratives for the fourth stage, a combination of an expert workshop, or focus group, and individual interviews will be used.

A focus group typically consists of eight to ten members, which discuss a particular topic during a couple of hours. A moderator is used to lead the discussions and steer the discussion in the right direction. Sometimes, the moderator also observes and takes notes during the discussion, but there may also be a separate observer. The latter option, the division of the tasks of moderator and observer over two people, is well advised (Sekaran & Bougie, 2009; Verschuren & Doorewaard, 2010). During the focus group, the experts are asked to start a discussion about possible futures for the Dutch energy ecosystem in which blockchain technology is implemented.

The purpose of the focus group is to derive the assumptions for the four scenarios. Thus, the focus group will be used to think of, and formulate the starting points from which the scenario narratives will be formulated. A consequence of the interactive character of a focus group is that the participants can influence each other, and that some participants may be more actively involved in the discussion than others. As counterpart of the focus group, individual interviews will be used afterwards (as discussed in sub-section 3.3.5).

The focus group was organised as one session, lasting approximately four hours. During this session a group of ten experts participated. The experts were divided into two groups. Each group discussed two opposing possible futures. The experts were selected based on their knowledge about the Dutch energy system, and/or their knowledge about blockchain technology and blockchain technology in the energy industry. The professional network of Enpuls, and the professional network of the supervisors of this research project were used to select a diverse group of experts (researchers, chief technological officers, business developers, consultants, a member of Topsector energie, etc). We selected a diverse group of experts, because the different fields of expertise offered different perspectives on the topic, which is beneficial for the richness and plausibility of the scenarios. Important to note, is that besides being experts, the participants are also (part of) important stakeholders. Hence, the group of experts also forms a representation of the industry. For a list of the participants see appendix A.

To be able to derive valuable results from the focus group, it is important that the discussions run smoothly and structured. Therefore, the workshop should be led by an experienced moderator, who is able to steer the group persuasively, help the group through impasses, ensure that all members participate in the discussion, and no member dominates the group (Sekaran & Bougie, 2009). For this study, an external agency, experienced in scenario planning, is used to moderate during the focus group session. Because the focus group was split into two discussions, two moderators were needed. The use of external moderators gave us the opportunity to focus on the observation of the discussions, take written notes, and intervene if needed. The researcher of this project, and a colleague of Enpuls took the role of observer during the focus group.

The focus group started with an explanation of this research, including strategic questions and the time horizon, and an explanation of the scenario planning methodology used for this study. This was followed by a discussion of the results of the survey and the CIM, and the scenario framework that had been constructed from these analyses. Thereafter, the group was split into two predefined groups. Each group was asked to discuss the assumptions of the possible worlds in two quadrants of the scenario framework. Group 1 started with the assumptions for the quadrants 1 and 4 (S^1 and S^4 in Figure 3), because these are two opposite worlds. Group 2 started with the assumptions for the quadrants 2 and 3 (S^2 and S^3 in Figure 3), also two opposite worlds. For each scenario, the groups were asked to answer the following questions in keywords:

1. What are the main reasons why this scenario has become reality?
2. What does this world look like?
    a. Which roles do you see in the energy ecosystem and how did they emerge?
    b. How are the roles in this ecosystem different from our current energy ecosystem?
3. Which parties or actors are change makers, and which parties or actors will obstruct changes?
4. What critical breakthroughs are needed for this scenario?

Afterwards, one person of each group gave a short, plenary feedback on their results to share their views on the scenarios. The conclusions served as input for the development of the scenario narratives, as will be seen in subsection 3.3.6.

3.3.5 Semi-Structured Expert Interviews

Lastly, interviews with participants of the focus group were held to validate the plausibility of the scenarios, and enrich the scenario narratives. The interviews were semi-structured, meaning that for each of the interviews the same build up was used, but the exact questions differed per expert. The complete interview protocol can be found in appendix B. Generally seen, the questions to test the validity (agreement with storyline, plausibility, diversity, extremeness, etc.) were similar for each of the experts that were interviewed. These questions included:

1. Questions regarding the scenario narratives itself. In this part of the interview, the experts were asked whether they agree with the way the scenario narratives were described, whether they think that the narratives had been logically derived, and whether they think that the narratives were complete.
2. Questions regarding the implications described for the scenarios. For each of the scenarios, several implications for the ecosystem were derived. In this part of the interview, the experts were asked whether they agreed with the implications derived and the completeness of the implications.
3. Questions regarding the characteristics of the scenario narrative. The experts are asked about the plausibility of the scenarios and the extremeness/provocativeness of the scenarios. This is important because plausibility and provocativeness are important elements of valuable scenarios.
4. Questions regarding the use of blockchain technology. For our study it is important to be able to say something about the potential impact of blockchain technology. During the interviews, the experts were therefore asked whether they thought that the use of blockchain is disruptive in the scenarios.
5. Questions regarding the obstacles for the scenarios. The experts were asked about the most important obstacles for each scenario to become reality. This is valuable information for the interpretation of each of the scenarios.

The questions asked to enrich the scenario narratives differed per expert. This strategy allowed to effectively make use of the expertise of each of the interviewees. These questions included:

1. Questions regarding a specific topic. For this part, the experts were asked to validate a specific part of a scenario narrative, or to explain more on a specific assumption made during the focus group, based on their field of expertise.

In total, a number of five interviews were held. The number of interviews was not predefined upfront. Instead, the interviews were planned until saturation was reached. The experts were selected based on:

1. Their knowledge on a specific field which required more detail in one or more of the scenario narratives.
2. Their input during the focus group.
3. The group in which they participated during the focus group: we selected a mix of experts from both group 1 and group 2 of the focus group.
4. Their level of expertise: we selected a mix of experts which have already been active in the industry for many years, and experts which are relatively new in the industry.

At request of the experts, the experts which have been selected for the expert interviews will not be mentioned by name. As mentioned before, the focus group and the interviews were used as counterparts in stage 4 and stage 5 of the scenario planning process. The focus group was a valuable method because of its interactive characteristic. However, this is also a possible limitation/risk of this method as mentioned before. In an interview only one person’s perspective is heard. Like for the focus group, this is both valuable characteristic, as well as a limitation of this method, because the experts’ opinions will always be coloured by their own experience, interests, and field of work.

3.3.6 Scenario Narrative Development and Validation Process

Additionally, it is important to elaborate on the strategy used for stages 4 and 5. During these stages, an iterative process was followed. Figure 5 represents the process followed during stages 4 and 5.

Step 1: As part of stage 4, the focus group was used to provide the scenario assumptions.

Step 2: Thereafter, from the scenario assumptions, a first version of the scenario narratives and implications were formulated, with the use of the knowledge derived from the domain studies from stage 1. Here, stage 4 and stage 5 start to overlap, because the assessment of the implications is part of stage 5 of our scenario planning process.

Step 3: The first version of the scenario narratives and implications were discussed with the first expert to validate and enrich the narratives and the implications. Then, the scenario narratives and implications were adjusted and discussed during the following interview.

Step 3 was repeated several times, until no new information was derived from the interviews. Thereafter, the final version of the scenario narratives were completed and the implications of each of the scenarios on the energy ecosystem were visualised using the framework developed in chapter 2.

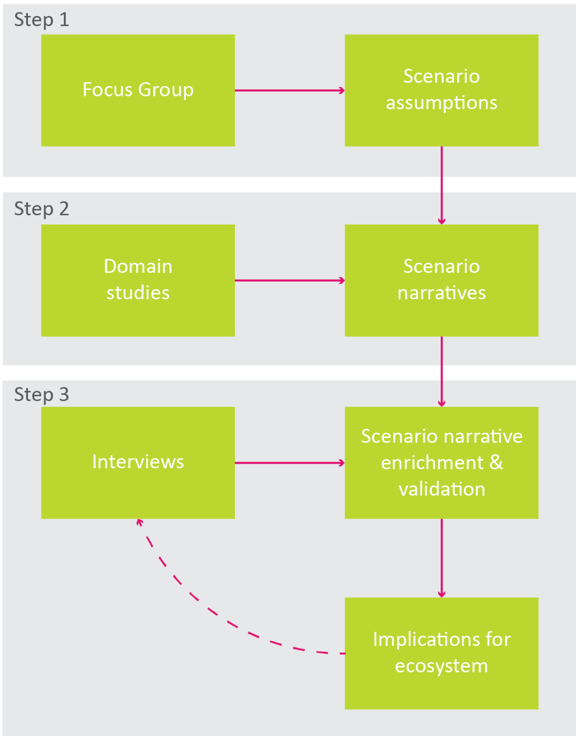

Figure 5: Scenario narrative development process

3.4 Conclusion

This chapter specified the research design of this research project. Scenario planning was found to be a highly appropriate method for this study, because of the existing uncertainty regarding both the development of the transition in the energy industry, as well as the development of blockchain technology. Scenario planning is used to identify plausible future states of industries, and examine how these future states might evolve. This helps organisations to determine a strategy for the future. Hence, this methodology is most useful to derive potential implications of blockchain technology on the energy ecosystem and its configuration. Because of the exploratory nature of this study, the intuitive logics approach to scenario planning was found to be most appropriate. The intuitive logic approach describes plausible, alternative development pathways for future states, which can be analysed and compared. The eight-step approach by Schwartz (1991) is used to derive the five stages of this research project:

1. Problem definition. Define the aim and the boundaries of the study and generate a clear understanding and overview of the context of the study.
2. Identify the key drivers. Identify and analyse trends which both directly and indirectly influence the context of the study, and determine the most important and uncertain trends.
3. Select the scenario logic. Define the scenario framework based on the two most important and uncertain trends, to structure the development of the scenarios.
4. Formulate the scenario narratives. Describe the principles for each of the scenarios, using qualitative storylines and the most important trends from stages 2.
5. Assess the implications. Assess the implications or potential impacts of the scenarios, using qualitative storylines and images.

Multiple tools exist to support the five stages of the scenario process. In this chapter, we have elaborated on the methods used for this study. Several tools are included and combined in the scenario planning process to construct a robust and traceable scenario planning process for the development of four robust scenarios. These tools include an extensive desk research on the industry and technology domain, the STEEP analysis tool to analyse and (re)cluster the trends collected from an external database, a survey and a CIM to identify the key trends based on their uncertainty, impact and interdependency, and a focus group and interviews to develop and enrich the scenario narratives, and to validate the plausibility of the the scenario narratives and scenario implications. Experts are included in several stages of the scenario planning process for three different reasons. First of all, the experts are a representation of the sector, as they are both experts as well as stakeholders. Secondly, the experts are included to increase the richness of the scenarios. Thirdly, the general thought is that the above mentioned reasons will increase the support for the scenario planning process and scenarios itself.

The five stages of this research project are summarised in Figure 6.

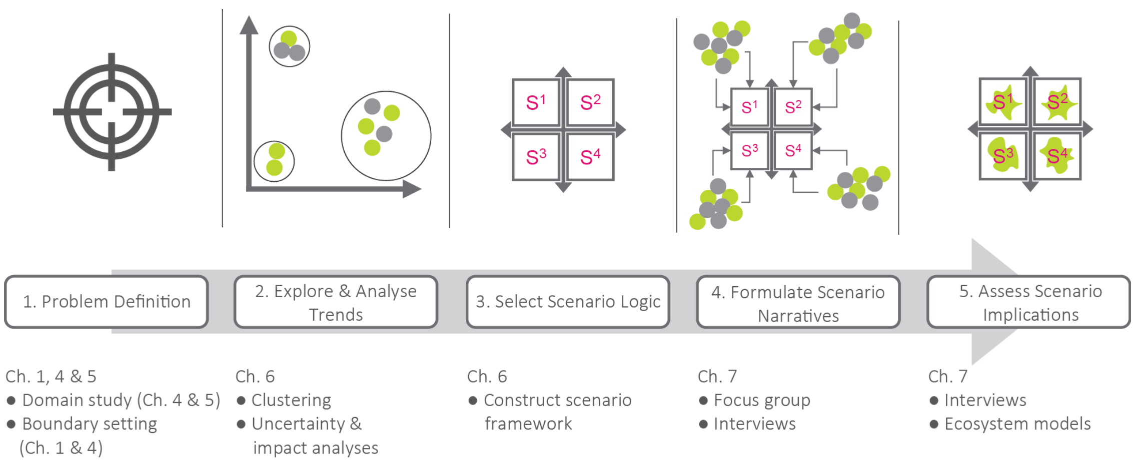

Figure 6: Scenario planning process

4. Blockchain Domain

Every day new blockchain articles, studies, blogs, conferences, and even prototypes appear. Clearly there is a lot of attention for blockchain, but only few people genuinely understand the technology, let alone can describe the implications and innovative features of blockchain. As a result, this attention mostly leads to inconsistency and misunderstanding of the technology. Furthermore, the technology is often viewed from a technical or economic perspective, but a formalisation or standardisation of the terminology is missing (de Kruijff & Weigand, 2017; Glaser, 2017; D. B. Meijer, 2017). Hence, although the technology we now call blockchain has already been introduced in 2008 by S. Nakamoto, a definition of the term blockchain is still missing.

In this chapter an overview of the blockchain technology domain is provided to answer the following sub question: *What is blockchain technology, how does it work, and what are the possibilities this technology brings forth for the energy sector?*

First, a description of blockchain technology is given in section 4.1. We will start with a general introduction to blockchain, followed by a detailed description of how a typical blockchain works. Thereafter the possible types of applications, and the architecture of blockchain technology will be discussed. Additionally we will elaborate on two of the most important characteristics of the technology. Secondly, in section 4.2 several applications of blockchain in the energy industry will be mentioned, although the applications mentioned in this chapter are probably only the tip of the iceberg when it comes to possible applications of blockchain technology for the energy industry. Lastly, we conclude with the implications of the technology based on what has been discussed before in section 4.3.

4.1 What is Blockchain Technology

In its core, blockchain is a *public, cryptographic database*, or, a *distributed, cryptographic ledger* (Swan, 2015). A ledger is a file, digital or non-digital, in which transactions are recorded. A ledger is mostly owned by one central party. Hence, a ledger can be seen as a record of ownership. A distributed ledger is a digital record of ownership that is not centrally owned, but distributed across a (open) network. In the case of a blockchain, this distributed ledger is continuously being synchronized, meaning that everyone in the network always has an up-to-date version of the record of ownership. Cryptography is used to code the information in the distributed ledger, to make the database 'hack proof'. This enables the secure transfer of assets, which can be physical, intangible, or digital, across a network.

To explain how this alters current transactional processes, we first refer to the exchange of a physical asset[1] (see Figure 7). The exchange of a physical asset between to people, for example a ticket for a concert, is relatively simple: Person 1 gives the ticket to person 2, and person 2 is now in possession of the ticket. Because both people were physically there, and the transfer physically took place, both person 1 and person 2 know what has been exchanged, and that person 1 cannot exchange the ticket again because the asset is no longer in its possession.

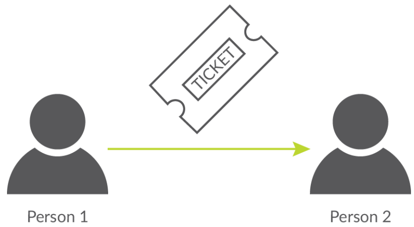

Figure 7: Exchange of a physical asset

Things change when an intangible or digital asset is being transferred between person 1 and person 2. In this case, an example of a digital asset could be an e-ticket for a concert (see Figure 8). Person 2 does not know whether he or she is the only one who received the concert e-ticket from person 1 or whether person 1 has more copies of the e-ticket. This is called the *double spending* problem. Today, a centralised ledger would be used to verify that person 1 has not transferred a digital asset to someone else before. A centralised ledger is a database in which all transactions have been noted by a *trusted third party*. Examples of thrusted third parties are banks, notaries, market place operators, etc.

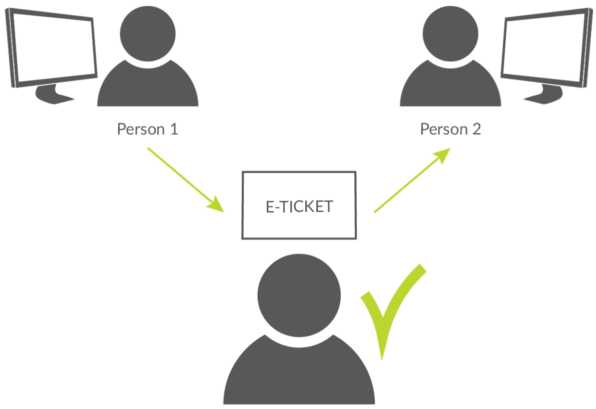

Figure 8: Exchange of a digital asset

Blockchain eliminates the need for a trusted third party through the use of a public ledger. This ledger is distributed across a network that validates the transactions to lead to consensus within the network. The trusted third party is no longer needed as the network is able to “create, evolve, and keep track of an immutable record of transactions” (Bharadwaj, 2016, pp. 3). A more detailed description of this process is provided in sub section 4.1.1 and Figure 9. To summarise, from a technical perspective “blockchain is a back-end database that maintains a distributed ledger which can be inspected openly”. From a business perspective “blockchain is an exchange network for moving transactions, value, assets between peers, without the assistance of intermediaries”. From a legal perspective “blockchain is a transaction validation mechanism, not requiring intermediary assistance” (Mougayar, 2016, pp. 28).

In subsection 4.1.1 we will further elaborate on the previously described blockchain process for the transaction of an asset, without the need for a trusted third party. Thereafter, we will describe the different types of applications

1 This explanation is based on (Custudio, 2013) and (D. B. Meijer, 2017)

which can be based on a blockchain in subsection 4.1.2, which are cryptocurrencies, smart contracts, and decentralised autonomous organisations. In subsections 4.1.3 and 4.1.4, we will discuss on the architecture of a blockchain. Lastly, in subsection 4.1.5 we will elaborate on trust and decentralisation, which are two important characteristics in blockchain technology.

4.1.1 How Does It Work?

A blockchain can literally be seen as a chain of 'blocks', consisting of the records of all transactions that have previously been made, in chronological order. Blocks can only be added to the chain, not deleted. Each member of the particular blockchain network has a copy of the chain of all transactions that have been made before. This chain grows each time new blocks consisting of transactions are added. The addition of a new block to the blockchain verifies the transactions in this block. In order to be valid, every block has to refer to its preceding block. This mechanism makes it particularly difficult to alter the blockchain, because that would mean that one would have to change the entire history on the blockchain, at every computer on which the blockchain has been stored, at the same time (Tapscott & Tapscott, 2016; van Bers, 2017). For our following description of a typical transaction process of a digital asset using blockchain, we refer to Figure 9 below. Again we use the e-ticket as an example of the digital asset being transferred.

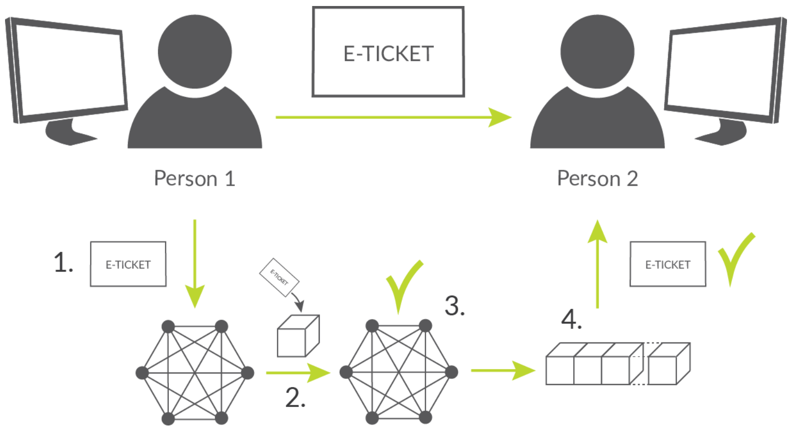

Figure 9: Exchange of a digital asset using Blockchain Technology

When two parties agree on a transaction, they have to specify the information relating the transaction, like the sender and the receiver, the type and size of the transaction, etc. The transaction and its relating information are send to each node in the network (step 1 in Figure 9). A node is a computer that is connected to the blockchain network, which collects new transactions, validates them, and puts the validated transactions into a block that has to be verified in order to be added to the blockchain (step 2 in Figure 9). The verification process is called *mining.* Nodes, or miners, start building a new block by adding unverified transactions into a new block. To prove validity of the block, the miner has to successfully solve a cryptographic puzzle: it has to find the right hash that corresponds to the information in the current block of transactions, and the hash of the previous block of transactions. It is very hard to solve this puzzle, but once it has been solved, it is easy to verify its validity. Once the miner has found the proof-of-work for its block it broadcasts the block to the other nodes in the network. If the other nodes accept the new added block (step 3 in Figure 9), they use the hash of the new added block to start building a new block based on newly added transactions (step 4 in Figure 9). The first to provide the answer to the puzzle, or to find proof-of-work for its block, is rewarded when the block is accepted by the other nodes and added to the blockchain. The more computation power the miner has, the better are its chances to solve the puzzle first (Antonopoulos, 2015; Eyal & Sirer, 2013; Nakamoto, 2008; PwC, 2016). The process described above is a typical description of a Bitcoin blockchain transaction process. Most blockchain processes work according the same processes, however, details differ. Important to add is that not everything that is recorded on a blockchain is necessarily true. The consensus mechanisms used for blockchain verify that a piece of data was added at a certain time, but it does not tell whether the piece of data was correct or not (Seppälä, 2016).

The mining process described above works according to the Proof-of-Work consensus mechanism. To participate in the mining process, each node has to solve a difficult cryptographic problem, which requires computational power, and each solution is rewarded. If a dishonest node wants to attack the blockchain, it has to solve the same problem as the other nodes in the network. Hence, only if the attacker has a significant amount of computational resources (more than 51%), the attacker will be successful. The downsides of this mechanism are the costs of the specialised hardware that is needed to run the computations, and the amount of electricity that has to be spent for the computations (BitFury Group, 2015). Both Bitcoin as well as Ethereum use this type of consensus mechanism.

Another possible consensus mechanism is the Proof-of-Stake mechanism. Instead of computational power, the stake of ownership in the network determines the possibility of a node to create and add a new block to the blockchain. This mechanism relies on the rationale that users with a high stake, will suffer the most if something malicious happens to the blockchain, therefore they will have the most interest to only add correct transactions to the blockchain (BitFury Group, 2015).

4.1.2 Applications

Blockchains itself are not the product people will use, instead they are the enabler for the products people will use: people may or may not know that there is a blockchain behind the product they use (Mougayar, 2016). An example is the Bitcoin. Often, blockchain is mistakenly thought to be the same thing as the Bitcoin. The difference, however, is that Bitcoin is an application based on blockchain technology. Bitcoin is a cryptocurrency, blockchain is the technology on which the Bitcoin as application has been built (see section 3.1.3).

The Bitcoin was the first application of blockchain technology, but currently numerous possible applications of the technology exist. Three categories of possible blockchain applications can be identified. First, there is the category of the cryptocurrencies like Bitcoin. This category is often referred to as Blockchain 1.0 (Swan, 2015).

The second type of application are the smart contracts, which belong to the Blockchain 2.0 category. A smart contract allows to execute processes automatically, through predefined 'if this, do that' conditions. Basically, a smart contract is a code that allows for a programmed contractual agreement between parties (Seebacher & Schüritz, 2017). Whereas blockchain 1.0 could be seen as the technology for the decentralisation of money and payments, blockchain 2.0 could be seen as the technology for the decentralisation of markets (Swan, 2015).

Lastly, there are the decentralised autonomous organisations (DAO), Blockchain 3.0. DAOs can be derived from smart contracts. They are organisations that rely completely on the laws and conditions defined from the smart contract principle.

4.1.3 Architecture: Core Software, Middleware, and Applications

Cryptocurrencies, smart contracts and DAOs are three of the possible applications of blockchain. These applications have to be built on a blockchain platform. Some of these applications, like the Bitcoin, have their own blockchain platform. In the case of Bitcoin this is called the Bitcoin Blockchain. Bitcoin is not the only blockchain platform, there are others like Ethereum and Bitshares. These platforms are examples of open source blockchain platforms. This means that these platforms are open to other parties for the creation of blockchains on their software platform. Ripple on the other hand is an example of a platform that is not open for the public, but has especially been developed for banks.

To understand blockchain and how the blockchain market can evolve, Mougayar (2016) identified three architecture layers: 1) infrastructure and protocols, 2) middleware and services, and 3) end-user applications. Blockchain platforms can be seen as the infrastructure. This consists of base or core software, or base or core protocols. Other software or protocols (middleware) can be built on this core software or core protocol to extend the functionality of it, and to build applications on top of them (Mougayar, 2016) (see Figure 10). Applications that, unlike the Bitcoin, do not have their own blockchain, use the core software of the Bitcoin blockchain or another blockchain platform, or they use both the core software and middleware created by others.

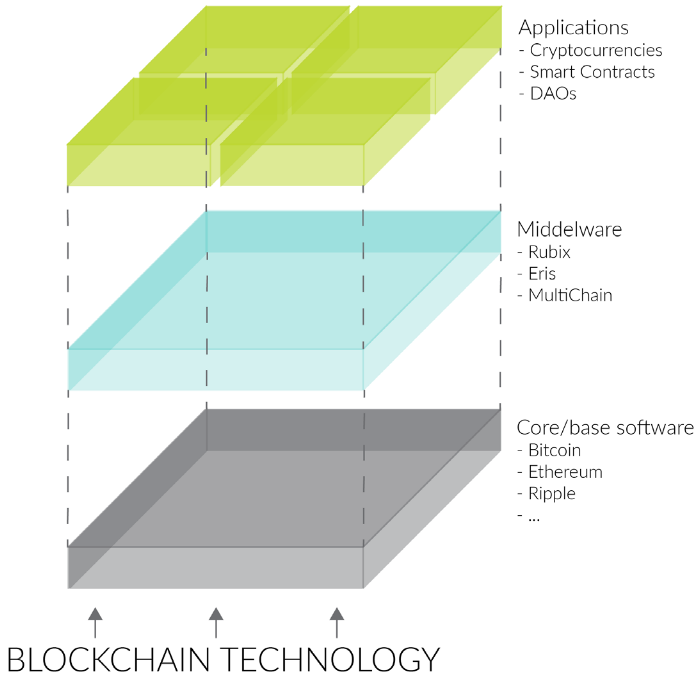

Figure 10: Blockchain architecture

Glaser (2017) uses two layers to describe the blockchain architecture: 1) the decentralised fabric layer, and 2) the decentralised application layer. The fabric layer refers to the blockchain code base, whereas the application layer denotes the code for the applications based on the fabric layer. Glaser emphasises the centralisation of control in the fabric layer. If a single organisation is responsible for the development and/or maintenance of the fabric layer (or the core or base software used by Mouyagar) this organisation has complete control over the development of the system's functioning. Hence, if the system is not open source, control is completely centralised, if the system is open source, the control is at the developers and people or organisations maintaining the system. In the application layer however, the code can be written by any participant. As a result, once the blockchain system is running, and participants built their own code on the blockchain system, the creators of the fabric layer are not in control of what happens in the application layer built on top of the fabric layer (Glaser, 2017).

4.1.4 Architecture: Public, Private, and Hybrid Blockchains

Most blockchains are entirely open and permissionless. This means that anyone can have access to the blockchain and interact in the blockchain network. Anyone can read the blockchain, send transactions, and participate in the consensus process. These blockchains are called public blockchains. Other blockchains, also known as private blockchains, are permissioned and require a participant to have certain credentials to have access to the blockchain and to be able to interact. Some private blockchains are fully private, where only one organisation has the right to write, and read permissions are either public or restricted. Others are permissioned, but not fully centralised. These blockchains are referred to as hybrid or consortium blockchains. Here the consensus process might be controlled by a consortium of organisations or institutions, and the right to read might be either public or private (Buterin, 2015).

Private blockchains have several advantages over public blockchains. First of all, the validators in a private blockchain are known, which leads to less risk. Secondly, transactions are cheaper because fewer nodes are needed for the validation process. Furthermore, if faults occur, these nodes can easily fix them manually. Lastly, private blockchains allow for more privacy, especially if read permissions are also controlled, because external parties do not have access to the blockchain (Buterin, 2015; PwC, 2016). Especially to (financial) organisations and institutions these advantages are appealing. However, one could argue that private blockchains no longer operate according to the core principles of blockchain. Private blockchains cannot said to be decentralised as there is still one organisation or group of organisations in control, and they are open to the possibility of tampering, or interventions by the organisation(s) in control of the blockchain. Additionally, because they have restricted accessibility, private blockchains will not experience the same network effects as public blockchains. This could stagnate the technology, making it vulnerable (Buterin, 2015; PwC, 2016; Tapscott & Tapscott, 2016).

4.1.5 Decentralisation and Trust

Decentralisation and trust are the two main characteristics of blockchain that are mentioned in almost every blockchain discussion. Blockchain is said to be a technology for decentralisation, and a technology enabling trust. In the case of blockchain, Seebacher and Schüritz (2017) argue that these two characteristics are closely connected and interrelated. The transparent nature of the technology, and the integrity and immutability of the data in a blockchain creates trust among participants which is needed for a decentralised system. The peer-to-peer network that is used as base for the blockchain technology, and the pseudonyms that are used to secure the participants privacy on the other hand encourage people to participate in the network (Seebacher & Schüritz, 2017).

According to Mougayar (2016), blockchain shifts trust. He argues that we will always need trust, but blockchain changes the way trust is delivered and earned. Blockchain is thereby able to disrupt economies of trust, because the cost of delivering trust is distributed through decentralisation. Increasing transparency requirements, by sharing identity and reputation formulation will help in achieving trust. Issues that are suited for blockchain according to Mougayar are: 1) anonymity, 2) identity, 3) decentralised data, and 4) security (Mougayar, 2016). Recently, Meijer (2017) argued that blockchain should be more related to control instead of trust, based on Nooteboom's conceptualisation of Reliance – Trust and Control. He concludes that blockchain technology increases control over counterparties in a transaction, while from a systems perspective, control decreases (D. B. Meijer, 2017).

4.2 State of the Art in the Energy Industry

In this section, several applications of blockchain in the energy industry will be discussed. Although the applications mentioned in this section are probably only the tip of the iceberg when it comes to possible applications of blockchain technology for the energy industry, we provide this overview to understand the current focus of blockchain applications in the energy industry. Additionally, the overview of current projects and pilots could serve as input or inspiration for the scenario. The overview below is a summary of the projects and pilots found in the documents we used for the development of this chapter.

The blockchain use case in the energy industry that is likely to immediately pop into everyone's minds is *peer to peer energy trading*. A few projects and pilots on this application of blockchain have already been set up around the globe. In Brooklyn for example, there is the Brooklyn Microgrid project in which the 'neighbour-to-neighbour' sales of solar energy is tested. In this project, smart meters are needed to record the energy produced, and blockchain technology is used for transactions and for smart contracts to automatically execute and secure the transactions. In this project, the participants are still connected to the traditional grid, but can also receive energy from a microgrid (Brooklyn Microgrid, n.d.; Engerati, 2016; PwC, 2016). In Australia and New-Zealand peer to peer trading is also being piloted. Here, a special blockchain, called the Ecochain, has been developed, whereas the Brooklyn project uses the Ethereum blockchain (Engerati, 2017a). What is special about the Ecochain is that is uses the proof-of-stake consensus mechanism instead of the proof-of-work consensus mechanism, which makes the Ecochain blockchain less energy consuming than for example an Ethereum Blockchain. Vattenfall's startup Powerpeer focusses on a digital peer to peer marketplace for self-generated energy in the Netherlands. Also in the Netherlands, Quantoz Technology and Energy21 are working together to explore the solutions blockchain could give for local power markets, by for example letting prosumers share flexibility and maintain grid connectivity services (Energy21, 2017; Engerati, 2017b). In Germany, TSO TenneT together with battery provider Sonnen, are running a pilot in which a network of linked residential storage batteries are used to absorb and release excess wind energy, using an IBM blockchain (Sonnen, 2017). Hence, this pilot is more focussed on the *balancing of the grid* in the case of (variable) renewable energy use. TenneT is also running a blockchain pilot in the Netherlands. This pilot is also focused on the balance in the high voltage grid, but this time electric vehicles (EVs) are used as batteries to balance the grid. The blockchain is used to record the EVs availability and action in response to signals from TenneT (Engerati, 2017c). Another project in Germany, called Blockcharge, enables the *sharing of charging stations for EVs and the billing of the energy transactions.* The owners of charging stations determine the charging tariffs for their charging station themselves (Share&Charge, n.d.). The Finnish energy company Fortum combines blockchain with the *Internet-of-Things*. They have developed a blockchain based solution that allows consumers to control appliances via the internet.

A different application of blockchain technology in the energy industry that is being explored is the application of blockchain to allow *multiple suppliers* at one connection. Currently, a consumer can only have one supplier of electricity, but in the future blockchain could enable the consumer to have for example one supplier for in-house electricity use and another supplier of electricity for their charging point for their EV. Furthermore, blockchain technology could enable *micro transactions*. This would for example allow consumers to continuously switch between energy suppliers to receive the cheapest energy available.

Most blockchain applications in the energy industry cannot go without smart meters. The combination of smart meters with blockchain technology may *increase efficiency in the billing process* for consumers. Smarter metering systems provide more accurate energy usage data and give consumers access and visibility of their data. This creates more transparency which is likely to lead to fairer pricing. Additionally, blockchain can be used to provide *certificates of origin* to ensure consumers that they really receive green energy for example (Besnainou, 2017; C. R. W. de Meijer, 2016).

From the overview presented above, we can conclude that there is much attention for the use of blockchain technology in the energy industry. We do however argue that the current blockchain projects and pilots in the energy industry are based on the way the energy industry system currently works. Additionally, we argue that blockchain technology is viewed from a technological perspective in each of the projects and pilots described. As a result, the projects and pilots are not likely to cause big changes for the energy ecosystem, but merely facilitate current processes leading to relatively small changes, not using the technologies full potential to compete with organisations and or markets.

Figure 11 shows different use cases for blockchain in the energy industry, including the parties which are currently exploring these possibilities.

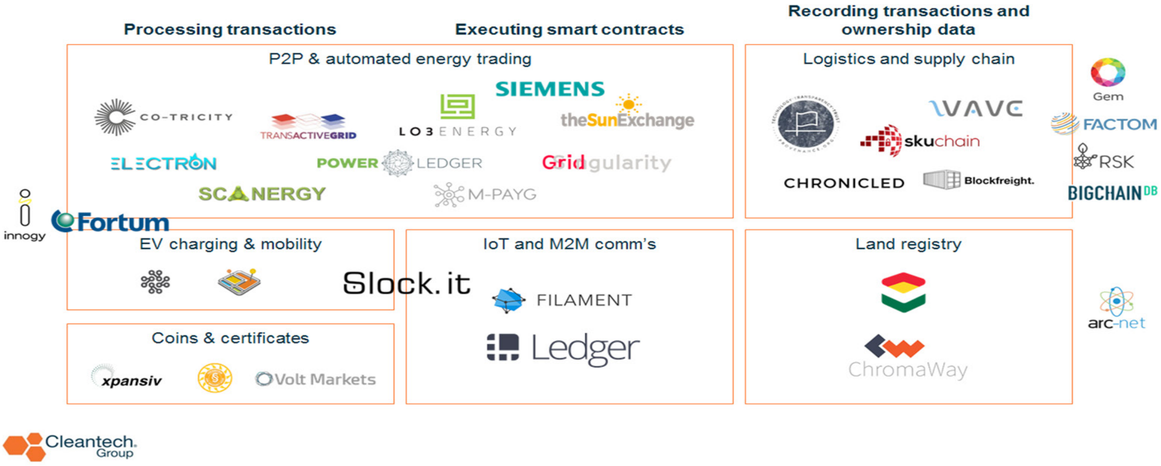

Figure 11: Blockchain use cases in the energy industry, from (Besnainou, 2017)

4.3 Conclusion and Implications

Blockchain is a *digital ledger* that is *chronologically* and *continuously* updated, *cryptographically* sealed, and *distributed* across all participants. This allows us to transact physical, digital and intangible assets with counterparties we do not necessarily trust, without the need for a trusted third party. As a result, blockchain leads to decentralisation and could transform established industries completely.

Through decentralisation, blockchain lowers entry barriers. For the energy industry this means that blockchain could open up the electricity markets for consumers. This would result in more transparency and a more accurate record of transactions. Secondly, blockchain offers an efficient way to record and distribute data. In the energy sector this would be beneficial for energy companies, but also for consumers as this will enable an easier and timely way to manage electricity bills, and more visibility of their data and transactions. This could also help to streamline the distribution of energy. Thirdly, blockchain could identify the energy's origin and corresponding price, resulting in increasing integrity in the industry.

"This could all result in increased competition, streamlined energy distribution, reduced energy wastage, transparency, renewed trust between end consumers and energy suppliers and as a result could help cut electricity bills" (C. R. W. de Meijer, 2016).

Blockchain use cases may extent to all processes within the energy value chain, from production, trade, transmission, distribution, and supply to the consumer. If blockchain technology is implemented industrywide, it may result in the transformation of the entire energy industry.

5.
Energy Domain

In this chapter the energy domain will be discussed. The purpose of this chapter is to analyse where in the energy industry system blockchain could be applied, and to find the main trends and developments that are currently taking place in this domain. Based on the framework for the description of the energy ecosystem from chapter 2, the second sub question *'How is the ecosystem around the energy industry system in the Netherlands currently arranged?'* will be answered.

First, in section 5.1, the current energy industry system in the Netherlands will be discussed based on the energy value chain. The six main processes and the related actors will briefly be described in subsections 5.1.1 and 5.1.2. Second, in section 5.2, the energy ecosystem for the current Dutch energy industry system will be formulated based on the findings in section 5.1 and the theoretical framework constructed in chapter 2. The ecosystem formulated in this chapter will provide a status quo of the Dutch energy industry for the scenario development phase.

5.1 The Energy Industry System

Energy markets have a few typical characteristics that distinguish them from other markets. First of all, the products originating from the energy industry are essential to the society's functioning. Secondly, the energy industry requires a special fit market design, as a result of the physical infrastructure on which the energy industry is built. In 1996 the Electricity Directive 96/92/EC[2] initiated the liberalisation of the European electricity industry. This meant the introduction of competition in the industry. The basic assumption behind the liberalisation of the energy market is that it would force organisations to be more efficient, which would be beneficial for consumers. Because not all parts of the industry are suitable for competition, the distribution networks are considered natural monopolies. To avoid the possibility that competitive parties exploit control over the monopoly functions, the competitive and monopoly functions needed to be unbundled (Correljé, de Vries, & Knops, 2010).

According to the energy value chain, the Dutch energy system consists of six consecutive, main processes: production, trade, transmission, distribution, metering and the supply of energy (see Figure 12). The transmission and distribution of energy are regulated by law, the other parts of the value chain are unregulated. The organisations for the distribution of energy can be considered as natural monopolies. The other components of the energy system are considered competitive activities. The three main flows, or the three main exchange processes, in the energy value chain are the physical flow (electricity), the information flow and the monetary flow. We will follow the value chain depicted in Figure 12 to start our analysis of the current energy domain. For simplicity, in this research we will only focus on the electricity market, and on the physical, information and monetary flows. Large consumers will not be taken into account, because they are out of the scope of this study, as mentioned in chapter 1.

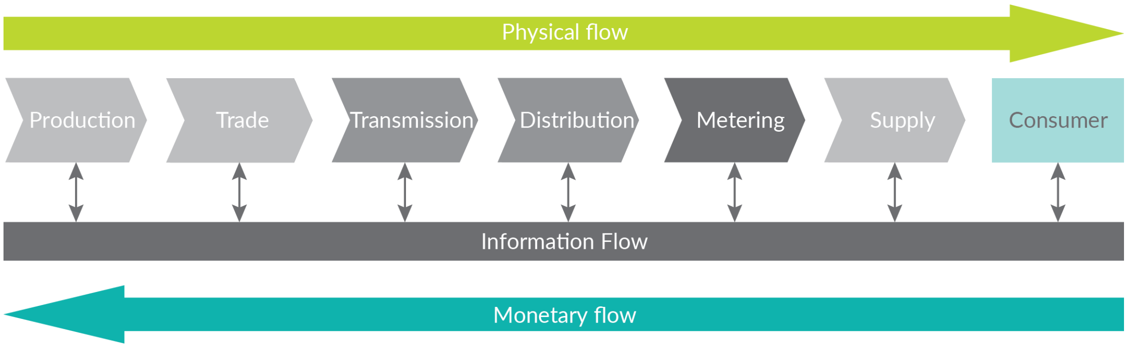

Figure 12: Energy value chain (adapted from (Fens, 2005))

5.1.1 Production, Distribution and Supply

The energy value chain starts with the production of energy. Electricity is produced by electricity producers, which are the owners of the power plants at which electricity is generated. The producers sell their electricity to suppliers, which sell the electricity to consumers. Or, the electricity producers sell the electricity they produced to the consumers themselves. In the latter case, energy producers are also the suppliers of energy to the end-consumer.

The distribution process is split into two processes: transmission and distribution. TenneT is the party responsible for the national high-voltage grid, or the transmission process in the value chain. In the Netherlands, they are the only Transmission System Operator (TSO). The core-task of the TSO is to secure and continue the supply of electricity by keeping the demand and supply of electricity balanced (TenneT, n.d.).

Distribution System Operators (DSO) are responsible for the regional energy grids that transport electricity from the transmission network to the end-consumer. There are ten DSOs in the Netherlands, each of them manages the distribution network in their own specific area. This means that a consumer cannot choose its own DSO. When the energy supplier has not assigned an external party to meter the electricity usage at the end-consumer, the DSO is also responsible for the process of metering.

The electricity suppliers have already been mentioned a few times. These organisations either both produce electricity themselves and sell the electricity produced to their end-consumers, or they buy electricity from electricity producers and sell the electricity to their end-consumers (in which case they are called retailers). The electricity suppliers are the organisations that are directly connected to the end-consumer. The consumer is free to choose the electricity supplier they prefer. Consumers base their choice for electricity supplier for example on the level of electricity prices, or on the choice for green or grey electricity.

The consumer is the end-user of the electricity, but the consumer sometimes takes on a second role: the production of their own energy. In this case, the consumer is called a *prosumer.* The consumers can be divided into two groups: 1) small consumers (households and small and medium firms), and 2) large consumers (large and/or industrial firms). The main difference between these two groups of consumers, is that the large consumers are allowed to participate on the energy markets described in the following subsection, and the small consumers are not.

5.1.2 Trade

Electricity itself is traded in different electricity markets: the *long-term market*, the *day-ahead market*, the *intra-day market*, and the *balance market*. The so called programme responsibility requires the *programme responsible parties* to notify the TSO of the electricity volume they will supply to, or take from the system, each fifteen minutes, one day ahead. If the programme responsible parties do not act according to the programme handed in the day before, the TSO can demand these parties to produce less or more, or take less or more energy to balance the market. If a party deviates from its programme, it is required to buy the extra electricity demand in the balance market, against the current market price in the balance market. For small consumers, the energy supplier has to take care of the programme responsibility. If the supplier is acknowledged as a programme responsible party, the supplier can take on this responsibility, if not, they can outsource the programme responsibility to an external party (Donker et al., 2015).

In the long term markets, agreements are made for trade on the long term which gives a certain security base. In the day-ahead market, electricity is traded one day ahead. After this market has been closed and all bids have been placed, the prices are determined. In the intra-day market, extra energy can be sold or bought after the day-ahead market has been closed. This can take place up to 5 minutes before the electricity is supplied (Donker et al., 2015).

The balance market, the day-ahead market and the intra-day market are all centrally organised, and not open for small users like households and small/medium organisations (Donker et al., 2015). This current system assumes a passive consumer, whose interests have to be represented by the energy provider and DSO (FUSE, 2017).

5.2 Energy Ecosystem

The energy value chain as discussed in previous section is useful as a starting point to explain the basic processes in the energy industry. However, the industry is not quite as linear as the energy value chain anymore, and not all relevant functions are included. Therefore, in this section the ecosystem concept is used to analyse and visualise the roles, functions and relationships within the energy industry. This means that we are going to model the networked system of different types of actors that are tied to each other through relationships, and interact both cooperatively and competitively within the energy industry.

The processes described in the energy value chain are used as starting point for the development of the energy ecosystem. We will use nodes and links to represent the actors and relationships in the ecosystem. The nodes will be labelled by the type of role or function they have, and for each node examples will be given of parties currently fulfilling this function or role. From previous chapter it became clear that a blockchain can facilitate transactions between parties that in principle do not trust each other. The physical flow, informational flow, and monetary flow can be seen as the main exchange processes, or transactions, taking place in the ecosystem. Therefore, we will distinguish physical, informational, and monetary links, or relationships, between the nodes. Because of the characteristics of these transactional links, the direction of the links will also be visualised. To determine the boundaries of the ecosystem, the following criteria have been set up:

Each node in the ecosystem has to;

1. Be directly related to, or affecting, one or more processes of the energy value chain, and/or
2. Affect services related to energy value chain, and/or
3. Affect the market forces in the ecosystem.

In the following subsections, the energy ecosystem will be built step by step. First, we start with the visualisation of the nodes and links concerning the physical flow. Second, we visualise the nodes and links concerning the information flow and the monetary flow. Thirdly, the main supervisory bodies will be identified to complete the energy ecosystem. Lastly, the three separate models will be combined, and the main supervisory bodies will be added to complete our model of the energy ecosystem.

5.2.1 Physical Flow

Figure 13 depicts the physical flows between the nodes, which is in this case the exchange of electricity. As we saw in the energy value chain, the physical flow starts at the producer, when the producer generates electricity. The TSO distributes the electricity via the high voltage grid to the regional grid managed by one of the DSOs. TenneT also works together with TSOs in other countries to compensate for national electricity surpluses and shortages (TenneT, n.d.). This means that TenneT imports or exports electricity from or to other countries when there are surpluses or shortages in countries that are connected to the Dutch high-voltage grid via cross-border connections: When the supply of energy is larger than the demand, the TSO distributes the surplus to one of the cross-border TSOs. When another country has a surplus, the TSO might take over (part of) the surplus the other country. We have labelled these foreign TSOs 'Cross-border TSO'. The DSOs distribute the electricity to the end consumer.

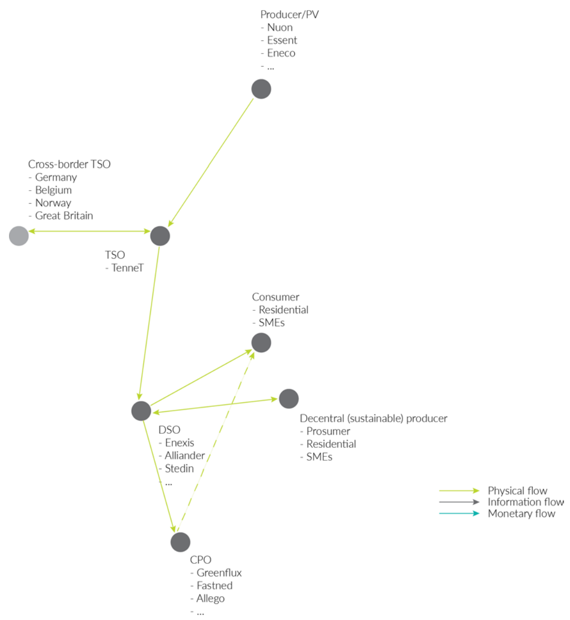

Figure 13: Energy Ecosystem - physical flow

Increasingly, the consumer also acts as a prosumer. When a prosumer has a surplus, he or she can sell his or her surplus back to the energy supplier, hence supply the energy surplus back to the grid. This is depicted by the link between the DSO and the 'decentralised (sustainable) producer'. We have added 'sustainable' to the function, because in most cases the electricity provided by these parties is likely to be produced from private solar panels, or sometimes even from private wind turbines.

As the number of EVs is increasing in the Netherlands, so is the number of Charge Point Operators (CPOs). A CPO is responsible for the charging points for EVs. They take care of the supply, installation, maintenance, and repair of the charging points. In this case, energy is distributed via the grid of the DSO to the charging points, and in the end supplied to the owner of an EV (dashed link between the CPO and the consumer).

From the figure it is clear that the TSO, DSO, and CPO fulfil an intermediary role in the physical exchange of electricity from the producer to the consumer. Because they are the owner of the assets that are needed for the distribution of electricity from the producer to the consumer, both the producer as well as the consumer are dependent on the TSO, DSOs, and CPOs. Only when the consumer acts as a prosumer, the consumer can (partly) circumvent these intermediaries.

Furthermore, what becomes clear from this figure is that the supplier, the party from which a consumer buys its energy, is not involved in the process of the physical exchange process of energy, although it might have looked like this in the energy value chain. Hence, the function of supplier purely exists to facilitate the monetary and informational flows between the consumer and other parties.

5.2.2 Monetary and Information Flow

Figure 14 depicts the monetary exchange between nodes in the ecosystem, Figure 15 the information/data flows between the nodes. Whereas previous diagram was still relatively simple, and relatively similar to the processes described in the energy value chain, in these two diagrams we see more complexity, many new parties appear, and no linearity. We will discuss the new functions that have appeared in these diagrams, and discuss their links with the other nodes.

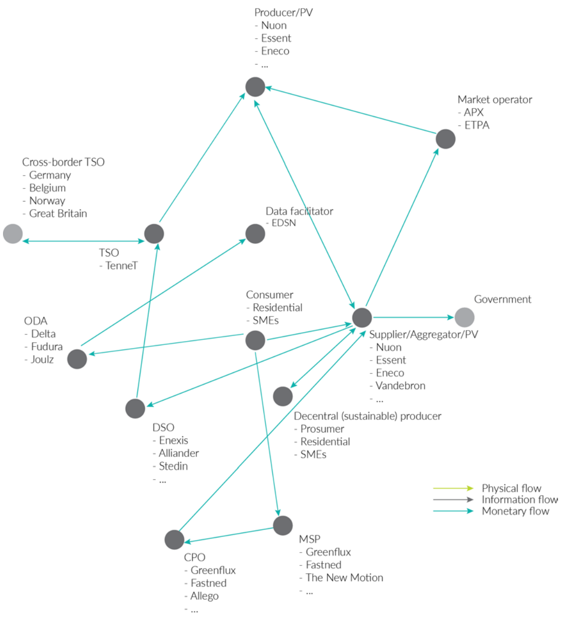

Figure 14: Energy Ecosystem - monetary flow

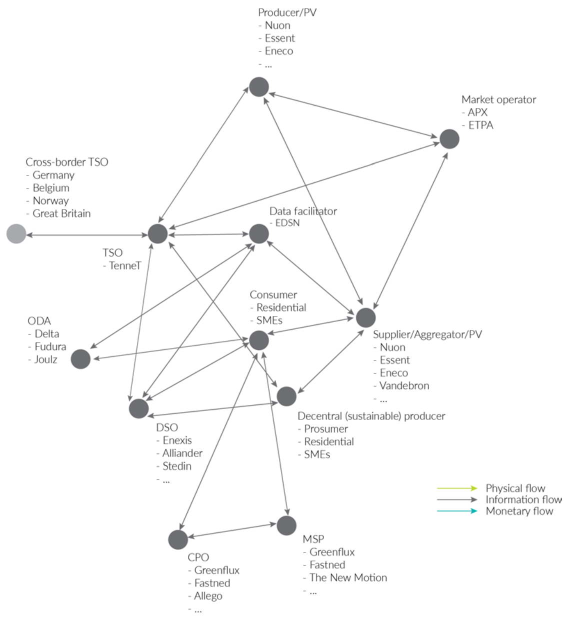

Figure 15: Energy Ecosystem - information flow

First of all, several 'service providing parties' appear, which provide services to the consumer. Namely the supplier/aggregator/PV, the Mobility Service Provider (MSP) and the ODA. The first function group, the supplier/aggregator/PV, have most direct contact with the consumer. Traditionally, a consumer signs an agreement with a supplier to receive electricity at a certain price, and a supplier buys electricity either directly from a producer or at an electricity market, this is pretty much the same as in the previously described energy value chain. Furthermore in this traditional case, the monetary flow starts at the consumer, who pays its electricity bill to the supplier. Part of this bill goes directly to the producer, or via the market operator to the producer. Another part of this bill goes to the DSO for the use of the regional electricity grid. The government is also included in the monetary diagram, because a considerable part of the bill the consumer pays goes, via the supplier, to the government in the form of taxes.

Because the number of small, decentral energy producers increases, new types of suppliers emerge which buy electricity directly from these small, decentral energy producers. Sometimes the regular consumer can even choose from which small producer it wants to buy its electricity. In the case of a prosumer, the prosumer gets paid by the supplier when it returns energy to the grid (in the form of a deduction on the final electricity bill). If the prosumer does not produce enough electricity on its own, the prosumer acts like a regular consumer.

Another emerging function is the function of aggregator. An aggregator offers consumers help to save energy and/or energy costs through flexible procurement of energy and/or return of energy. Often, the energy supplier fulfils this role.

With the emergence of EVs, the function of MSP also arose. A MSP sells mobility products and services, like a charging subscription, and a charging card. Hence, if an EV is charged at a charging point, the CPO sends an invoice to the right MSP, which in its turn bills the consumer. Hence, the function of the MSP is much like the function of a regular energy supplier, but specifically for the EV owner.

The third service provider we see emerging is the ODA, or Independent Service Provider (in Dutch: Onafhankelijke Service Provider). An ODA is a party which is certified to request smart metering data from data facilitator EDSN. The ODA visualises this data at request of the consumer, which can use this information for energy monitoring purposes.

The data facilitator and the market operator can also be seen as service providing parties, however instead of providing services to consumers, they provide services to market parties. The data facilitator is a central platform for administrative links between different market roles. The DSO is responsible for metering data, and has to register the connections in their regions and which household is contracted at which supplier. Hence, the DSO provides the data facilitator with (administrative) data regarding connections, energy contracts, address changes, and (smart) metering data. The TSO, DSOs, suppliers and ODAs can request this data at the data facilitator. The market operator provides a platform for the trade of energy in the day-ahead market, the intraday market and the balance market. In the day-ahead auction, members of the markets submit their orders, the supply and demand are compared, and the market operator calculates the market price for each hour of the next day.

5.2.3 Supervisory Bodies

To complete our ecosystem, the three main supervisory bodies have to be added to our model. The ACM (Authority Consumer & Market) is an independent supervisory body protecting both consumers and enterprises. They strive for equality in the market, well-informed consumers and honest enterprises (ACM, n.d.). The NEDU on the other hand is more of a platform for the market parties within the Dutch energy industry. NEDU helps their member parties to reach agreements and ensure that these agreements are documented (NEDU, n.d.). The European Network of Transmission System Operators for Electricity (ENTSO-E), is a network of TSOs, representing 43 TSOs from 36 European countries. They have the responsibility to enhance the cooperation between the member TSOs and to assist in the development of a European electricity transmission network (ENTSO-E, n.d.).

5.2.4 Aggregated Model of the Energy Ecosystem

In Figure 16, the previously described models have been combined into one model for the energy ecosystem. What becomes clear from our figure, is that there are many parties involved in the distribution of energy from the producer to the final consumer. Some of these parties are needed in this process, because they own important assets for the distribution, like the TSO and DSO. Other parties, like the supplier and the data facilitator, are intermediaries which collect and distribute money and/or data. The real added value of these roles could be questioned. As became clear in chapter 2, these are the roles blockchain technology could have a real impact on.

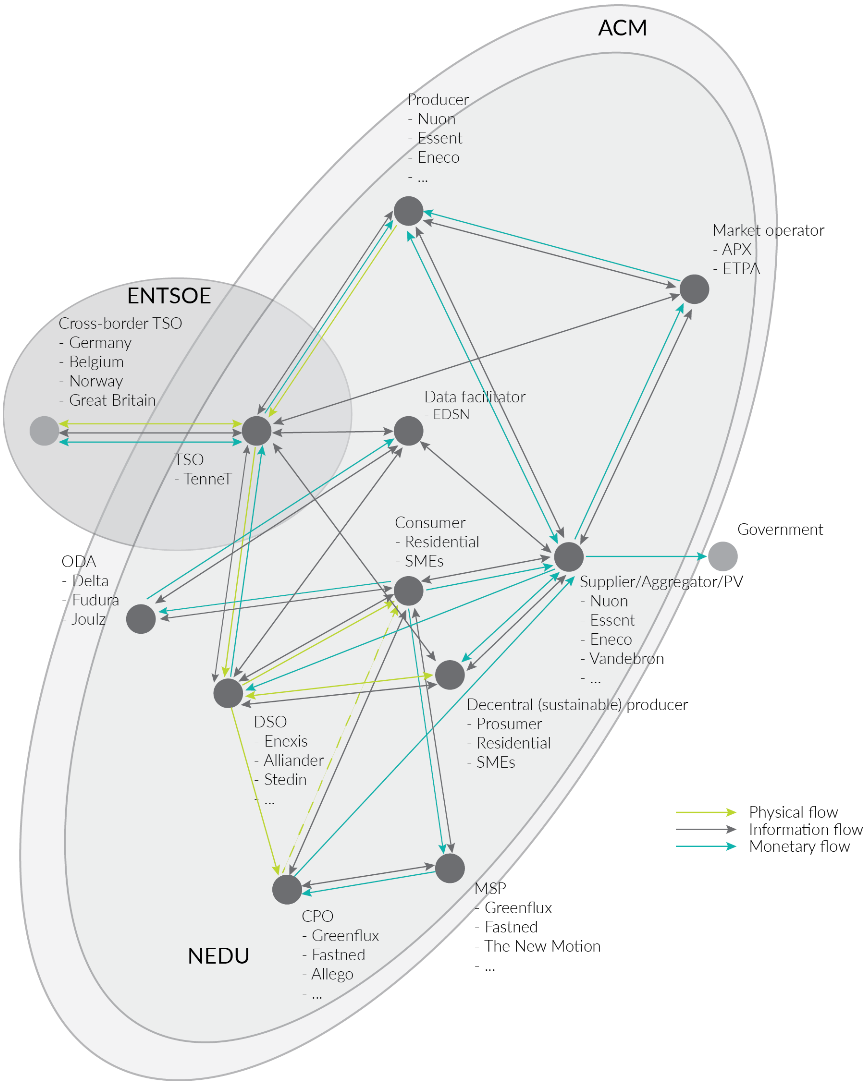

Figure 16: The Dutch energy ecosystem

5.3 Conclusion

In this chapter the domain of the energy industry has been explored. We started our description of this domain with the energy value chain. The energy value chain is often used to describe the different processes within the energy industry. We found that the energy value chain consists of six main, consecutive processes, namely: production, trade, transmission, distribution, metering and the supply of energy. However, the energy industry appeared to be not as linear as the value chain anymore because of the emergence of new functions, actors, and services. Therefore, we have used the concept of business ecosystems described in chapter 2, to model the energy ecosystem. To visualise the ecosystem we have used nodes, representing the roles existing in the ecosystem, and links, representing the mutual relationships between the nodes. The energy value chain served as starting point for this energy ecosystem. To determine the boundaries of the ecosystem, the following criteria have been used: Each node in the ecosystem has to;

1. Be directly related to, or affecting, one or more processes of the energy value chain, and/or
2. Affect services related to energy value chain, and/or
3. Affect the market forces in the ecosystem.

Because the main exchange processes in the energy industry are the exchange of electricity, money and data, we have distinguished physical, monetary and informational links to represent the relationships between the nodes. The energy ecosystem has been built step by step. First, we started with the visualisation of the nodes and links concerning the physical flow. Thereafter we have visualised the nodes and links concerning the information flow and the monetary flow. Lastly, the three main supervisory bodies have been added, and the three separate models have been combined to complete our model of the energy ecosystem.

The visualisation of the energy ecosystem has led to two main findings. First of all, from the previously presented figures, we can conclude that new technologies have emerged and new roles and services have been formed around this, compared to the more simplistic energy value chain. For example, the improved performance of solar panels has created room for the decentralised producer. The increasing need for flexibility due to the increased use of intermittent energy sources has led to the emergence of the aggregator. The emergence of the EV has opened up the ecosystem for the CPO and MSP, and the increasing number of smart meters at households has led to the entrance of the ODA to the ecosystem, to help consumers to monitor their energy usage.

Secondly, our model of the energy ecosystem has made the middlemen in the energy industry visible. These intermediary functions solely exist to distribute monetary or informational flows between other parties. Examples of these parties are the supplier, the MSP, the data facilitator and the market operator. All of these parties serve as trusted third parties to facilitate transactions between other parties in the ecosystem. As we have seen in chapter 2 and chapter 3, these are the functions in which blockchain technology could play a role.

For the following chapters, the model of the ecosystem that has been formulated in this chapter will be used as the status quo for the energy industry system. The model of the ecosystem will help to pinpoint where and how blockchain could potentially change the configuration of the energy ecosystem.

6. Scenario Planning Results

To assess the potential disruptive power of blockchain technology in the Dutch energy ecosystem, different future scenarios on ecosystem configurations for the Dutch energy ecosystem will be formulated. The following chapter provides the results of the first three stages of the scenario planning process.

First, we start with a recap of the steps taken to determine the scope of this study, which concerns stage one of the scenario planning process in section 6.1. Previous chapters provided an understanding of the focal issue of this research project, and the domains concerning this focal issue. In this section, the scope is briefly summarised. Secondly, the results of the second stage of the scenario planning process will be discussed in section 6.2. This stage concerned the identification of trends, and the analysis of the identified trends to find the key drivers for change. First the trends that have been identified, using a critical analysis of an external trend database, will be discussed. Secondly, the process and results of the analyses that have been performed to identify the most important and uncertain trends will be provided. Lastly, the selection of the scenario logic will be described in section 6.3. The results of the analyses described in section 6.2 provide the input for the selection of the scenario logic. The result of this chapter is a scenario framework, which will be used in the following chapter to formulate the scenario narratives which are the describing part of the scenarios.

6.1 Scope

The scope for the scenario planning process is derived from the overall scope of this study. The focal issue is the potential and disruptive impact of blockchain technology for the energy industry, with the main focus on changes in the configuration of the corresponding ecosystem. The main stakeholders have been identified in chapter 4, as the members of the energy ecosystem (see Figure 16). The boundaries of this ecosystem also form the boundaries for the scenario planning process, whereby the focus is on the processes, roles and functions directly related to the processes of the energy value chain for small users. Major energy consumers are out of the scope of this study, because they concern a different energy value chain, hence a different energy ecosystem.

The strategic questions that have been formulated for the scenario analysis are:

1. What could the Dutch energy ecosystem look like in the future?
2. What is the potential disruptive impact of blockchain technology on the Dutch energy ecosystem, with the focus on the disappearance, change, and emergence of roles and functions?

The time horizon used for the scenarios is 10-15 years, hence the scenarios will be formulated for the year 2030.

6.2 Trends & Developments

As mentioned in chapter 3, for this part of the process, it was not needed to search for, and collect, trends and developments in the energy industry. Instead, an extensive list of trends and developments, compiled by a project team of Enexis, was available and could be used for this study. The project team of Enexis has clustered a total of 909 trends and developments into 29 trend clusters. First of all, in section 6.2.1, the remaining 29 trends will be critically analysed to determine their relevance for this specific scenario planning project. Additionally, because a number of clusters 29 clusters is considered to be too much to keep the scenario planning process manageable, the number of clusters has to be narrowed down. Secondly, in section 6.2.2 the remaining trends will be analysed to be able to identify the most important and uncertain trends. This is needed for the next stage, in which the scenario framework needs to be constructed, based on the key drivers for change. Table 1 represents the list of trends developed by the Enexis project team, including a description of each cluster.

Table 1: Trend clusters developed by Enexis project team. Source: (Kuiper, 2015).

Trend cluster name and description
1. Acceleration of technological breakthroughs New technological developments emerge for existing technologies.
2. Increase of affordable and available energy storage possibilities Storage and conversion to energy carriers which can be relatively easily stored.
3. Increase in large-scale (central) sustainable electrical production Shifts between energy carriers (electricity, gas, heat) in the central energy production.
4. Increase in decentralized energy production Production shifts from centralized production to decentralized production.
5. Increasing awareness / attention for sustainability There is an increased awareness and attention to sustainability, both intrinsic at consumer as stimulated by the government (in the form of subsidies, CO2 taxes).
6. Increasing scarcity of resources Resources like fossil fuels and raw metals become scarce. Also there is a shortage of room for the production of biofuels. The result is a price increase of resources.
7. Increasing complexity of energy distribution Due to changes in supply and demand the requirements to the physical energy network change. The networks become more complex, among others due to the increase in the usage of IT in the networks.
8. Increase in the amount of new energy services and service providers There is an increase in service providers on the field of energy and a corresponding increase in the amount of services which can be provided. Developments at service providers are speeding up (energy savings, demand-side management, flexibility).
9. Decreasing energy usage of the end user / client Energy usage in the residential sector decreases, on the one hand due to better insulation and local energy generation, on the other hand due to increasing energy awareness. There are more and more energy users in and around the house which could make the energ usage 'behind the meter' rise.
10. Increasing customer involvement with energy Energy becomes more important. Customers are consequently more demanding and expect more from DSOs in terms of information, service etc.
11. Increasing urbanisation and shrink regions Urbanisation and shrink regions change demands in investments in these regions.
12. Economic model develops towards more bottom-up initiatives There are more and more local and small-scale initiatives, in which ownership and usage are handled differently. Examples are the participation-sharing economy and crowd/funding.

13. Increasing instability of global financial systems Integration of global financial markets expands local problems to a larger area.
14. Increasing desire for meaningfulness The public debate shifts from doing the things right, to doing the right things. This leads to different choices on the balance of work and the private environment.
15. Increasing government steering / regulation on the energy market Energy is becoming an important topic in politics. As a result the government interferes more on security of supply. Regulation increases both nationally and from the EU.
16. Increasing flexibility of the labour market Legal principles of fixed contracts and freelancers are more and more similar. More and more people have a flexible working relation.
17. Sustainable transport rises As the transport sector is required to become sustainable, a shift occurs towards transportation with no direct fossil fuel usage. Electric vehicles, hydrogen vehicles and transport based on green gas rises.
18. Increase in public involvement with energy related questions The public is more involved with projects concerning storage, gas, CO2 collectors etc. and also carries strong opinions on them.
19. Increasing desire for self-sufficiency Increase in human (individual) independence of existing institutions. Self-sufficiency is a priority.
20. Increase in number (and tasks) of energy corporations Collective self-sufficiency rises; tasks and complexity of corporations will increase, from production to distribution and delivery.
21. Emergence of new energy carriers / forms of energy Among others nuclear fusion, LNG, biogas, shale gas, ´heat´ as source, hydrogen.
22. Increasing need for flexibility to account for fluctuations in energy supply and demand Increasing need for controllable generation and controllable usage for a better fine-tuning of variable supply and demand. Examples are controllable generation and dynamic tariffs.
23. Increase in the importance and usage of data The amount of data and the connection between data from various sources are increasingly more important, providing options for new forms of services and monitoring.
24. Increasing contradictions in the society Increasing contradictions arise between 'have's' and 'have-not's'. For a growing group of people access to new digital applications is becoming a problem; the energy bill threatens to become too expensive.
25. Increase in geopolitical unrest This can lead to new collaborative efforts and/or more need for self-sufficiency.
26. Increase in specialisation and collaboration in / over the value chain Through increasing complexity in the energy value chain and specialisation of firms there is an increasing need for interdependence.
27. Emergence of the (bio-based) circular economy Increasing scarcity of resources lead to the emergence of a circular and bio-based economy. Renewability and reusability of resources are key.
28. Increase in integration between electric, gas, and heat through local optimisation More often than not people look for the best solution on a local level by integrating energy carriers.
29. Increase in aging population The aging population leads to a labour shortage and requires firm attention to the field of customer communication.

6.2.1 Clustering

Clustering and re-clustering is a subjective process. As a result, other researchers could have come up with a different set of clusters than we did. To reduce this risk, we followed a structured process based on two steps to increase the robustness of the re-clustering process. The first step concerns the determination of the relevance of each cluster for our research based on four criteria. The second step concerns the categorisation of the clusters using STEEP.

First, the relevance of the trend clusters for this scenario planning process had to be analysed. The following criteria were used to determine whether or not a trend cluster is relevant for this study. Each cluster has to cover trends;

1. Directly related to or affecting one or more processes of the energy value chain, and/or
2. Affecting services related to energy value chain, and/or
3. Affecting the market forces in the ecosystem, and/or
4. Affecting the adoption of blockchain technology in the ecosystem.

Most trends cover at least one of the criteria defined above. Trend clusters 11, 13, 14, 16, 24, and 25 however, did not meet at least one of the four criteria. Therefore, we conclude that they are outside the scope of our research, and as a result, irrelevant for our scenario planning process.

Secondly, the remaining clusters have been structured using STEEP. STEEP is short for Social, Technological, Economic, Environmental, and Political forces. Each cluster was categorised into one or two of the STEEP categories to structure the clusters based on their overarching topic.

These two steps resulted in a re-clustered list of trend clusters: trend clusters covering the same criteria and the same STEEP categorisation form a new trend cluster. Of course, when we started combining and rephrasing trend clusters after proceeding these two steps, it has been carefully checked whether the new trend cluster covered all clusters that had been combined during the re-clustering process, and no strange combinations were made. This way we were able to re-cluster some of the clusters by combining, rephrasing, and re-clustering them into a larger cluster covering the same overarching topic. Table 2 on the next page summarises this process. In total, a number of twelve clusters have been identified from the data. The description of the twelve remaining trend clusters can be found in Table 3.

First of all, three trend clusters met all four criteria of step one of the re-clustering process: Cluster 1- '*Acceleration of technological breakthroughs*', Cluster 4 - *'Increase in decentralised energy production'*, and Cluster 15 - *'Increasing government steering/regulation on the energy market'*. Furthermore, cluster 1 has been categorised into 'Technology', because it describes a purely technological development. Cluster 4 has been categorised into 'Technology' and 'Social', because it is a combination of a technological and a social development: there is an increase in technologies to enable decentral energy production (solar panels, wind turbines, etc.), which is largely driven by social developments. Cluster 5 has been categorised into 'Political' because it purely describes political activity. Hence, all three clusters cover the same criteria, but a different topic. Therefore, these three clusters have not been re-clustered but remained the same.

Table 2: (Re)clustering process

Trends	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Social	Technological	Economic	Environmental	Political	Cluster
	Criteria				STEEP					
1. Acceleration of technological breakthroughs										11
2. Increase of affordable and available energy storage possibilities										1
3. Increase in large-scale (central) sustainable electrical production										4
4. Increase in decentralized energy production										3
5. Increasing awareness / attention for sustainability										7
6. Increasing scarcity of resources										8
7. Increasing complexity of energy distribution										12
8. Increase in the amount of new energy services and service providers										9
9. Decreasing energy usage of the end user / client										8
10. Increasing customer involvement with energy										7
11. Increasing urbanisation and shrink regions										–
12. Economic model develops towards more bottom-up initiatives										7
13. Increasing instability of global financial systems										–
14. Increasing desire for meaningfulness										–
15. Increasing government steering / regulation on the energy market										5
16. Increasing flexibility of the labour market										–
17. Sustainable transport rises										8
18. Increase in public involvement with energy related questions										7
19. Increasing desire for self-sufficiency										7
20. Increase in number (and tasks) of energy corporations										10
21. Emergence of new energy carriers / forms of energy										1
22. Increasing need for flexibility to account for fluctuations in energy supply and demand										2
23. Increase in the importance and usage of data										12
24. Increasing contradictions in the society										–
25. Increase in geopolitical unrest										–
26. Increase in specialisation and collaboration in / over the value chain										12
27. Emergence of the (bio-based) circular economy										8
28. Increase in integration between electric, gas, and heat through local optimisation										1
29. Increase in aging population										6

Secondly, fourteen trend clusters covered criterion 1, 2, and 3. Cluster 2 – *'Increase of affordable and available energy storage possibilities'*, Cluster 21 *'Emergence of new energy carriers/forms of energy'*, and Cluster 28 – *'Increase in integration between electric, gas, and heat through local optimisation'* were also categorised into the same category, namely 'Technlology'. Therefore, after carefully reviewing the clusters, they have been re-clustered into a new cluster because they match on the basis of the criteria they meet and the category they belong to. We have rephrased the cluster into *'The emergence of new developments in energy technology'* to cover all three trends. Cluster 5 – *'Increasing awareness/attention for sustainability'*, Cluster 10 – *'Increasing customer involvement with energy'*, Cluster 12 – *'Economic model develops towards more bottom-up initiatives'*, Cluster 18 – *'Increase in public involvement with energy related questions'*, and Cluster 19 – *'Increasing desire for self-sufficiency'* cover criterion 1, 2, and 3 and are all five categorised into the category 'Social'. They are re-clustered into the cluster *'Increase in customer awareness and involvement in the energy market'*. Cluster 6 – *'Increasing scarcity of resources'*, Cluster 9 – *'Decreasing energy usage of the end user/client'*, Cluster 17 – *'Sustainable transport rises'*, and Cluster 27 – *'Emergence of the (bio-based) circular economy'* were all four categorised into 'Social' and 'Environmental' because all clusters had a social and an environmental component. Therefore, they are clustered into the cluster *'Increasing sustainable energy use'*. Cluster 3 – *'Increase in large-scale (central) sustainable electrical production'* was the only cluster covering criterion 1, 2, and 3 which had been categorised into 'Technology' and Environment'. Therefore, this cluster was not re-clustered and remained the same. For Cluster 20 – *'Increase in number (and tasks) of energy corporations'* the same applies. It was the only cluster to cover criterion 1, 2, and 3, categorised into categories 'Social' and 'Economic'. Therefore, this cluster was also not re-clustered and remained the same.

Thirdly, there were three clusters that met criterion 1, 2, and 4. Cluster 7 – *'Increasing complexity of energy distribution'*, Cluster 23 – *'Increase in the importance and usage of data'*, and Cluster 26 – *'Increase in specialisation and collaboration in/over the value chain'* met these three criteria, and were categorised into the category 'Technology'. Because the three clusters implied the increased importance in data they have been combined into the cluster called *'Increasing importance of data'*.

Fourthly, Cluster 29 – *'Increase in aging population'* was the only cluster that met criterion 2 and 4, because aging is likely to increase the need for services, and different ways of communication towards this increase group of elderly people. Additionally, because the number of elderly is increasing, the adoption of blockchain technology could be slowed down. Because there were no other clusters meeting the same criteria, Cluster 29 remained the same, but we rephrased the name into *'Aging'* for simplicity.

Fifth, Cluster 22 – *'Increasing need for flexibility to account for fluctuations in energy supply and demand'* was the only cluster to only meet criterion 1. Therefore, this cluster was not re-clustered. We only rephrased the name of this cluster into *'Increasing need for flexibility'*, for simplicity.

Lastly, Cluster 8 – *'Increase in the amount of new energy services and providers'* was the only cluster to meet criterion 2. We therefore did not re-cluster this trend cluster, but only rephrased the name into *'Increase in energy service and service providers'*.

Table 2 summarises the twelve resulting trend clusters that are used in the following steps of the scenario planning process, and provides a description for each of the trend clusters. In the next step the trend clusters will be ranked on impact, uncertainty, and cross-impact to determine the key driving forces for the scenario framework.

Table 3: Trend clusters and description

Trend cluster name and description
1. The emergence of new developments in energy technology The development of new energy carriers or new forms of energy, for example hydrogen and improvements in energy storage.
2. Increasing need for flexibility The need for flexibility to balance fluctuations in demand and supply. Examples are controllable energy production and dynamic tariffs.
3. Increase in decentralised energy production Energy production shifts from central production to decentral production.
4. Increase in large scale sustainable energy production Sustainable energy is increasingly produced centrally, think of large scale wind- and solar parks.
5. Increasing governmental steering in the energy market Energy is becoming an important governmental topic. This results in increasing government interference and more regulations on the energy market, from the Dutch government, as well as from the European Union.
6. Aging Aging in the Netherlands leads to different consumption patterns and more attention for (other forms of) communication and services in the energy sector for this growing group of elderly people.
7. Increase in customer awareness and involvement in the energy market The Dutch consumer increasingly wants to be independent from established institutions. More often self-sufficiency is a priority.
8. Increasing sustainable energy use The Dutch consumer uses less energy due to better insulation, local energy production, more awareness and insight into their energy consumption, and the emergence of circular economy. Additionally, transport is becoming more sustainable due to the emergence of electric transport.
9. Increase in energy service and service providers More (and new) services and service providers enter the energy market. For example for energy savings, help with independent energy production, and advice.
10. Increase in energy cooperations Consumers increasingly buy energy through energy cooperations.
11. Acceleration of technological breakthroughs There is an increase in technological breakthroughs, not only in the energy sector but also outside the sector, think of Blockchain, Internet of Things and Artificial Intelligence.
12. Increasing importance of data The use and importance of data is increasing. Interconnectivity of data, people and systems results in more information provision and the emergence of new services and monitoring. Think of Internet of Things and Artificial Intelligence.

6.2.2 Impact and Uncertainty Analysis

For the first part of the analysis of the trend clusters, a survey is used to assess the impact of each cluster on the energy ecosystem, and the uncertainty of the development of each cluster. The clusters described in section 6.2.1 have been used as input for the expert survey. A sample of experts (N=30) has been asked to judge each cluster on its potential impact on the energy ecosystem and its uncertainty. A Likert scale of *very small (0)* to *very high (5)* has been used to assess both the impact of each trend cluster as well as its uncertainty. The tool SurveyMonkey has been used for the survey. The sample of experts consisted on the one hand of the group of experts for the focus group, and on the other hand of employees of Enexis/Enpuls, all with sufficient knowledge of the energy industry (as previously described in section 3.3.3). Because the survey was kept 'in-house' the survey could be executed in a short time period (8 days). In total, 22 respondents completed the survey, hence the response rate is 73,3%. An example of the survey questions (in Dutch) is given by Figure 17.

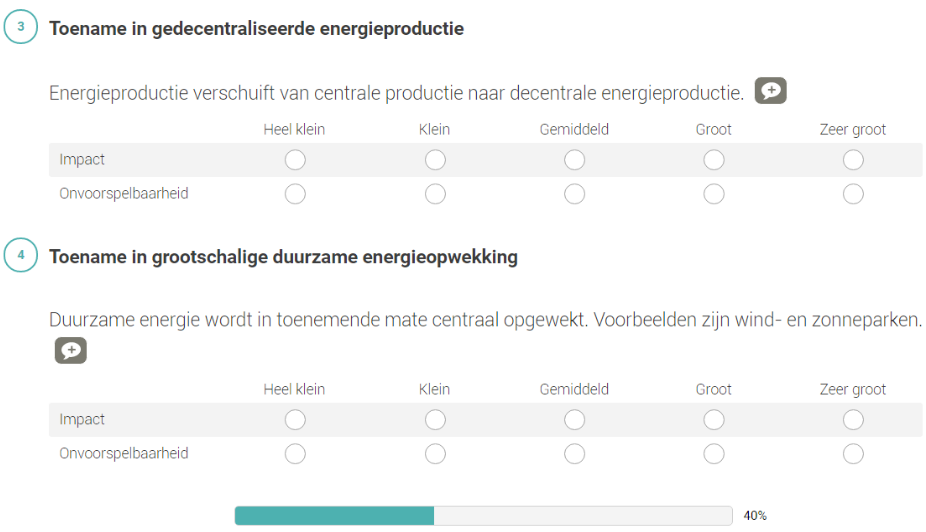

Figure 17: Example questions survey (in Dutch)

For the second part of the analysis, a CIM used to determine the impact of each cluster on the other clusters. For each cluster, its impact on another cluster is given a score between 0 and 3. If the impact of a cluster on another cluster is low/close to zero, this cluster will be given a score of 0, if the impact of a cluster on another cluster is high, this cluster will be given a score of 3. When the impact of each cluster had been analysed and scored, the mean for each row and each column were determined. The row mean provides the average impact of one cluster on the other clusters. The column mean provide the average impact the other clusters have on one cluster (hence, this is a dependency score). The complete CIM can be found in appendix C.

The results of both the impact and uncertainty survey and the CIM are provided in Table 3. In the first two columns, the impact and uncertainty scores are given. The scorers in these columns are the average scores of the trends resulting from the impact and uncertainty survey, on a scale of 0 to 5. A high impact score means that a trend is thought to have a high impact on the ecosystem, hence the trend is likely to change the ecosystem. A low impact score means that the impact of the trend on the ecosystem is expected to be low. A high uncertainty score means that the development of a trend is uncertain. A low uncertainty score means that there is little uncertainty about the development path of a trend. The last column provides the row mean results from the CIM, on a scale of 0 to 3. A high cross-impact score means that the trends has a high impact on the development of other trends, on average. A low cross-impact score means that the trend has, on average, little impact on the development of the other trends.

The results provided in Table 4 are used to select the scenario logic in section 6.3. In this section, the results will be interpreted to be able to select the two trends with the highest impact, highest uncertainty and highest cross-impact scores for the scenario frameworks, because these trends are expected to be the biggest drivers for change.

Table 4: Results survey and cross-impact analysis

Trend	Impact	Uncertainty	Cross-impact
1. The emergence of new developments in energy technology	4,3	3,5	1,8
2. Increasing need for flexibility	3,7	2,6	1,6
3. Increase in decentralised energy production	3,7	3,0	1,9
4. Increase in large scale sustainable energy production	3,5	2,7	1,6
5. Increasing governmental steering in the energy market	3,6	3,3	1,6
6. Aging	2,4	2,4	0,5
7. Increase in customer awareness and involvement in the energy market	3,4	2,6	2,4
8. Increasing sustainable energy use	3,6	2,8	1,9
9. Increase in energy service and service providers	3,3	2,8	1,6
10. Increase in energy cooperations	2,4	2,6	1,6
11. Acceleration of technological breakthroughs	4,4	3,9	2,0
12. Increasing importance of data	3,9	3,3	1,6

6.3 Selection of the Scenario Logic

The results from the survey and the CIM are used to colour-code the trends based on their impact, uncertainty, and cross-impact scores. We colour-coded the results to identify the key drivers for change that will be used to construct the scenario framework. Table 4 provides the colour-coded results of both the survey and the CIM. A red cell stands for an above average/high score (a higher impact/uncertainty/cross-impact than the average trend), a yellow cell stands for an average score, and a green cell stands for a below average/low score (a lower impact/uncertainty/cross-impact than the average trend). A key driver for change will have high impact, uncertainty, and cross-impact scores compared to the other trends.

Table 5: Colour-coded results survey and cross-impact analysis

Trend	Impact	Uncertainty	Cross-impact
1. The emergence of new developments in energy technology			
2. Increasing need for flexibility			
3. Increase in decentralised energy production			
4. Increase in large scale sustainable energy production			
5. Increasing governmental steering in the energy market			
6. Aging			
7. Increase in customer awareness and involvement in the energy market			
8. Increasing sustainable energy use			
9. Increase in energy service and service providers			
10. Increase in energy cooperations			
11. Acceleration of technological breakthroughs			
12. Increasing importance of data			

From the table, one can immediately see that trend 11, '*acceleration of technological breakthroughs*', scored above average/high on all three of the components of this analysis. This makes this trend an obvious key driver for change that has to be included in the scenario framework. Secondly, based on the results of the analyses, both trend 1, '*emergence of new developments in energy technology*', as well as trend 3, '*increase in decentralised energy production*' could be included into the scenario framework. Although the nature of trend 11 is explicitly different from the nature of trend 1, both trends cover technological developments. Therefore, if both trend 1 and trend 2 are included into the scenario framework, this might lead to overlap and confusion during the trend formulation phase. Therefore, we choose to select trend 3 as the second axis of the scenario framework. This results in the following scenario framework (Figure 18):

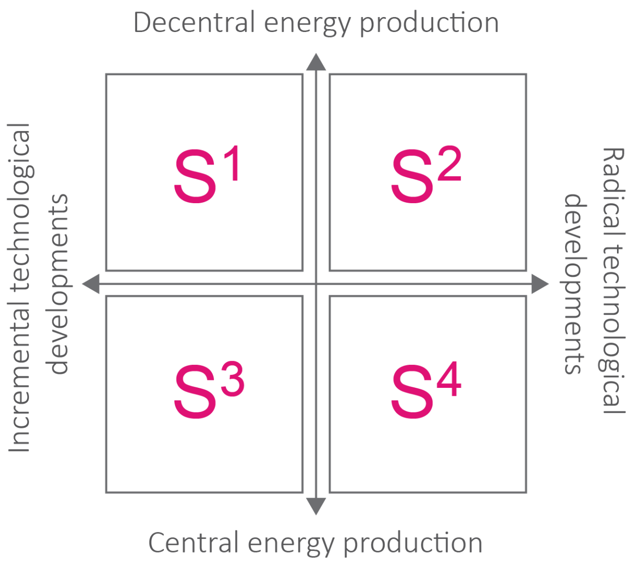

Figure 18: Scenario framework

6.4 Conclusion

In this chapter, the results of the first three stages of the scenario planning process have been provided and discussed. First, we started with a recap on the steps taken to determine the scope of the scenario planning project for stage 1. We specified the focal issue of this project as the potential and disruptive impact of blockchain technology for the energy industry, with the main focus on changes in the configuration of the corresponding ecosystem. The ecosystem modelled in chapter 5 specified both the stakeholders for this project, as well as the boundaries for the scenario planning process, whereby the focus is on the processes, roles and functions directly related to the processes of the energy value chain for small users. We chose a time horizon of 10-15 years, hence, the scenarios will be developed for the year 2030. The strategic questions that have been formulated for the scenario analysis are:

1. What could the Dutch energy ecosystem look like in the future?
2. What is the potential disruptive impact of blockchain technology on the Dutch energy ecosystem, with the focus on the disappearance, change, and emergence of roles and functions?

Secondly, the trend list from Enexis has been analysed critically, using four criteria to determine the relevance of the trends for our scenario planning project, and the STEEP analysis tool to categorise the trends. Based on the four criteria and the STEEP categorisation, the trends have been re-clustered into twelve trends. Furthermore, these twelve trends have been analysed on their impact on the ecosystem, the uncertainty of their development path, and the impact they have on the development of the other trends, using an impact and uncertainty analysis through an expert survey, and a CIM.

Lastly, based on the results of the impact and uncertainty analysis, and the cross-impact matrix, the key drivers for change have been identified to construct the scenario framework that will be used in the next stage to develop the scenario narratives. The trends *'acceleration of technological breakthroughs'* and *'increase in decentralised energy production'* were found to be the two most important and uncertain trends, and were therefore used to construct the scenario framework represented by Figure 18.

7. Scenario Narratives

During a focus group, the assumptions for the four scenarios have been formulated. The results from the workshop have been translated into four scenario narratives. The narratives have been developed further using interviews to enrich and validate the narratives. In this chapter, the final scenario narratives will be provided. These scenario narratives will be used to derive an answer to research question 4 *'What are possible scenarios for the ecosystem configuration of the Dutch energy industry system, when blockchain is implemented as an institutional technology?'* and research question 5 *'Based on the evaluation of the possible future scenarios for the ecosystem configuration of the Dutch energy industry system, what is the potential of blockchain technology?'*

Sections 7.1, 7.2, 7.3 and 7.4 describe one scenario each. For each of the scenarios, we start with a discussion of the scenario narrative development process. In this part we start with a discussion of the main results of the focus group (see appendix D for a summary of the focus group results). Thereafter, we explain our interpretation of these results for the further development of the scenario narratives. This was needed, because the experts' expectations for the future were coloured by their own experience, interests, and field of work. The working versions of the scenario narratives were discussed during five expert interviews, and adjusted each time before they were send to the next expert. Therefore we also describe the main results of the interviews. Secondly, we provide our final version of the narrative for each of the scenarios. Thirdly, we discuss the implications of the scenarios on the energy ecosystem for each of the scenarios, using the model of the energy ecosystem from chapter 5. The implications are based on our own interpretation of the scenarios and have been validated during the expert interviews, and adjusted if needed. Lastly, we evaluate the scenarios using the results of the expert interviews. The scenarios are evaluated based on their plausibility, divergence, provocativeness, and the disruptiveness of blockchain technology in each of the scenarios.

Section 7.5 provides the general implications of the scenarios on the energy ecosystem. First the changes in roles and functions are analysed. Secondly, the changes in the structure of the ecosystem are described and analysed using the network properties described in section 2.3.1.

Although the scenario narratives are based on expectations voiced by experts, and could possibly be seen as extrapolations of events currently taking place, it is important to note that *the scenario narratives described are possible future worlds and are therefore fictional.*

7.1 Scenario One – Power Play

The first scenario is called *'Power Play'*. This scenario has been developed for the first quadrant of the scenario framework. For this possible future world, the two predefined assumptions which followed from the scenario framework were:

- Incremental technological developments
- Central energy production

7.1.1 Scenario Narrative Development

For scenario one, the experts were asked to envision the energy ecosystem of the Netherlands in the year 2030, in which energy is mainly centrally produced and technological developments have been incremental.

Focus group

The main results of this discussion by the first group of experts were:

1. The experts shared the opinion that there will be one group of organisations, dominating the energy industry. *"Power to be remains power to be"* was the credo during this discussion. There would be little to no political urgency to change. According to the experts, there were two possible options for this world:
    a. The functions and roles within the energy ecosystem remain the same, and the incumbent parties do everything to keep it this way.
    b. The functions and roles within the ecosystem remain the same, but have shifted to other parties like Google, Tesla, Amazon, Apple or Albert Heijn. A reason for this could be that these parties have better customer relationships.

    For both options, the experts expected there to be one big party, leading a consortium of smaller parties. As reason for this, one expert mentioned that *"energy is a good way to dominate the world"*.
2. About the fact that technological developments are mainly incremental in this future world, one of the experts said: *"As current developments are already incremental, in this world, the current development paths will be followed. Hence, the solar panels will develop the way they currently develop."* Therefore, decentral energy production was assumed to be inferior to central energy production. Another more extreme thought was that decentral energy production could have been forbidden.

During the rest of the discussion, the experts focussed on option a. They argued that for this case, it could be that a power lobby by large, established companies to keep energy production centralised, would have led to this scenario. The incumbent energy companies poldered and compromised to keep their stake in the energy industry, as a reaction to the development towards decentralisation and self-sufficiency. Furthermore, it was also mentioned that these companies could start to invest in large scale, central energy storage possibilities if the transition towards sustainable energy production and use continued. As an example Shell was mentioned as a potential party to invest in hydrogen plants to store energy, because this would create a new market for them. The experts argued that a blockchain system could be used to enforce the consortium of energy incumbents, as this would allow the consortium to *"create a barrier to entry"*, and allow no one to be in between the producer and the consumer. Additionally, this could remove the incentive for the consumer to arrange their energy supply themselves. As an example, an *"EDSN hyperledger"* was mentioned, from the IBM hyperledger. However, as some of the experts argued, in this case, *"blockchain is not used the way it is supposed to be used", and "it is not possible anymore to see what happens behind the scenes"*. Challenges for this storyline that were mentioned during the workshop mainly concerned political challenges. The government has to allow this development, because the consortium blockchain, with a high barrier to entry, could be seen as, or lead to, cartel formation. Additionally, *"the blockchain could be replaced by a trustable partner with a decentral database"*, hence the use of a blockchain could be questioned.

Scenario narrative development

For the development of the storyline for scenario one, we followed the experts in their choice to focus on option a, because this pathway can be logically derived from the trends identified in chapter 6. We found that the EDSN hyperledger conceived by the experts, created possibilities for the incumbent energy companies in the form of a lock-in, efficient and transparent data and monetary exchanges, and the exclusion of intermediaries. If a blockchain is used for direct transactions between the producer of energy and the consumer, and to exchange data between the consortium parties, we argue that the blockchain will take over the role of EDSN, the market place operator, and the energy supplier/retailer, because these are the parties that are in between the consumer and producer as we learned from chapter 5. If the data which is currently managed by EDSN is exchanged automatically between all parties, we argue that it must also become easier and faster for consumers to switch between energy producers to reduce their energy bills. Moreover, it must be possible to pick another energy producer each time smart metering data is read, exchanged, and stored. Hence, although this blockchain could lead to serious risks for consumers in the form of pricing agreements by the consortium, we argue that it could also create possibilities for the consumer. Because we assume that the average consumer cannot and does not want to be bothered with this process each time of the day, we included the use of smart contracts to support and facilitate this process for the consumer. This is a logical addition to the blockchain system, because the blockchain infrastructure already included the data needed for this type of application.

Expert interviews

During the expert interviews we discussed our idea of the use of blockchain in this scenario, as described above. The experts confirmed the implications of the use of blockchain to remove the intermediaries between the energy producers and the consumer. They agreed that the role of the data facilitator, energy supplier, and market operator could be automated in this case. Where some of the experts thought that the automation of the switching process using smart contracts could give consumers the opportunity to receive benefits from fluctuating energy prices, other experts questioned this. One expert questioned whether *"it would be possible to compete between wind energy and wind energy"*. However, this expert thought it could help facilitate the flexibility problem, and relieve the consumer. Therefore, the expert did see the potential of the use of blockchain for this case. One expert raised the idea of a consumer profile using smart contracts to facilitate the process for the consumers. This way, the consumer would only have to define its preferences, and the rest of the process would be automated.

Because the blockchain in this scenario is a permissioned blockchain, developed by a consortium of organisations, some of the experts questioned the value of the blockchain. One expert argued that for the creation of a permissioned blockchain trust is required between the parties that are included in the blockchain. Therefore, the expert said *"As trust is not an issue in this case, the blockchain could also be replaced by a distributed database".* However, according to the same expert, there could also be other reasons why the use of blockchain would be preferred over a distributed database. As an example the expert mentioned the fact that the energy infrastructure is a critical infrastructure. A blockchain would decentralize this system, and as a result, protect the infrastructure against external attacks: *"the system is decentral, thus, if something goes wrong at one place in the system, the system would keep running".*

Secondly, we discussed the need for programme responsibility in this scenario. The use of blockchain removes the function of the energy supplier, which is currently programme responsible for the consumer, but energy is still centrally produced. Although the blockchain automates process of programme responsibility there has to be a party which has to remain responsible for this process. The experts shared the opinion that the DSO is likely to take on this responsibility at the regional level, and the TSO at the national level.

The following section provides the final version of the scenario narrative for scenario one.

7.1.2 Scenario One

It is the year 2030. We live in a world that, at first sight, has not changed much since the year 2017. Energy is mostly centrally produced. This means that energy is produced by a few large players, at large scale, and sold to consumers. Only a small part of the energy production is decentralised, but there has not been a real breakthrough in decentral energy production. Technological developments have mainly been incremental. Technologically seen, things have improved which has led to increased performance, efficiency and cost savings, but the past period is not characterised by radical breakthroughs. Large scale, centrally produced energy is more attractive because of scale-ups and improvements in central energy storage regarding performance (stability) and costs.

In the past few decades, decentralisation and self-sufficiency have emerged as a trend amongst the Dutch consumers. The incumbent firms of the energy industry recognised this trend. In fear of losing their market share, they started lobbying for central energy production, and made compromises to change their position in de industry. An example is Shell. Shell saw its sales decline and was forced to look for new solutions. They have specialised themselves in hydrogen plants for large scale energy storage. As a result, energy technology has improved step-by-step. The Dutch government has been quite actively involved in the energy market. They have protected the incumbent firms of the energy industry, as a reaction to the increasing trend towards decentralisation and self-sufficiency. The transition towards sustainable energy production and usage however, is something they have left to the energy industry itself. As the technology for renewable energy production has shown an evolutionary development path, the production costs of renewable energy have dropped. Because this implied costs saving opportunities for the incumbents, the share of renewable energy has slowly been increasing.

In their lobby for central energy production, the incumbents of the energy industry have created a hybrid blockchain to create a barrier to entry for new entrants. This blockchain system has replaced the data facilitating role of former data facilitator EDSN. Administrative data regarding grid connections and metering data now flows directly between the members of the blockchain. Because the blockchain is permissioned, not every party can enter the blockchain network: they first need to ask for permission. This gives the members of the blockchain a lot of decision-making power, and has vanished the small decentralised prosumers from the ecosystem.

The replacement of the central data facilitator by a blockchain also brings forth new opportunities for consumers. Because administrative data is easily updated and automatically distributed to the network, the blockchain allows households to switch automatically and immediately between energy providers, based on their own preferences. Every household has its own energy profile in which the preferences of the consumer have been defined. For example, household X only wants green energy, at a price between €a and max. €b. These preferences are captured in smart contracts. The system will match the consumer with a producer that fits best with the consumers' preferences. Hence, as energy prices fluctuate, the system will automatically match the consumer with another producer if this is a better match with the consumers' predefined profile.

Programme responsibility used to be the responsibility of the former energy suppliers. This has for a large part been automated because of the use of the blockchain network. In the blockchain, smart metering data from the consumers and the energy producers is collected to balance demand and supply. The TSO is responsible for the national balancing process, the DSO is responsible for the balancing process in their regional grid.

Foregoing developments have made smart meters and smart metering data important, because the financial settlements in the energy industry, and the balancing process have been automated through the use of blockchain technology. As a result, the former roles of the energy supplier, the data facilitator and the market operator have been disintermediated by a blockchain.

To conclude, the energy industry is controlled by a consortium of energy companies. The consortium uses a permissioned blockchain to create a lock-in, and remove the intermediaries between the energy producer and the consumer. As a result, the trade of energy, the financial settlements, and the balancing process have been automated, and consumers are automatically and continuously matched to the energy producer which fits best with their predetermined preferences.

7.1.3 The Ecosystem

From the description of events in scenario one, it is clear that the energy ecosystem changes due to the blockchain use case that emerged in this scenario. Some of the roles in the ecosystem which has been modelled in chapter 5 completely disappear due to the developments in this scenario. As described in the scenario narrative, the roles of supplier, data facilitator and market operator are directly replaced by a blockchain. Developments in large-scale energy production plants in combination with the opportunities of the blockchain also eliminate the role of the decentralised producer. Because the role of the MSP is much like the role of the regular energy supplier, it is likely that this role will also disappear. Lastly, the function of the ODA will probably also not last in this new ecosystem. Because all the data that is needed for their service is captured in the blockchain, the function of the ODA is likely to be replaced by an application that can be built on the blockchain. In Figure 19 the current energy ecosystem is shown. The roles which have disappeared, or are likely to disappear in this scenario, have been given lighter shades.

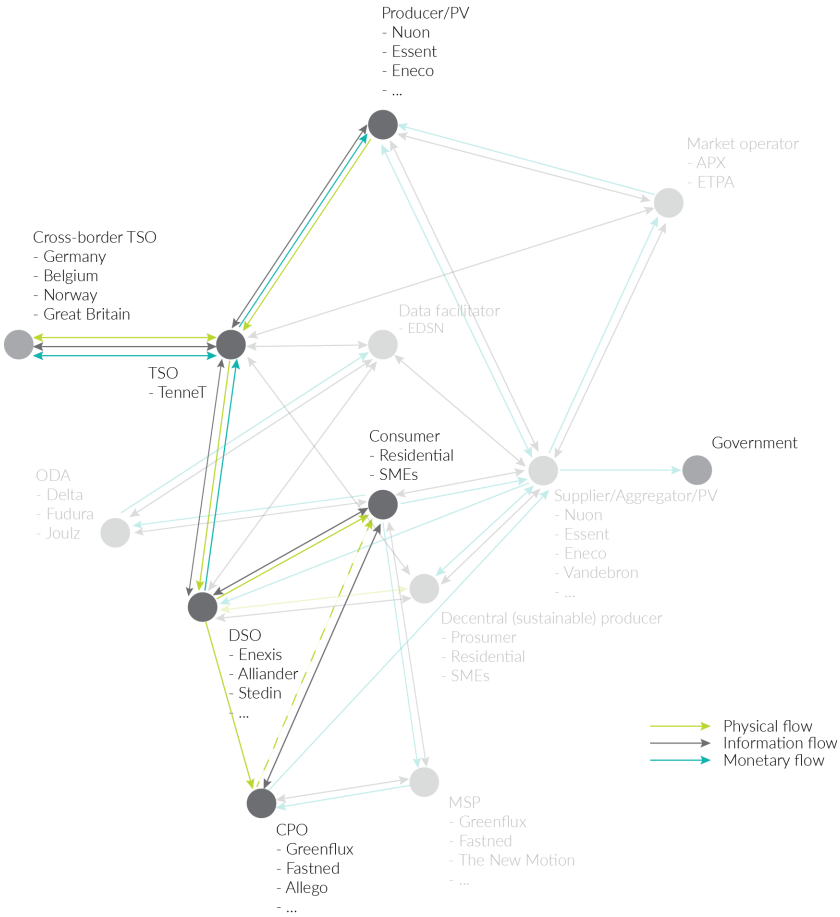

Figure 19: Implications of scenario one for the ecosystem

In this ecosystem, programme responsibility has been automated. The TSO is still responsible for the national balancing process. Hence, the current role of the TSO remains but in this case the TSO no longer receives the planned energy usage from the energy supplier as programme responsible party, but directly from the consumer, via its smart meter, which automatically exchanges energy usage data through the blockchain.

As a result of the changes in the roles of the ecosystem, the configuration of the ecosystem for the energy industry also changes. Figure 20 provides a possible new configuration of the ecosystem for the energy industry, following from scenario one. In this ecosystem, the physical flow still follows the traditional path: from producer to TSO, from the TSO to the DSO via the high voltage grid, and finally from the DSO to the consumer via the regional grid (and/or the CPO). The supplier used to be responsible for the distribution of the monetary flow and information flow from the consumer to the other members of the ecosystem. The implementation of a blockchain in scenario one has changed this: money is directly exchanged between the consumer and the other nodes. EDSN used to be responsible for the information flows between the TSO, DSO and the supplier. With the implementation of the blockchain all data is directly exchanged between the producer, TSO, DSO, CPO, and the consumer. As a result, trade also takes place via the blockchain.

The TSO is still used as the intermediary for the exchange of the physical, monetary, and informational flows between the members of the ecosystem and the foreign TSOs. The government is also still included in this ecosystem. In our new version of the ecosystem, the government only receives taxes paid by the consumer. However, the government could also be included in the blockchain system to exchange data. This way, the government could have a supervisory role over the system, to protect its citizens.

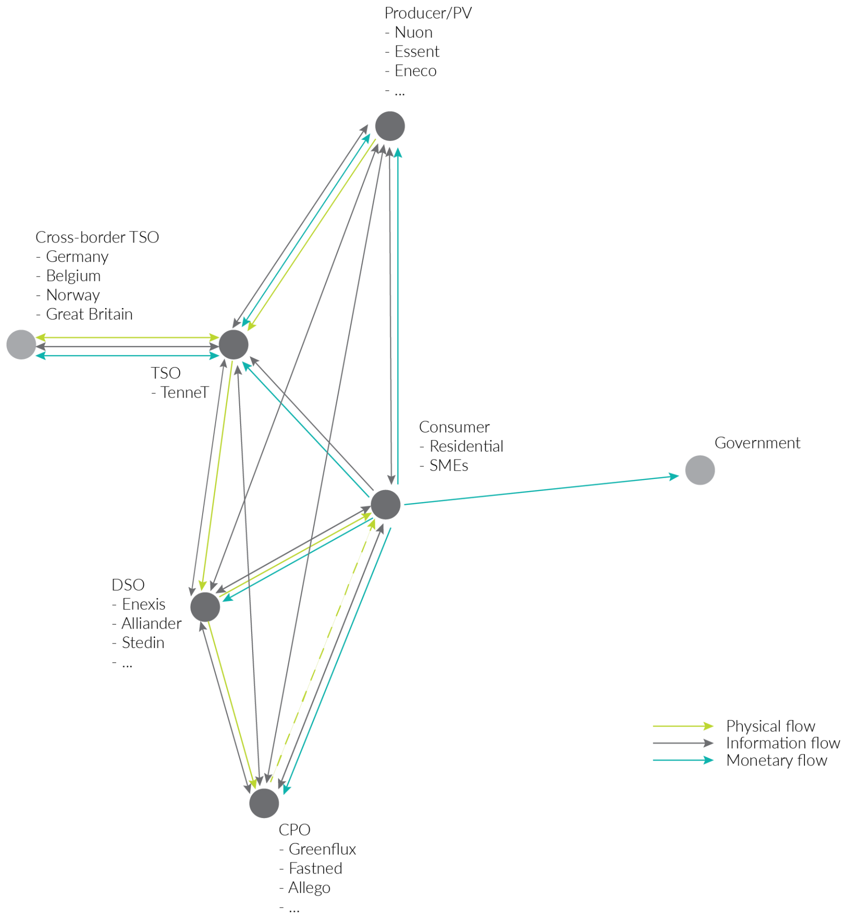

Figure 20: Ecosystem resulting from scenario one

In chapter 2, different ecosystem species have been identified: *keystones, dominators,* and *niche players*. The keystones generally only make up a small part of the ecosystem, but play a system wide role because they provide a stable and predictable set of common assets that other organisations use for their own offerings. Dominators most often only harm the ecosystem, they are the organisations which eliminate other organisations from the ecosystem. The dominator will either try to directly own a large part of the ecosystem, or extract as much value from the ecosystem as possible, without much direct control. Niche players try to differentiate themselves from other organisations in the ecosystem (see subsection 2.2.2).

In this scenario, the TSO and DSO have kept their function in the ecosystem because of their keystone role. They provide a set of common assets, namely the national and regional grid, which are still needed to transport energy in this scenario. Hence, this characterises them as keystones for this scenario. The producers on the other hand, could be seen as dominators. By creating a hybrid blockchain, they have eliminated other firms from the ecosystem to own a large part of the ecosystem. The CPO and the new role of storage facilitator can be seen as niche players. Although they are both dependent on the TSO, DSO and producers, they have specialised themselves in a particular domain which has protected their role in the ecosystem.

7.1.4 Evaluation Scenario One

In chapter 3, we found that the scenario narratives are used to open eyes, provoke, and to stimulate. In order to do so, it is important that the scenario narratives are creative, rigor, internally coherent, and plausible. During the interviews we asked the experts to give evaluate the scenario narratives based on these characteristics. In one of the interviews, an expert mentioned that this scenario is *“negatively provocative, but not unrealistic”,* because this movement is currently visible in France and Germany. In these countries, this movement is politically driven and the lobbying takes place to protect incumbent organisations. Other experts also argued that this scenario is extreme, but plausible. It was also mentioned that this scenario would help the government to achieve its sustainability goals, because it is easier to achieve the targets with large, central sustainable energy production than with smaller decentral prosumers. One expert questioned the plausibility of this scenario in the long term, because decentral energy would eventually also become cheaper as sustainable energy technology is being developed further. The experts shared the opinion that the use of blockchain in this scenario is disruptive, because of the automation of many processes. Lastly, one expert called blockchain disruptive *“in the commercialisation of the lock-in”.* With regard to the roles in the ecosystem, some of the experts argue that blockchain is less disruptive in this case.

7.2 Scenario Two – Power to the Devices

The second scenario is called *‘Power to the Devices’*. This scenario has been developed from the second quadrant of the scenario framework. For this possible future world, the two predefined assumptions which followed from the scenario framework were:

- Radical technological developments
- Central energy production

7.2.1 Scenario Narrative Development

For scenario two, the experts were asked to envision the energy ecosystem of the Netherlands in the year 2030, in which energy is mainly centrally produced and technological developments have been radical.

<u>*Focus group*</u>

At first, the experts were focussed on technological developments in the production, transportation, and storage of energy during this discussion. As a result, some of the experts were more involved in the discussion than others. We therefore had to explicitly steer this group to the main strategic questions (see subsection 3.3.4 and section 6.1 for the strategic questions). When the focus shifted to the strategic questions, the other experts became more involved, and the experts were able to formulate valuable input for the scenario narratives. The main results of this discussion by the first group of experts were:

1. The experts shared the opinion that radical technological breakthroughs would make sustainable energy cheaper than fossil energy. Examples of technological breakthroughs which the experts expect for the future were large scale central energy storage, the transport of energy over large distances (continental), and wireless power (superconductivity).
2. The current infrastructure will be used intensively, because energy is centrally produced at large scale. The technological developments allow for this to happen.
3. Technological developments make the cost of blockchain transactions (close to) zero.

The experts argued that the event which led to these developments would likely be of political nature. For example, a geopolitical event which stimulated Western Europe to become self-sufficient could have accelerated the technological developments described in point 1. One expert mentioned that for this case, *“there could be a European directive to use blockchain to ensure transparency”*. With the current geopolitical developments, this does not seem unrealistic. Therefore, we have incorporated this cause into our scenario narrative.

To finance the self-sufficiency of Western Europe, one of the experts argued that blockchain could be used to crowd-fund large scale projects. As a result, large scale energy production facilities are not owned by one entity, but there is a large group of people, organisations, and/or institutions owning a small part of such a production site. This way, the experts argued *“the non-fundable would become fundable”*. Hence, the energy production would be central, but the ownership of the production sites would be decentralised. We included this idea in our working versions of the narratives to further explore the potential of this idea during the expert interviews. Another expert mentioned that *“the blockchain inconveniences could be solved in this scenario, and the transactions costs of using blockchain could have dropped to zero”* and *“artificial intelligence could have been developed up to the extremes”,* making smart devices the standard.

Scenario narrative development

The development of AI, mentioned by the expert as described above, was an important trigger for the development of the narrative for scenario two. Our thought was, if internet of things, artificial intelligence, and blockchain technology are being developed up to the extremes, this would allow devices to be integrated into the energy system. As a result, the devices consumers own could become active on the energy market, instead of the consumers themselves. These devices could be programmed to trade on the energy market in a certain way, to be as energy efficient as possible. This could facilitate the consumer, and create more room for flexibility in the retail market. Furthermore, our thought was that the large scale storage solutions mentioned during the focus group could create new business opportunities. With fluctuating energy prices, due to the use of sustainable energy production, it could be that consumers buy storage space to store energy when energy prices are low due to particular weather conditions for example.

Expert interviews

During the interviews, first discussed our general idea for scenario one. One expert mentioned that the main condition for this scenario is a dramatic price drop for centrally produced sustainable energy. Otherwise, decentral energy production will still be attractive. Another expert said *“If central energy storage is insufficient, I see possibilities for the trade between devices and the market. If there is sufficient storage to solve the flexibility problem, I do not completely see the value of this”*. Although we partially agree with this expert, it is our believe that even if there is sufficient storage capacity available during peaks or lows, it will still be less costly to sell energy directly, than to store energy and sell it at a later point in time. One reason for this, is that electricity produced from wind and solar energy will most likely have to be transformed into something storable, and if sold, it might even have to be transformed into electricity again.

Secondly, we discussed the idea of devices being active on the energy market. Some experts emphasised the increasing interactions on the energy market in this scenario. One expert mentioned that each device could have a different energy supplier. *"In fact, you would ask devices to optimise their energy price when you turn the device on"* the expert said. Furthermore, the expert argued that the price fluctuations for this scenario will be higher than the price fluctuations in scenario one, because *"the price will be so low due to radical technological developments, that the differences in the low prices will be more significant"*. Although this expert agreed that this could help solve the flexibility problem, the expert argued that not every device will be used for this problem. As an example, the expert mentioned the TV, *"if you want to watch TV, you turn your TV on and want to be able to watch TV"*. About the example of a washing machine we included at first as illustration, the expert said *"you do not want your washing machine to run at night when the demand for energy is low, because if you get your laundry out of the machine in the morning, it will all be wrinkled"*.

Lastly, the use of blockchain to decentralise the ownership of central production sites had to be explored further during the interviews. The experts agreed that blockchain technology would be highly appropriate do decentralise the ownership. Blockchain would be used to record investment agreements and obligations, and to divide the returns of the production sites, which would in fact also be transactions. This matches with our findings in chapter 4, in which we found that in principle, blockchain is a distributed digital record of ownership. Where three out of five experts found this application *"fascinating"*, *"an innovative way to change ownership in a central system"*, and *"a logical development as we already see the use of blockchain as investment form in real estate"*, two experts questioned its relevance and viability. The first expert thought that the distribution of property rights was out of the scope of this study, because the focus is on blockchain in the energy sector. Secondly, the expert thought that *"Only if transaction costs drop dramatically, it would become very easy to exchange property rights via blockchain"*. We agree with the expert on the second thought. However, for every scenario, a dramatic drop in the transaction costs of blockchain technology would be necessary. Additionally, one of the main assumptions for this scenario was that technological developments would have made the transaction costs of blockchain (close to) zero. We disagree with the expert on the first thought, because it would change the ownership of production facilities, hence, it would change the roles and functions in the energy ecosystem. The second expert questioned this application because *"in the blockchain, you say that something is the truth, while this does not necessarily have to be the truth"*. Again, we agree with the expert, however this is also something which is true for every blockchain application. As a solution to this problem, there could be one party, which is not active in the blockchain network, supervising the transactions in this blockchain network. Or, it could work like the Bitcoin blockchain, where after a certain period new Bitcoin, or in this case new property rights, are added to the network. We therefore believe that this application is of relevance for our study, and should be included into scenario two.

The following sub-section provides our final version of the narrative for scenario two.

7.2.2 Scenario Two

It is the year 2030. We live in a world that, at first sight, has not changed much from the year 2017. Energy is mostly centrally produced. This means that energy is produced at large scale, and sold to consumers. Only a small part of the energy production is decentralised, but there has not been a real breakthrough in decentral energy production. From a technological perspective a lot has changed. Radical technological breakthroughs have changed our world, and made the use of renewable energy many times cheaper than fossil energy. Hence, we live in a world in which we fully rely on renewable energy. Technological developments from outside the energy industry have become more important in the industry. This has resulted in an industry system in which the production of energy is still centralised, but the trade of energy has completely been decentralised.

Geopolitical instability has encouraged Western Europe to become self-sufficient. This has stimulated the search for technological breakthroughs in the field of energy production, storage, and transport. Examples of these developments are large scale energy storage solutions and the transport of energy over large distances. These developments have mainly resulted in an increase of centrally produced renewable energy, because the new transport possibilities allow Western Europe to place large solar parks on sites with many sun hours, and large wind parks at sites with much wind, which do not necessarily have to be nearby the final destination of the energy produced. Large scale storage solutions allow the wholesale market to offer flexibility to balance the network during peaks or lows. Because energy is still mainly centrally produced, the existing energy infrastructure is still intensively being used to supply energy to the Dutch households.

The Dutch government and the European Union have been actively involved in this transition process. For example, the European Union has set a directive to use blockchain technology to increase transparency. This is important to trace back the origin of the energy, amongst others. To be able to finance the large scale projects, the fragmentation of ownership of the production and storage sites has been stimulated politically. European citizens can now invest a wind energy park for example. A blockchain is used to capture agreements and ownership, but also to settle the revenue of the production site as ownership is decentralised. Because investments in wind and solar farms have a higher return than savings accounts at banks, people have started to seize these opportunities.

New parties have entered the energy industry with new products and services using IoT, AI, and blockchain technology. For example, households own devices that can directly communicate with the energy market through a blockchain system. Devices can be programmed to act in a certain way, and the rules for action are captured using smart contract constructions. For example, you can programme your devices to optimise their energy costs once you use the device. Hence, the trade of energy is decentralised through 'machine-to-market' energy trade. The energy sources, which are mainly wind and solar energy, make this attractive for the consumer, due to their fluctuations in supply. The flexibility problem is now being solved at the consumer level, as capacity management has become dynamic. This is attractive for both the consumer, as well as the producer, because it is still less costly to sell energy directly, than using storage. The blockchain system can be seen as the new trading platform for the energy industry. It has automated the financial settlements, exchange of metering data, and programme responsibility, and thereby covers the former functions of the market-operator, the energy supplier, and the data facilitator.

The combination of central storage possibilities and the use of a blockchain as market platform has also resulted in the emergence of a new function: the storage facilitator. The storage facilitator sells storage to consumers. For example, if energy is cheaply produced, consumers can buy this energy and store it at the storage facility against a particular tariff.

To conclude, although energy is still centrally produced, the ownership of the production and the trade of energy has strongly been decentralised due to technological developments and political interventions. A blockchain network is used to increase transparency in the energy industry, and allows domestic appliances to be active on the energy market.

7.2.3 The Ecosystem

For scenario two, the same functions disappear from the ecosystem as in scenario one. Again, the functions of the energy suppliers, data facilitator, and market operators are covered by a blockchain. The role of the decentralised energy producer again disappears due to the developments in large-scale production sites. Also for the MSP and the ODA, the implementation of blockchain technology has the same consequences as in scenario one. Because the MSP has a function similar to the energy supplier, it would be logical that this function is also covered by a blockchain. Because data about energy usage is automatically exchanged through the blockchain, the function of the ODA will probably be replaced by an application built on the blockchain. Figure 21 shows the implications of this scenario for the current ecosystem. The functions that are removed from the ecosystem have again been given a lighter shade.

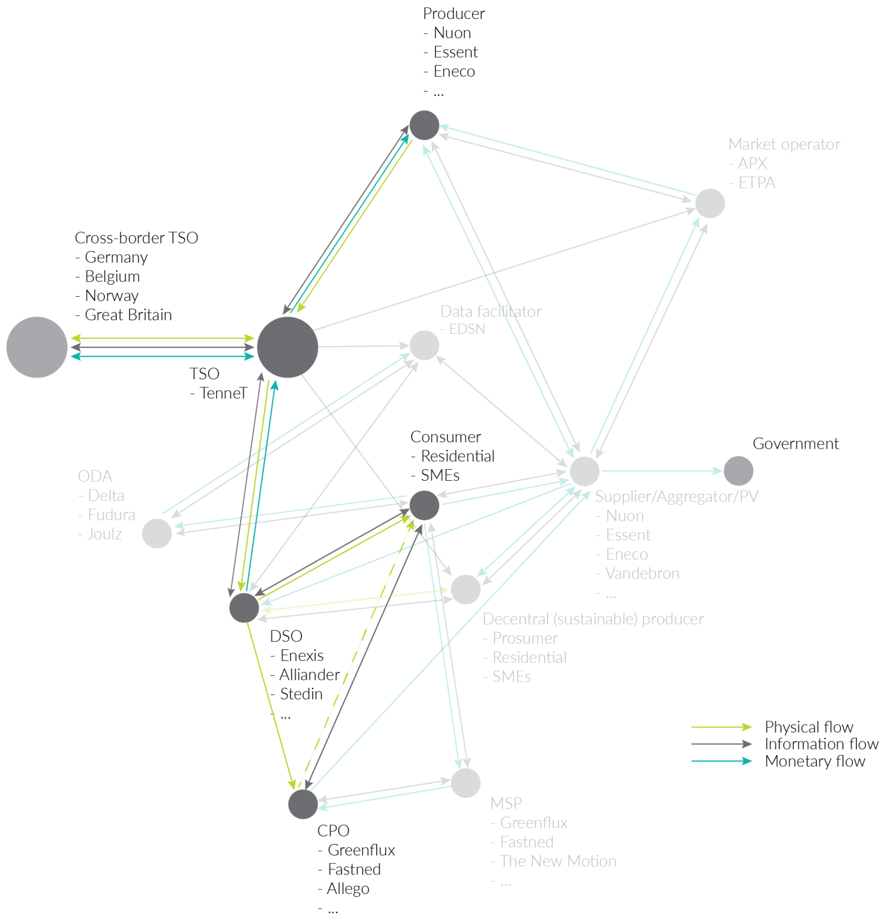

Figure 21: Implications of scenario two for the ecosystem

In this scenario, devices trade at the energy market in the name of their owner. Hence, the consumer has more influence on the energy market, through their devices. The relationship between the Western European TSOs intensifies because of the developments in large distance energy transportation. Hence, the role of the TSOs have become even more important. The large scale storage facilitator emerges as a new function in the ecosystem. Because this could be used by the consumer, producer, and TSO, this function could even be seen as very important in this ecosystem. Figure 22 provides a possible new ecosystem as a result from the events described in scenario two. In this scenario certain functions have increased in terms of importance. Therefore some of the nodes have increased in size to show their increased importance. The physical flow still mainly follows the traditional path. An exception is when a storage facility is used before energy is supplied to the end-consumer. Again, a blockchain is used to distribute the monetary and information flows between the members of the ecosystem, hence all nodes are connected via monetary and/or information links. The TSO fulfils the intermediary role between the Dutch energy ecosystem and foreign energy ecosystems.

A special characteristic of this scenario is difficult to visualise in Figure 22: the fragmented ownership of the large scale production plants. In this scenario, Western European citizens can invest their money in large scale production plants. Hence, the ownership of the production plants will become decentralised while the production is centralised.

In this scenario, the TSO and DSO still fulfil a keystone role, because their assets are necessary for the functioning of the ecosystem. It is difficult to assign a dominator in this ecosystem. The blockchain or the initiator of the blockchain could be seen as a dominator because the blockchain has replaced various functions in the ecosystem. However, because the blockchain is public, the blockchain is not centrally owned. Hence, the blockchain itself could also be seen as a keystone player providing a common infrastructure for the parties which remained in the ecosystem. The CPO, storage facilitator, and producer can be seen as niche players, because they have specialised themselves in a particular domain, which has secured their function in the ecosystem.

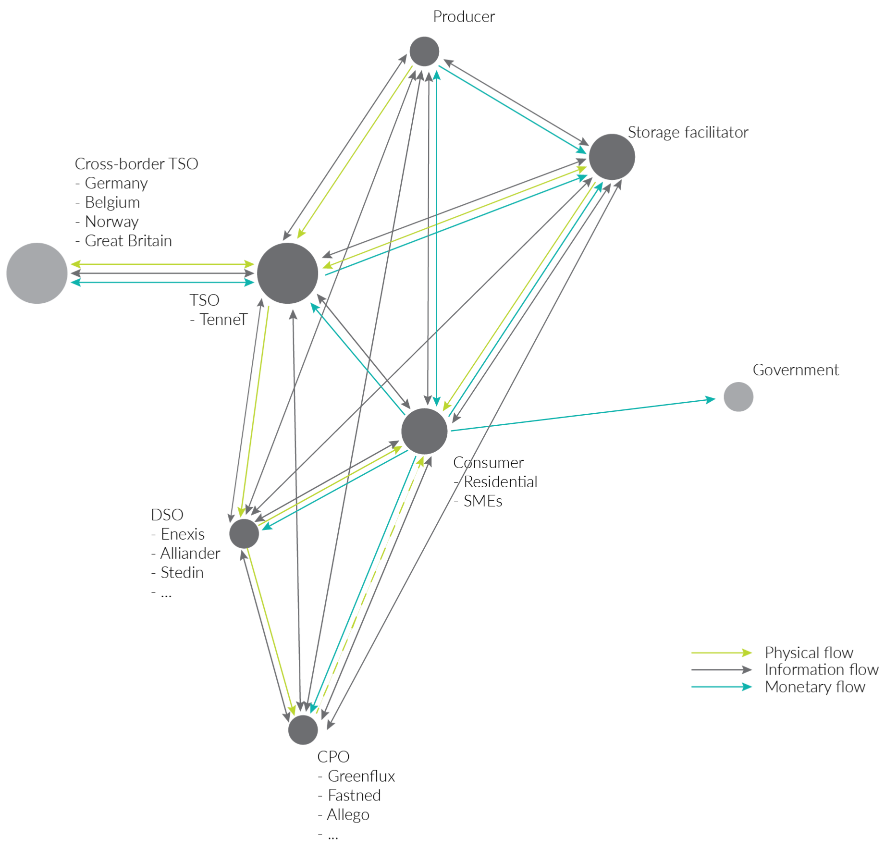

Figure 22: Ecosystem resulting from scenario two

7.2.4 Scenario Evaluation

During the interviews, one expert thought of this scenario as *"an interesting scenario"*, the expert did not think of before. However, the expert expects that this scenario will only be plausible if there would be political intervention. Furthermore, the expert added *"it is a scenario in which we could keep much freedom, but technological developments would lead to a central organisation of the energy system".* The other experts shared the opinion that this scenario is a highly plausible scenario. According to one expert *"this scenario is much like the direction we are heading right now. Compared to the other scenarios, it is a world which is easier to understand for us".* On the other hand, some experts thought this scenario implied a radical change, and is much more disruptive than scenario one because of the decentralisation of trade. It was also mentioned during the interviews that there could be an important role for the DSO in this scenario: *"In this scenario, DSOs are needed that do not think in own assets, but in the facilitation of efficient deployment of assets of the consumer in such a way that the grids can also be used efficiently"*.

If blockchain is purely used for transparency, the blockchain can again be replaced by a database, one expert argues. However, according to this expert, the use of blockchain is logical in this case, because of the devices which are included in this scenario. In principal, the devices and producers do not trust each other, therefore, the use of blockchain would be more convenient than a database. The experts' opinions about the decentralisation of ownership of production facilities using of blockchain technology has been discussed in section 7.2.1. The experts agreed that blockchain would be an extremely appropriate technology to support this. Lastly, the experts mentioned that for both blockchain applications, the technology has to be able to handle the large amount of transactions. The current blockchains are not capable of this.

7.3 Scenario Three – Power to the People

The third scenario is called *'Power to the People'*. This scenario has been developed for the third quadrant of the scenario framework. For this possible future world, the two predefined assumptions which followed from the scenario framework were:

- Incremental technological developments
- Decentral energy production

7.3.1 Scenario Narrative Development

For scenario three, the experts were asked to envision the energy ecosystem of the Netherlands in the year 2030, in which energy production is mainly decentralised and technological developments have been incremental.

<u>Focus group</u>

The experts were unanimous during the discussion about this scenario. They all agreed on the fact that for this scenario, energy will be shared at a local level. The main results from the discussion of this scenario were:

1. Although there have not been radical technological breakthroughs, energy technology has kept developing and led to increased performance, efficiency, and cost savings for existing energy technologies.
2. There have been events which have made decentral energy production much more attractive than central energy production. Examples of events are the abolishment of the Dutch netting agreement, and the increasing vulnerability of centralised systems due to cyber-attacks.
3. Blockchains are used at a local level, and transaction costs have dropped dramatically.

As one of the experts mentioned during the focus group, for this scenario *"sharing has to become attractive"*. Three reasons were mentioned which could explain why households would want to become self-sufficient and share energy production with their neighbours. First, one expert mentioned the possibility of technological stagnation at the level of the TSO and DSO: *"What if there is an increase in congestion at the grid? Consumers will lose their faith in the DSO and want to arrange energy production and supply themselves".* Secondly, another expert mentioned the Dutch netting agreement: *"In the future, the netting agreement will be abolished. This will lead to asymmetries between the prices a prosumer has to pay in the case of a shortage, and will receive in the case of a surplus. As a result, a prosumer will avoid to sell its surplus to the energy supplier. Instead the prosumer would rather sell its surplus directly to its neighbours."* Lastly, it was mentioned that central systems could have become vulnerable due to cyber-attacks. As a result, the shift towards decentralised systems could have been stimulated, as it is much more difficult to shut down a decentralised system because it runs at multiple places which all have to be attacked at the same time.

For this scenario, it is again assumed that the transaction costs of blockchain technology have dropped dramatically. Additionally, the experts assumed that blockchain had become more user-friendly. As a result, they expected that local blockchains could have been set up, to trade energy at a local level. The blockchains would in this case be used *"to test whether people honour their commitments"*. In this scenario, the experts argued that *"blockchain would become a service"*, to facilitate the consumers' desire to become self-sufficient.

Scenario narrative development
The three reasons mentioned by the experts which could lead to the decentralisation of the energy industry are all relevant, as all three of them have been mentioned in various news articles in the past couple of months. Additionally, it is reasonable to think that these events will eventually lead to a desire for a completely different energy system. Therefore we have incorporated these events in our scenario narrative as important events leading to the development of bottom-up initiatives. The ecosystem described by the experts is similar to the 'peer-to-peer' energy market which is often described when the use of blockchain in the energy industry is discussed. However, the system which is described in this scenario is actually 'peer-to-market'. In this scenario, we see many small local energy markets arise, based on blockchain technology. As mentioned before, it is assumed that consumers cannot and will not be physically active on the energy market at each time of the day. Therefore, in this scenario, we have again added the principle of smart contracts to create consumer profiles to automate trading and unburden the consumer. Additionally, we identified a new business opportunity for this scenario. In this scenario, energy is produced locally. This means that the households produce energy themselves, for example via solar panels, and need domestic batteries, and other kinds of equipment to participate on the local markets. We expect organisations to jump into this business, offering a complete package from equipment needed, to the installation of the equipment, and the set-up of the blockchain profile.

Expert interviews
During the interviews, one of the experts mentioned the importance of the stimulation of sharing again. The expert argued that *"if sharing is not stimulated, there will be a central party enforcing households to share, and there will be no 'power to the people'".* Therefore, the expert argues that changes in law are needed when this scenario becomes reality. Furthermore the expert mentioned the importance of the DSO. To enable households to share, they need a reliable grid which allows them to do so. The other experts shared the opinion about the importance of the DSO for this scenario. One expert even said *"by nature, this will be the scenario towards which the DSO will move"*. Another expert proposed that the DSO could build and facilitate the blockchain networks that are needed in these local energy markets. The experts did not think that the TSO would become unnecessary. The TSO will lose its importance for the retail market, but the experts share the opinion that the TSO will be needed for base-loads, to provide reserves, and for the wholesale market. The experts agreed on the importance of the use of smart contracts to facilitate the local energy trade. As one of the experts mentioned, *"people do not want to be bothered with energy"*.

In the following sub-section, our final version of the narrative for scenario three will be provided.

7.3.2 Scenario Three
It is the year 2030. We live in a world that looks very different from the year 2017. Energy production has almost completely been decentralised. This means that every household in the Netherlands has the ability to produce its own energy and/or buy energy from small, local energy producers. Technological developments have mainly been incremental. Energy technology as well as other technologies have been improved which has led to increased performance, efficiency, and cost savings, but the past period is not characterised by radical breakthroughs. Developments in small scale energy technologies for production and storage of energy fulfilled the Dutch consumers' desire to be self-sufficient and has led to the decentralisation of energy production. Markets have become local, the wholesale market serves large industrial users. Consumers and small and medium enterprises (SMEs) only use the wholesale market in times of energy scarcity and to share energy between local markets.
In the year 2023, the netting agreement (in Dutch: salderingsregeling) has definitively been abolished. This has made it less attractive for a prosumer to supply their energy surplus to the energy supplier, because the abolishment has led to asymmetry between the price the energy supplier receives for the energy it sells to the prosumer, and the price the prosumer receives for the energy it sells to the energy supplier. For the consumer

it would be more beneficial to sell the energy directly to someone in their neighbourhood. Additionally, central systems have become more vulnerable over the years due to cyber-attacks. These two events were the main drivers for more bottom-up initiatives, and led to the decentralisation of the energy industry, because consumers lost their confidence in the centralised energy system.

At the same time, blockchain technology has been further developed. It has become more user-friendly, lost most of its inconveniences, and most importantly of all, the transaction costs dropped immensely. As a result, blockchain technology is easily accessible and many applications and services are developed on top of the technology. Regulations have been changed to facilitate, and stimulate energy sharing. Many local blockchains have been set up ever since for local, peer-to-market settlements. The market rules for local trade are captured in smart contracts, and so are the energy profiles for every consumer. Hence, in the first place the local blockchains are used to check whether people honour their commitments. They are used for the financial settlements, and to check whether a producer produces the exact same energy volume as the volume he is selling at the market, and if the volume is produced from the source the producer says it is produced from. In the second place, they are used to automate trading and unburden the consumer: the consumer does not physically trade energy at the local energy market, this is done via rules in personalised smart contracts.

To help people become self-sufficient, new services have emerged. Organisations have specialised themselves in the installation of domestic energy production technologies. They sell a complete package: they install solar panels, charging points for an EV, small domestic batteries, and make sure that the consumer is ready to trade their surpluses automatically via the blockchain market trading platform all at once.

Peer-to-market energy trade has led to a lower dependency on the national energy grid: people only use the central production facilities when their own energy production is not sufficient. This has decreased the role of the TSO in the retail market. The DSO on the other hand plays an important role in this scenario. Where it mainly used to be the national grid that had to be balanced, it now is the regional grid which has to be balanced, because energy is locally produced. Hence, balancing has shifted to the regional level. The DSO has a trusting and facilitating role in the decentralisation of the energy industry.

To conclude, with the rise of multiple local energy markets, energy production and trade has decentralised. The local markets are based on a blockchain network and use the regional energy grid of the DSO for the transport of locally produced energy. The market rules and consumer profiles for local trade have been captured in smart contracts to automate trading, facilitate the consumer, and check whether people honour their commitments. New services have emerged to help households become active on the local energy markets.

7.3.3 The Ecosystem

In this scenario, the blockchain replaces the functions of the energy supplier, the data facilitator, and the market operator again. The role of the MSP and the ODA are again assumed to be covered by the blockchain, for the same reasons as explained in previous scenarios. The combination of the events occuring in this scenario, and the application of the local blockchains has diminished the role of the central energy producer, and increased the importance of the decentral energy producer, as well as the number of decentral energy producers. As a result, the role of the TSO and the cross-border TSO also diminishes for the retail market. Only in times of scarcity, the TSO and the central energy producer play a role in the retail market. The regional grid on the other hand is still being used for the local transportation of locally produced energy. As the DSO plays a facilitating role in this scenario, the role of the DSO becomes much more important. Once the domestic battery performance increases however, there is the risk for the DSO, as well as for the TSO, to become redundant. Figure 23 visualises the implications described for the ecosystem. The roles which disappear from the ecosystem have again been given a lighter shade.

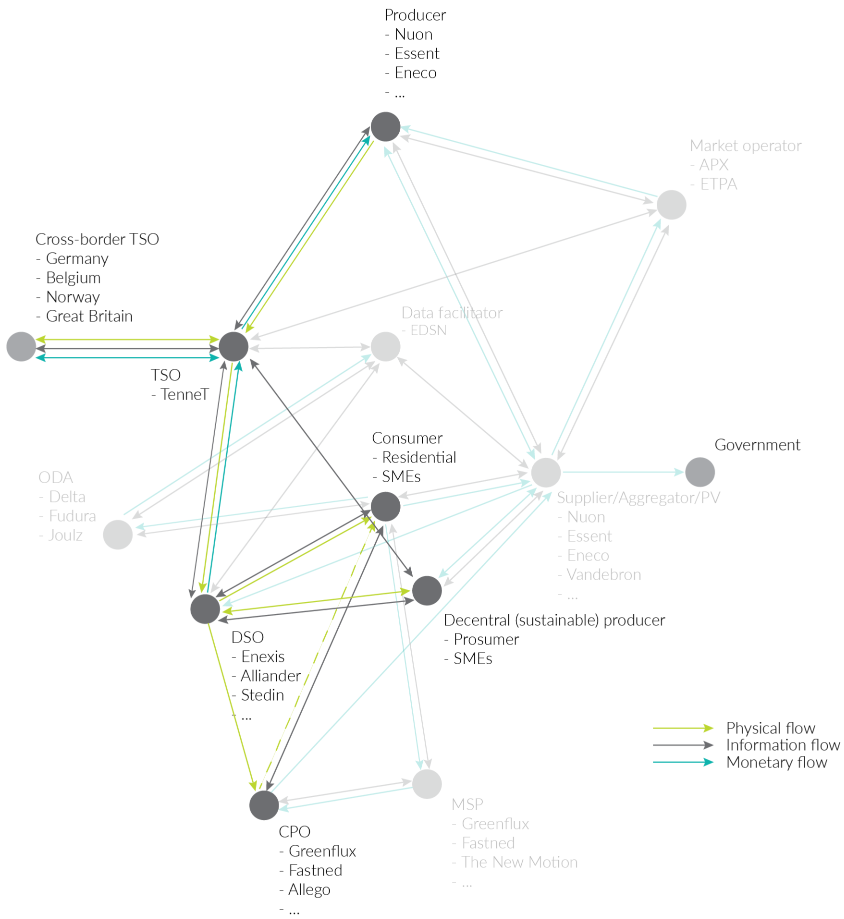

Figure 23: Implications of scenario three for the ecosystem

In scenario three, we also see a new role emerging in the ecosystem: the energy products & service provider. Their function is to provide the products and services to consumers to produce and trade energy themselves, and provide services to unburden the households that are already prosumer. Figure 24 shows a possible new configuration of the ecosystem for scenario three.

For this scenario, the DSO could be seen as the keystone of the ecosystem. They have become extremely important for the facilitation of the decentralised energy industry. On the other hand, the DSO could also be seen as a dominator: if the DSOs were the initiators for the local blockchain energy markets, stimulating the decentralisation, they can be seen as the organisations eliminating the TSO and central producers from the ecosystem, to gain a larger part of the business ecosystem. The energy products & service providers are the real niche players in this market. They saw a trend emerging and created their own business case. Once the majority of the consumers has become a prosumer however, their role is likely to decrease in the near future.

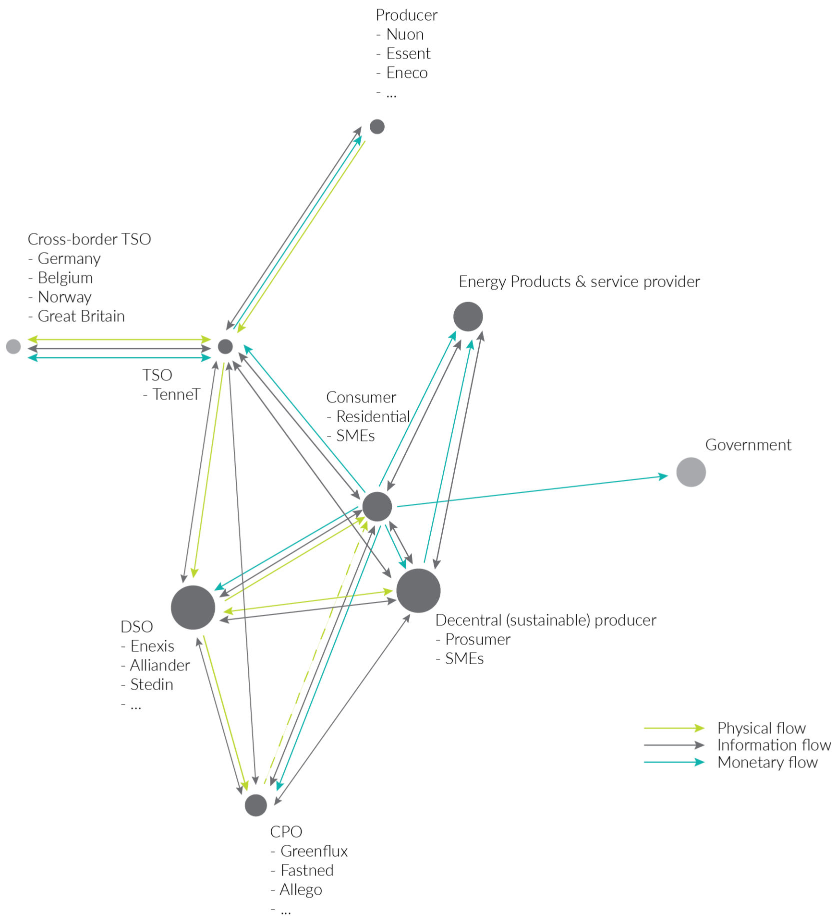

Figure 24: Ecosystem resulting from scenario three

7.3.4 Scenario Evaluation

One of the experts thought this scenario is a *"very attractive and sensible scenario"*, although it could be difficult to realise due to the changes in regulations which are needed. However, the expert said *"this could possibly be the only way we can keep the energy system running"*. Additionally, this system of local energy markets is unique, because it does not exist anywhere yet according to this expert. Another expert mentioned that this scenario will be very provocative and extreme to most people, although the expert itself does not think it is very extreme. The other experts shared the opinion that this is a plausible scenario. Nevertheless, one expert argued that this scenario will be less logical, because the amount of sustainable energy will probably be lower than for scenario one or two. Hence, this scenario will probably not help to reach the sustainable energy targets.

About the use of blockchain technology, one of the experts said *"in this scenario you use blockchain on a platform that is primarily aimed at solving engineering issues. Blockchain is super appropriate for this. The systems described in this scenario are stable systems. If the Netherlands is able to create something like this, this will be something the whole world could use."* Another expert agrees on the appropriateness of blockchain technology for this scenario. The expert said *"Blockchain is used because there are many prosumers, who actually do not trust each other. The blockchain is used to control if what the prosumer says it produces, sells, or buys is the truth. This is very important in this scenario."*. Lastly, one expert mentioned that people who are against digitalisation and decentralisation, because of privacy issues for example, will be a challenge in this scenario.

7.4 Scenario Four – Land of Plenty

The fourth scenario is called *'Land of Plenty'*. This scenario has been developed from the fourth quadrant of the scenario framework. For this possible future world, the two predefined assumptions which followed from the scenario framework were:

- Radical technological developments
- Decentral energy production

7.4.1 Scenario Narrative Development

For scenario four, the experts were asked to envision the energy ecosystem of the Netherlands in the year 2030, in which energy production is mainly decentralised and technological developments have been radical.

Focus group

During the discussion of this scenario, some of the experts were overly enthusiastic. They sometimes overruled the other experts during this discussion. As a result, the main assumptions for this scenario which followed from the focus group were considered extreme. The results would not have been unrealistic if the scenarios would have been formulated for the year 2050, however as the scenarios were formulated for the year 2030, the plausibility was little. Therefore, we had to interpret the results from this discussion differently, and test them during the interviews. In the end, we were able to satisfy the 'enthusiastic experts' as well as the others. Four out of five interviewees even said that it will be likely that we will first move towards a world similar to scenario two or three and then move towards the direction of scenario four. The main assumptions which followed from the focus group discussion were:

1. There is a shift from energy scarcity to energy abundancy. Solar energy follows Moore's Law: solar energy becomes very cheap and enables to produce energy anywhere and everywhere. There are breakthroughs in energy storage, and the system does not need to be balanced anymore because everything has become DC (Direct Current). The result is an overcapacity, and the cost of energy has become (almost) zero.
2. There is a mobile ecosystem in which cars and drones produce and store energy, and supply energy at their arrival at a particular destination. Everywhere in the environment, energy can be produced and supplied.
3. Machines and robots have become extremely important. They have made established companies less relevant and they have become a source of income for the consumer.

When the discussion started, one of the experts said *"This scenario is the most likely scenario. It is the extrapolation of the current day".* For this scenario, the experts argued that a possible cause for these developments could be that there have been disasters and accidents at central production facilities. As a result, governments, consumers and firms have become anxious to invest in central grids and central production facilities and the system decentralised. The developments in energy technology and the reluctance to invest in a centralised system supported each other in this development. If energy would become free, one expert mentioned *"this would be the best lock-in ever, because no one can make money with energy anymore. It would be like oxygen."*. Additionally, the expert emphasised the use of 'smart machines' in this scenario: *"Machines will create value without the need for organisations. Money will then be less of an issue.".* Because machines and robots have become very important in this scenario, the experts expected blockchain to play an important role in the connection between the machines and robots, and between the machines and robots and human beings. The experts expect that privacy will be a challenge in this scenario. If everything is connected through one open blockchain, identity management will be important one expert said.

Scenario narrative development
During the plenary feedback, some of the experts already questioned the assumptions made for this scenario. This confirmed our feeling that the assumptions made for this scenario might be too extreme. We therefore decided to interpret the assumptions differently. The first step, was the decision see this scenario as the start of the development towards a world described during the focus group. Hence, in 2030 we are at the start of a revolution in the energy industry. We see energy technology develop extremely fast, and in some places these developments are already leading to an abundancy of energy. Secondly, we proposed that blockchains would be used as a supply chain solution, to support devices and households in bringing energy to the places where it is needed.

Expert interviews
The experts we interviewed agreed with our decision to say that we are at the start of a revolution: a transition from a scarcity based energy system towards abundancy. The experts all think that it is not unrealistic to think that technology will develop in such a way that we are able to create an abundancy of energy, at low cost. However, although some were a bit more optimistic than the others, they all agreed that it will probably not go this fast. According to one expert *"we have to be able, and to be allowed, to dream. If we would not dream, we will never realise anything"*. *"If you look at the development curves and price curves, this scenario is very well defendable"*, and *"considering the current developments, it is not unrealistic to think that we are moving towards an enormous cost reduction for solar energy"* the expert followed. According to another, less optimistic expert, *"this [scenario] remains science fiction for now".* However, this expert does expect us to slowly evolve from scenario three towards some version of this scenario. A third expert also does not think it will go this fast, however, the expert thinks that this will not be because of technology, but because of the depreciation expenses of current assets and resistance. The expert expects that it will take long before things have changed: "*probably, we will first move towards scenario two and then slowly evolve into scenario four".* A fourth expert agrees on this opinion. The last expert thought it is likely that we will move towards scenario four, however, the expert admitted to be fan of scenario four.

If we are able to make energy technology this effective, one expert said that the coupled system of demand and supply will not exist anymore. In this case *"pricing will be based on long term expectations, and you do not have to think about market issues anymore"*. Because energy is about to become free in this scenario, the experts argue that blockchain will not play a role in the trade of energy. Blockchain will be used for logistics, like we proposed before. Additionally, the experts mentioned that blockchain could be used to facilitate the network, and to protect data against abuse.

The following sub-section provides our final version of the narrative for scenario four.

7.4.2 Scenario Four
It is the year 2030. A lot has changed since the year 2017. Energy production is increasingly being decentralised. Radical technological breakthroughs are changing our world, and the use of renewable energy is many times cheaper than fossil energy. We are at the start of a revolution in the energy industry. We used to rely on a scarcity based system in which energy was 'pushed' into the grid, which had to be balanced. Now, we are changing towards a system which uses the abundant layer of solar and wind energy to create new systems in which energy can be produced at almost no cost.

In the past decade, the amount of large scale, central, renewable energy production sites have increased immensely to be able to reach the energy targets set by the national government and European Union. The performance of the large-scale renewable production plants have increased over the years. However, there has been an increase in incidents at centralised energy production sites. Both the government, the consumer, as well as the industry have become anxious to invest in central energy production. As a result the demand for decentralised energy production grew. This is leading to enormous optimisation and efficiency gains for solar energy amongst others. One could say that the developments in this technology are following Moore's Law, which results in very cheap solar energy. For storage possibilities we see the same developments: the performance of small, domestic batteries to store energy has increased enormously and resulted in very low prices. In some cities, these developments have already led to an abundancy of energy.

We see a mobile ecosystem emerge in which cars and drones amongst other things, can produce and store energy, and deliver energy when they arrive at their destination: vehicle-to-grid. Central energy production as a buffer is becoming redundant. The developments in IoT and AI have led to the application and combination of these technologies in the energy industry. For example, we see an increase in the use of robotics and machines which can communicate with each other, and with human beings, and participate at local energy markets. This makes established energy companies less relevant.

Due to these events, there is a shift towards networks. Blockchains are deployed to ease these networks: they function as a supply chain. They are used to facilitate demand and supply, to protect data against abuse, and to allow machines, devices and people to communicate with each other. If the home battery is almost empty for example, it communicates this through the blockchain, and other devices are asked to produce energy to charge the battery, or they are send out to get new energy to recharge the home battery. Big data is used to optimise the efficiency of the blockchain. Because consumers increasingly depend on these blockchain systems, the user interface of the blockchain has been improved to make it as user friendly as possible: for the consumer, the network behind the system is invisible. In a reaction to these developments, the infrastructure and regulations have been adjusted to allow consumers to switch freely between the national grid infrastructure and local energy infrastructures.

To conclude, we are at the start of a revolution in the energy industry. Due to enormous technological developments, the costs of energy are dropping fast and an abundancy of energy is starting to emerge. Smart devices are increasingly able to produce, store, and supply energy themselves. As a result, we see a mobile ecosystem arise in which blockchain is used to facilitate energy demand and supply, to facilitate communication, and to protect data against abuse.

7.4.3 The Ecosystem

Scenario four represents a world in which we are at the start of a revolution for the energy industry. Hence, we are shifting from one ecosystem to another, but there are still a lot of questions to be asked. In the year 2030, the ecosystem will look similar to the ecosystem for scenario two, but the developments in this scenario will make the future of many roles uncertain, see Figure 25.

In scenario four, a blockchain has replaced the functions of the energy supplier, the data facilitator, and the market operator again. The role of the MSP and the ODA are again assumed to be covered by the blockchain, for the same reasons as explained in previous sections. Besides the role of the consumer, the future of the other roles in the current ecosystem are questionable.

Figure 26, provides a possible configuration for the ecosystem of the energy industry in the year 2030, following scenario four. Because solar energy is becoming much cheaper, and investments in central energy production sites are decreasing, there is a shift visible from the central energy producer to the decentral energy producer: the number of prosumers increases. As a result, the role of the cross-border TSO also decreases. Besides the performance of solar energy, the performance of domestic storage possibilities is also increasing. Therefore, the use of the regional grid will diminish, and so will the role of the DSO.

In previous scenarios, the government was included in the ecosystem, because a large part of the consumers' energy bill goes directly to the government in the form of taxes. In this scenario, when energy is close to being free, it is questionable whether the government will still be able to receive tax payments from the trade of energy. The CPO is also removed from the ecosystem. As solar energy and storage capacity are following development paths close to Moore's Law, it is likely that charging points are no longer needed to charge EVs because they can recharge themselves using solar energy and their battery capacity.

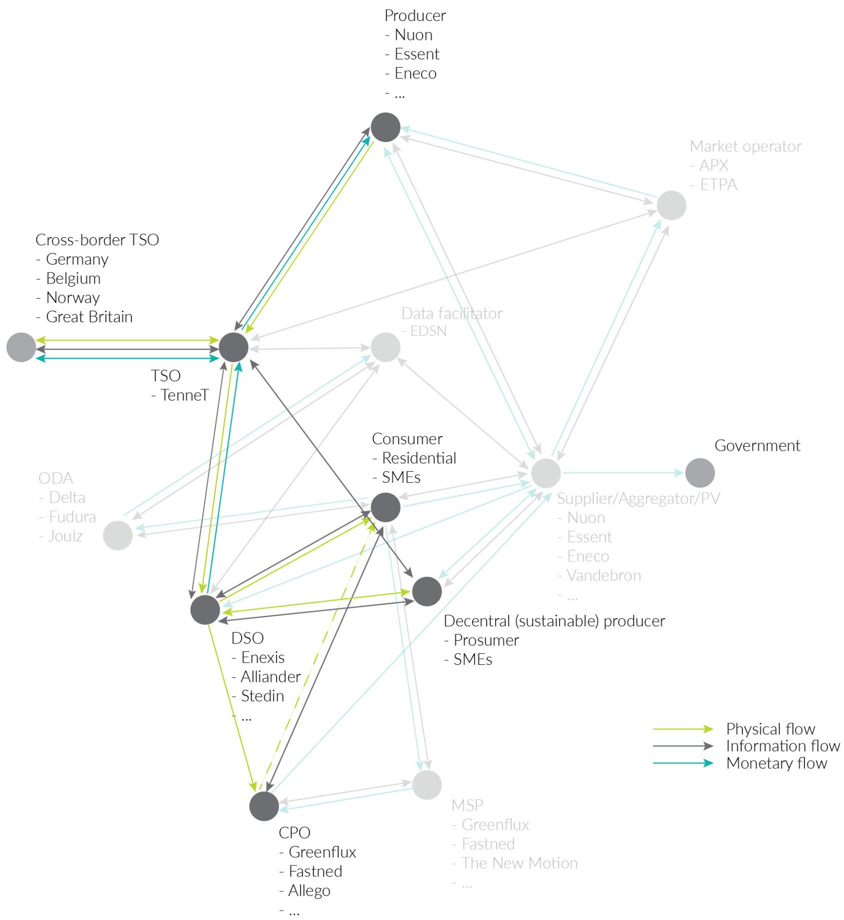

Figure 25: Implications of scenario four for the ecosystem

Because the ecosystem is shrinking, it is difficult to assign ecosystem member roles. A keystone is not clearly visible anymore, because there are no parties involved in the ecosystem with a clear set of common assets as the ecosystem is decentralising. From the perspective of the organisations within the ecosystem, the decentral producer could in this case be seen as a dominator, eliminating the others from the ecosystem, to gain a large part of the ecosystem.

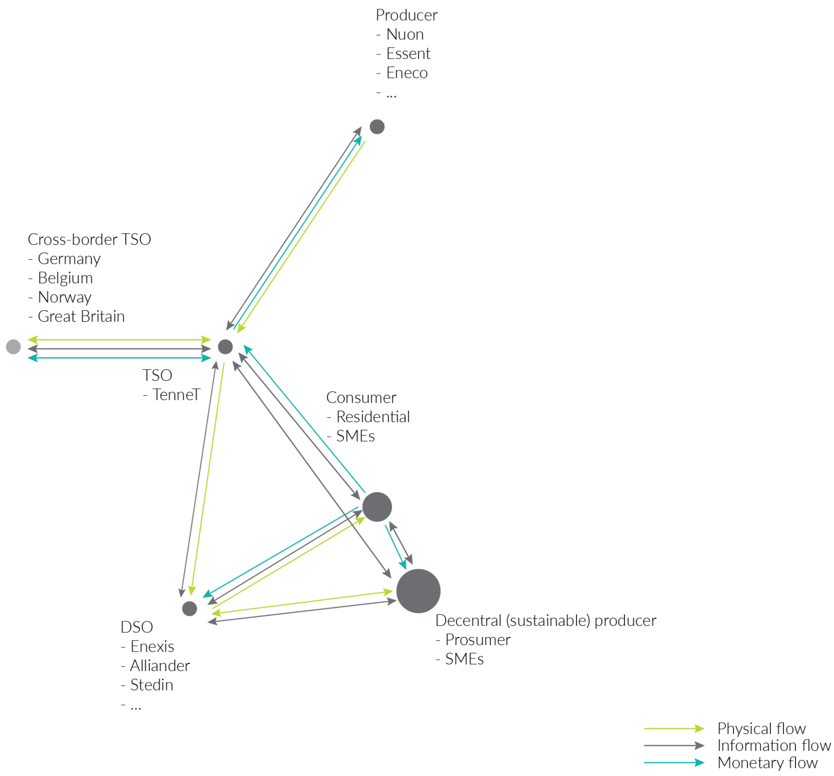

Figure 26: Ecosystem resulting from scenario four

7.4.4 Scenario Evaluation

In section 7.4.1 we have already discussed the plausibility of scenario four according to the experts. Generally, the experts agree on the fact that scenario four is a plausible scenario. The experts' opinions do however differ on the time horizon for which scenario four could be plausible. Where some of the experts are optimistic and dare us to dream, others admit that "*A few tricks will be needed before this scenario could become reality. Scientifically seen, it is unclear whether this scenario could actually become real.*" Another expert said "*We are going to move to the start of this scenario. Actually, we are already moving towards this point. For the year 2050, it is therefore truly a reasonable scenario. Probably, there will be a world in the future similar to this scenario. When, and how remains the big question however.*".

According to the experts, the blockchain case is in this scenario is fairly strong, because there exist entities which are self-owned, and no human being has control over it. About the implications on the ecosystem, the experts agree with our expectations. There are a lot of roles of which their future is unclear or questionable. This is however not solely due to the implication of blockchain. Blockchain technology does disrupt the ecosystem in this scenario, but the disruption is also caused by the extreme technological developments inside, as well as outside the energy industry.

7.5 General Implications

Previous subsections described the changes in the energy ecosystem for each of the four scenarios with regard to the changes in roles and functions of the members of the ecosystem. In this section we will discuss the general implications we can derive from the four scenarios. Subsection 7.5.1 describes the general implications regarding the roles and functions in the energy ecosystem. Subsection 7.5.2 describes the general implications regarding the structure of the energy ecosystem.

7.5.1 Ecosystem Members

In each of the four scenarios, the same functions seem to be directly affected by the implementation of blockchain technology: the functions of the energy supplier, the data facilitator and the market operator are replaced by a blockchain system. As a result of the implementation of blockchain technology to automate these functions, the functions of the MSP and the ODA are also likely to be automated.

Other roles and functions in the ecosystem do not necessarily change due to the implementation of blockchain technology, but due to other events occurring in the scenarios, or a combination of the implementation of blockchain technology and the events occurring. For example, in scenario one and scenario two, the role and function of the decentral energy producer disappears because technological and/or political developments make the use of large scale central production plants more attractive. This is strengthened by the implementation of blockchain technology and the resulting convenience for many of the ecosystem members. For scenario three and four the same applies: the role and function of the central energy producer disappear because technological and/or political developments make the use of large scale central production plants more attractive, but this is strengthened because the implementation of blockchain technology facilitates these developments. In these scenarios, this also affects the role and function of the TSO and DSO for the energy retail market, because the dependency on the national and/or regional grid decreases due to developments in each scenario, and the facilitating role of blockchain technology in these developments.

7.5.2 Ecosystem Structure

Besides the changes in roles and functions, the structure of the ecosystem also changes for each of the scenarios. In chapter 2, four network properties have been identified to describe the (changes in the) structure of an ecosystem: *density, centrality, cliques,* and *diversity.* The density of an ecosystem is about the connectedness of the ecosystem: the more links relative to the total possible links, the higher the density of the ecosystem. Centrality says something about the degree of centrality in the ecosystem: are there members of the ecosystem around which the cohesion of the ecosystem is organised, are the members directly connected to other members of the ecosystem, or are there intermediary members? Cliques are subgroups within an ecosystem that consist of at least three nodes, which are all directly connected to each other. With diversity the variety of different roles, functions and links are meant (see subsection 2.3.1 and appendix E for diagrams).

First we start with the density for each of the scenarios. For each of the four scenarios, we see the density increase. Because in all four scenarios several nodes disappear, and per scenario a maximum of one new node emerges, the number of total possible ties decreases. The total amount of ties on the other hand, increases in each of the four scenarios. This can almost completely be attributed to the implementation of blockchain technology in each of the scenarios: in all four scenarios the number of ties increases because the nodes are directly connected to other nodes via a blockchain. In scenario two, the density becomes the highest. In scenario one, the density is the lowest compared to the other scenarios, but still a lot higher than in the current ecosystem. This means that the connectedness of the members of the ecosystem increases for each of the four scenarios.

Secondly, we see the centrality in each of the four scenarios decrease. In the current situation, the energy supplier is clearly the most central node in the ecosystem, connecting the other nodes with each other. The energy supplier is followed by the TSO and the DSO. Additionally we see the market operator, the data facilitator, the ODA, and the MSP as intermediary parties in the ecosystem. In the four scenarios, the connectedness of the members of the ecosystem has increased and intermediary roles have been replaced by a blockchain. As a result, the centrality of the ecosystems decreases. In scenarios two and three, the consumer can be seen as a node with slightly more connections than the other nodes, but this is because of their connection with the government. In scenarios three and four, the TSO has a slightly more central role, because of the connection with cross-border TSOs. However, because the TSO loses its importance in these scenarios because of the decreasing dependency of the national grid, it is questionable whether the TSO really is a central actor in these two ecosystems. Hence, we can conclude that for each of the four scenarios, the combination of the implementation of blockchain technology and the technological and/or political developments have led to less centrality in the ecosystems.

Thirdly, the number of cliques in the scenarios decreases, but the number of nodes within a clique increases. This is mainly because the blockchain network in each of the scenarios connects the nodes which are part of the blockchain network, with all other nodes in the blockchain network. In scenarios one, two, and four, only one clique can be identified. In scenario three, there are two cliques. This is because the energy products & service facilitator is assumed to be connected to both the consumer as well as the decentral energy producer, but not to the blockchain network. Therefore, the nodes connected to the blockchain network can be considered as one clique, and the energy products & service facilitator, the consumer, and the decentral energy producer can be seen as a second clique.

Lastly, the diversity of roles and functions in each scenario decreases. This is mainly because the ecosystems 'shrink': roles and functions still exist, but are automated via the blockchain network, therefore the number of nodes in the ecosystems decrease. Within each of the function groups however, the diversity increases for some of the scenarios. In scenario two for example, the ownership of the central energy production sites becomes fragmented, therefore, the diversity within the function group 'producers' increases. The same applies to scenarios three and four, in which the function group 'decentral energy producer' grows in number and diversity because most households will become 'decentral energy producers'. Because we only focused on the physical, monetary, and information flows in the ecosystem, the variety of relationships does not change. Table 6 on the next page provides a summary of the implications for the ecosystem structure in each of the scenarios.

7.5.3 Conclusion

To conclude, for each of the four scenarios the roles and functions in the ecosystem change, and as a result the structure of the ecosystem also changes. Hence, the configuration of the ecosystem changes for each of the scenarios. This change can partly be attributed to the implementation of blockchain technology, and partly by the events occurring in each of the scenarios. Hence, we argue that blockchain technology does disrupt the roles and functions in the ecosystem, however, not all changes in the ecosystems for the four scenarios can solely be ascribed to the implementation of blockchain technology. The potential of blockchain technology lies in the replacement of the roles of central data facilitator, the energy supplier, and the market operator. First of all, if a blockchain is used for the distribution of data, thereby taking over the role of the central data facilitator, direct, transparent, and continuous exchange of data is possible. As a result, the role of the energy supplier also becomes questionable, because in principle, if a blockchain is used for the exchange of data, direct exchange of smart metering data between the producer and the consumer also becomes possible. It does not matter whether the producer of energy is a large central energy producer, or a prosumer for this case. If smart contracts are then applied to increase the energy efficiency of households, and to solve the flexibility problem, the blockchain automatically takes the role of market operator. As a result, the density of the ecosystem becomes higher, the centrality lower (hence the ecosystem decentralises), there are less cliques (because of the decentralisation and removal of intermediaries), and the diversity of roles within the ecosystem also decreases. We conclude that blockchain technology can be implemented as an institutional technology in the energy ecosystem, thereby making the ecosystem more robust, flexible, secure, and efficient, and being a competitor of both organisations as well as markets.

Table 6: Summary implications on the ecosystem structure

	Density	Centrality	Cliques	Diversity
Scenario 1 Power Play	Increases → connectedness increased, because several nodes disappear, but the number of ties increases due to a blockchain system which directly connects nodes with other nodes in the ecosystem.	Decreases, because the connectedness increases and intermediaries are replaced by a blockchain system. All nodes are equally connected, except for the government ant the cross-border TSO.	1 → there is one clique visible, covering all main members of the ecosystem: they are all directly connected with each other.	Decreases, because there are less functions left.
Scenario 2 Power to the Devices	Increases → connectedness increased, because several nodes disappear, but the number of ties increases due to a blockchain system which directly connects nodes with other nodes in the ecosystem.	Decreases, because the connectedness increases and intermediaries are replaced by a blockchain system. All nodes are equally connected, except for the government ant the cross-border TSO.	1 → there is one clique visible, covering all main members of the ecosystem: they are all directly connected with each other.	Decreases, because there are less functions left, but diversity within 'producers' increases
Scenario 3 Power to the People	Increases → connectedness increased, because several nodes disappear, but the number of ties increases due to a blockchain system which directly connects nodes with other nodes in the ecosystem.	Decreases, because the connectedness increases and intermediaries are replaced by a blockchain system. The consumer is slightly more central because of its link with the blockchain network, the government, and the energy products & service facilitator.	2 → there is one clique visible, covering all main members of the ecosystem: they are all directly connected with each other. And there is one clique visible consisting of the consumer, the decentral producer, and the energy products & services facilitator.	Decreases, because there are less functions left, but diversity within 'decentral producers' increases
Scenario 4 Land of Plenty	Increases → connectedness increased, because several nodes disappear, but the number of ties increases due to a blockchain system which directly connects nodes with other nodes in the ecosystem.	Decreases, because the connectedness increases and intermediaries are replaced by a blockchain system. From the model, the TSO is seen as a central node, however, its importance has decreased in this scenario.	1 → there is one clique visible, covering all main members of the ecosystem: they are all directly connected with each other.	Decreases, because there are less functions left, but diversity within 'decentral producers' increases

8. Conclusion and Discussion

The goal of this study is to explore whether there might be different ways to organise the energy ecosystem with blockchain as the enabling technology. Therefore, the following research objective has been formulated:

The objective of this research is to develop future scenarios on ecosystem configuration within the Dutch energy industry to explore the disruptive power of blockchain technology

In this final chapter, we will provide an answer to the corresponding main research question:

What are possible consequences of the implementation of blockchain as institutional technology on the business ecosystem configuration of the Dutch energy industry?

First, we start this chapter with the main conclusion of this research project. Secondly, we provide the conclusions for each of the sub questions that have been formulated in chapter 1. Thereafter, we discuss the scientific and practical contribution of this research. This is followed by a discussion of the limitations of this research. Lastly, we provide our recommendations for areas of future research.

8.1 Main Conclusion

For this study we choose not to view blockchain technology from a technology-focussed perspective. Instead, we used a new institutional economics perspective and studied blockchain as an institutional technology, to explore the disruptiveness of blockchain technology for the Dutch energy industry. Blockchain technology is viewed as an institutional technology, because it has the ability to coordinate people in, for example, making economic transactions, as it enables new types of contracts and markets. This way, blockchain can compete with organisations and markets.

Based on the theoretical possibilities of blockchain technology, and expectations voiced by experts, we have formulated four future scenarios to explore the disruptive power of blockchain on the Dutch energy industry:

1. Scenario One – Power Play
2. Scenario Two – Power to the Devices
3. Scenario Three – Power to the People
4. Scenario Four – Land of Plenty

These scenarios are the outcome of a scenario planning process. During this process we gained a deeper understanding of both the blockchain domain as well as the energy industry domain through a thorough literature study (chapters 4 and 5). Furthermore, we analysed trends using multiple analysis tools to create a framework for our scenarios (chapter 6). And lastly, we used a focus group in combination with expert interviews to develop and validate our scenarios and scenario implications (chapter 7).

To answer our main research question, four important consequences of the implementation of blockchain technology as an institutional technology on the business ecosystem configuration of the Dutch energy industry were found. First of all, in each of the four scenarios, we saw that the implementation of blockchain technology affected the business ecosystem configuration of the Dutch energy industry.

Secondly, in each of the four scenarios, the same functions within the energy ecosystem change or are replaced as a direct result of the implementation of blockchain technology. The functions of the supplier, the data facilitator, the market operator, the MSP, and the ODA are directly replaced by an application based on blockchain technology.

Thirdly, in each of the four scenarios the other roles and functions change or are replaced as an indirect result of the implementation of blockchain technology. The impact on the functions of the TSO, the DSO, the producer, the decentral producer, and the CPO is different per scenario. These functions are mainly affected due to technological and/or political developments, which are facilitated by blockchain technology and applications built on blockchain technology.

Lastly, for the structure of the energy ecosystem, we saw that in each of the four scenarios the density of the ecosystem became higher, the centrality lower, the number of cliques decreased, and the diversity of roles within the ecosystem also decreased. Hence, the implementation of blockchain technology leads to decentralisation, and the removal of intermediaries in the energy ecosystem. As a result, the energy ecosystem will become more robust, flexible, secure, and efficient.

To conclude, we argue that the energy industry should recognise blockchain as an institutional technology. We acknowledge the fact that there still is a long way to go before blockchain can and will be used the way we presented in this study. There are still a lot of uncertainties, issues, and inconveniences that need to be solved. However, when we focus on the possibilities which blockchain could theoretically provide, we argue that blockchain has the potential to disrupt the energy ecosystem. In all of our four scenarios, the business ecosystem configuration for the energy industry changed due to the implementation of blockchain technology. In all of our four scenarios the energy ecosystem decentralised. And above all, in all of the four scenarios, blockchain is a potential competitor of both organisations, as well as markets within the energy industry. Therefore, we argue that blockchain is not solely a technology with the potential to lead to efficiency gains. Instead, blockchain is a technology with the potential to change the entire business ecosystem of the energy industry. As a result, the future of multiple functions in the current energy ecosystem becomes questionable.

In the following section, we provide a recap of the answers to the five sub questions that were used to derive this conclusion.

8.2 Sub Questions Recap

In chapter 1, five sub questions have been formulated to derive an answer to the main research question. In this section, a conclusion for each of the five research questions will be provided. Based on these conclusions, we derived our answer to the main research question of this study.

8.2.1 Research Question 1

> SQ1: What are business ecosystems and how can ecosystem configurations be analysed?

In chapter 2, we provided a theoretical framework to be able to discuss and analyse the energy industry system, and potential changes in this energy industry system. First, we started with the selection of an inter-organisational network concept to describe and analyse the energy industry system with the use of academic literature. We discussed the concepts of business ecosystems, value chains and value networks. Based on three predefined criteria, the concept of business ecosystems was found to be most appropriate for this research. We defined business ecosystems as:

"A business ecosystem is a networked system of different types of actors that are tied to each other through relationships, and interact both cooperatively and competitively."

Secondly, we identified two components to describe and analyse the configuration of an ecosystem: *the members of the ecosystem and their mutual relationships*, and *the structure of the network*. For the first component, we found that ecosystems can be visualised using *nodes* to represent the members of an ecosystem, and *links* to represent the relationships between the members of an ecosystem. The members of an ecosystem can be described based on their function in the ecosystem, and on the role they play in the ecosystem. Three ecosystem roles have been identified in the literature and which were used for this study are: *keystones, dominators,* and *niche players.* The relationships between the members of an ecosystem are typically exchange processes, which we categorised into four types of exchange processes: *1) goods and services, 2) affective and liking, 3) information and ideas*, and *4) influence and power*. To analyse the structure of an ecosystem, we found that the concepts of social network analysis can be used. For this study we used four typical properties of networks that are used in social network analysis: *1) density, 2) centrality, 3) cliques*, and *4) diversity*.

8.2.2 Research Question 2

> SQ2: What is blockchain technology, how does it work, and what are the possibilities this technology brings forth for the energy industry?

To provide an answer to this research question, we first refer to chapter 4. We found that a blockchain is a *digital ledger*, which is *chronologically* and *continuously* updated, *cryptographically* sealed, and *distributed* across all participants of the blockchain network. As a result, blockchain technology enables the transaction of physical, digital, and intangible assets, between counterparties that do not necessarily trust each other, without the need for a trusted third party. Additionally, a blockchain can either be permissionless or permissioned. Hence, this answers the first part of sub question 2 in a nutshell. To answer the second part of this research question we refer to the last part of chapter 2 (section 2.3), and chapter 4. In chapter 2, we used transaction cost economics to explain how blockchain could potentially change the energy industry system. We found that blockchain technology can be used as an instrument to control opportunism, because blockchain has the ability to organise the need for trust in a different way. Hence, because blockchain has the potential to replace central authorities, blockchain could decentralise the energy ecosystem, and drive down transaction costs. Therefore, blockchain technology could be a potential competitor for organisations or markets. Secondly, in section 4.1.1 we provided an explanation of a typical blockchain process. We found that in a typical blockchain process, information about a transaction is distributed across the blockchain network, and that special nodes, called miners, work following a consensus mechanism to validate transactions. To answer the last part of the research question, for the energy industry, the possibilities of blockchain technology concern the opening up of the energy market to consumers, transparent and accurate transaction records, and an efficient way to distribute data. Hence, blockchain technology could help to ease the management of electricity bills, increase the visibility of data and transactions, and streamline the distribution of energy.

8.2.3 Research Question 3

SQ3: How is the ecosystem around the energy industry system in the Netherlands currently arranged?

In chapter 5, we used the theoretical framework provided in chapter 2 to describe and analyse today's energy industry system in the Netherlands. Our description of the energy domain started with the energy value chain. We found that the energy industry appears to be not as linear as the value chain anymore. To visualise the ecosystem, we have used nodes to represent the functions existing in the ecosystem, and links representing the relationships between the nodes. To determine which functions to include in the ecosystem and which not, three criteria have been used. Additionally, we only focussed on the physical, monetary, and information flows within the ecosystem, because these flows represent the main exchange processes in the energy industry system. The ecosystem has been built step by step: first, we started with the physical flow, then the monetary and information flow were modelled, and lastly the three models that followed from these steps were combined into an aggregated model for the Dutch energy ecosystem (see Figure 27). The visualisation of the energy ecosystem has led to two main findings: 1) new technologies have emerged, and new functions have been formed around this, compared to the more simplistic value chain, and 2) our model of the energy system has visualised the middlemen in the energy industry.

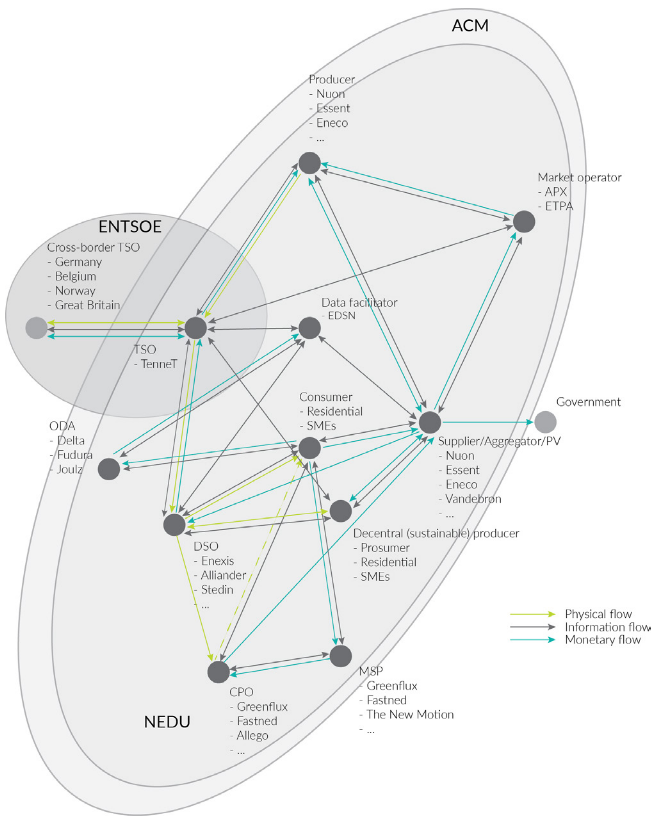

Figure 27: The Dutch energy ecosystem

8.2.4 Research Question 4

> SQ4: What are possible scenarios for the ecosystem configuration of the Dutch energy industry system, when potential blockchain solutions are implemented?

The scenario planning method that has been used for this study is based on the eight-step methodology by Schwartz (1991). The goal of this method is to identify key drivers for change, or put differently, to identify trends, developments, or events that have a high impact and high uncertainty. The two main key drivers for change have been used to formulate a scenario framework. The scenario framework has been used to guide the scenario formulation. This resulted in the following four scenarios:

1. Power Play – Central energy production and incremental technological developments
2. Power to the Devices – Central energy production and radical technological developments
3. Power to the People – Decentral energy production and incremental technological developments
4. Land of Plenty – Decentral energy production and radical technological developments

During a focus group the assumptions for the four scenario narratives have been formulated. Thereafter, expert interviews were used in an iterative process to enrich and validate the scenario narratives.

8.2.5 Research Question 5

> SQ5: Based on the evaluation of the possible future scenarios for the ecosystem configuration of the Dutch energy industry system, what is the potential of blockchain technology?

In the last part of chapter 7, we concluded that for each of the four scenarios, the roles and functions in the ecosystem change: we see functions disappear, change, and emerge, and for each of the scenarios we see different member groups take on different member roles. Some of the roles and functions are directly affected by the implementation of blockchain technology, like the functions of the energy supplier, the data facilitator, and the market operator. Other functions are indirectly affected by the implementation of blockchain, like the DSO, TSO, and the (decentral) producer. As for the structure of the network of each ecosystem, we also see changes as a result of each of the scenarios. First, for each of the scenarios, we see the density increase compared to the structure of the current ecosystem. Hence, we can conclude that the connectedness of the nodes in the ecosystem increases. Secondly, we see the centrality in each of the scenarios decrease compared to the centrality in the current ecosystem. This means that for each of the scenarios, the ecosystem decentralises and the cohesion of the ecosystem increases. Third, the number of cliques in each of the scenarios decreases compared to the number of cliques in our current energy ecosystem, as a result of the increased density and decreased centrality. Lastly, the diversity of roles and functions decreases, because many functions are automated using blockchain technology.

Hence, the potential of blockchain technology is not solely concerned lower production costs. We have seen that blockchain can be characterised as an institutional technology, being a potential competitor of organisations and markets. In the energy industry, blockchain has the potential to replace the roles of central data facilitator, the energy supplier, and the market operator. As a result, the ecosystem decentralises and three important intermediaries can be removed from the ecosystem. This will make the ecosystem more robust, flexible, secure, and efficient.

8.3 Scientific and Practical Contribution

Within this research we have addressed the potential implications of blockchain technology on the business ecosystem of the Dutch energy industry. As such, this research project has made several contributions, of both scientific as well as practical value.

New institutional economics perspective on blockchain technology

We have looked at blockchain technology from a new institutional economics perspective, instead of a technology based perspective, in an attempt to close the gap between the emerging blockchain technology and the challenges for the energy industry. This way, we have provided a different perspective on the use of blockchain technology than most articles which have recently been published on blockchain technology. On the use of blockchain in the energy industry, we have not seen this perspective before. Instead of just focussing on supportive blockchain solutions for the energy industry, we have focussed on larger possibilities of this technology for the energy industry. This is important, because through this perspective, we found bigger consequences for the members of the ecosystem, and new ways to organise the energy industry with the implementation of blockchain technology. Hence, for the energy industry, we provided a new perspective on blockchain technology. Both scholars and practitioners can use this valuable perspective for further research on the organisation of the energy industry and of future business models for firms active in the energy industry.

Four scenarios

We have developed four different scenarios to explore if blockchain technology could provide a potential solution for the forthcoming challenges in the energy sector. We therefore based our study on available blockchain literature, concepts, and expectations voiced by experts. Through the four scenarios we have provided ideas of how blockchain can be used in the energy industry, which have not been formulated before. Furthermore, our research has pointed out that blockchain technology has the potential to change the configuration of the energy ecosystem, and the potential to provide a solution for the challenges in today's energy transition. For some of the actors in the energy industry this research has even made it clear that the implementation of blockchain technology will make their current role in the ecosystem in the future redundant. With the scenarios we have given an insight in the extremes towards which the energy industry could potentially move. The scenarios itself provide a starting point for future research on the use of blockchain technology presented in this research. Additionally, the scenarios could be modelled to test the cases and their implications. For the current members of the ecosystem, the scenarios provide a comprehensible representation of possible future directions to which the energy industry could move. The scenarios provide the current energy companies with an important tool on the potential of blockchain technology in their business environment, and to determine their position in the blockchain debate. Hence, the scenarios will help these organisations to consider their future business strategy.

Energy ecosystem model

Because our focus was on the implications of blockchain technology for the current members of the energy ecosystem, we have created a model to visualise the current ecosystem of the Dutch energy industry, and to analyse the implications of blockchain technology on the configuration of this ecosystem. This was needed, because we did not find a model including all important actors and in the energy ecosystem, and their mutual relationships. Our model provides a new way to look at the energy industry, presenting important actors, relationships, and flows, which are not included in the frequently used energy value chain. The model of the energy ecosystem is therefore of both scientific, as well as practical value. It provides scholars an extensive model to analyse the energy industry. Our model could serve as the basis for the further development of a model for the energy ecosystem, and to generate and test new ways to organise the industry. For practitioners, the energy ecosystem provides a comprehensible way to explain the energy industry, to analyse their current and future position within the industry, and to reflect on the way they have arranged their business models.

Value for Enpuls

Lastly, for Enpuls this research project provides valuable input to determine their opinion about blockchain technology, and the value of blockchain technology for the energy industry. It helps Enpuls to set direction for new research projects and new innovations and cases. Furthermore, the scenarios and the main conclusion of this research project help Enpuls to open the eyes of the rigid energy sector in their mission to drive for change and stimulate the energy transition.

8.4 Discussion

In this section, we will critically reflect on the choices made in this research and the processes and methodologies used. First, we will reflect on the scenario planning process that has been used in this study. Second, we will reflect on the focus group that has been used to formulate the scenario narratives. Third, we will reflect on the theoretical concepts used for this research project. Lastly, we will discuss the assumptions made about the development of blockchain technology.

8.4.1 Scenario Planning Methodology

For this research, scenario planning was used as methodology. This method is used to explore the extremes for the energy industry, but the resulting scenarios are not predictions of the future. The scenario narratives are based on expectations voiced by experts, and could be seen as extrapolations of current developments. However, the scenario narratives described are not forecasts. They are possible future worlds and are therefore fictional. Additionally, as a result of the method used, we derived four possible future worlds, but there are innumerable possible futures one can come up with. However, because we have selected a scenario framework consisting of the two most important driving forces according to experts, the four scenarios should be seen as the extremes for the industry.

Secondly, as has already been pointed out in chapter 3, contrary to other scientific methods, the outcomes of scenario planning are difficult to validate, because there exists no empirical data against which the scenarios can be tested, as scenarios describe worlds that could exist in the future. As a result, the credibility of scenario narratives can be questioned. Additionally, scenario planning is often used in practice, but relatively little academic research has been carried out on its performance and underlying theories. This is mainly because the scenario planning technique has been developed from practice and experience. As a result, some academics share the concern about how we know if we have ‘the right’ scenarios, and how we go from scenarios to decisions.

Third, to structure our research and decrease bias, an impact and uncertainty analysis, a cross-impact matrix, and a focus group have been used. Because this research is part of my Master Thesis project, there was no project team involved during the entire scenario planning process, as is usually the case for scenario planning projects. As a result, the analysis of the trend clusters, the re-clustering process, and the cross-impact matrix have not been carried out by a project team, but in consultation with my external supervisor, Frank van Rossum, and Jester, the agency experienced in scenario planning process, which covered the moderator role during the focus group. To derive valuable input and enrich our results, a survey has been send out for the impact and uncertainty analysis, and a focus group has been organised. Because specific knowledge was needed for these components, most participants of the focus group are active in the same industry (the energy industry, the field of blockchain technology, or a combination of both). Hence, a certain amount of bias could not be ruled out. For example, it is possible that the participants are overly optimistic about developments in the energy industry or the developments in blockchain technology, than others would be.

Lastly, the survey for the impact and uncertainty analysis has been send to employees from Enexis and Enpuls, and to the participants of the focus group. We have kept the survey internal, because the survey had to be finished within one week. As a result the results of the survey could contain bias because part of the respondents are employed at the same company.

8.4.2 Focus Group and the Scenario Narrative Development Process

For our research we have used a focus group. To explore the extremes of the industry, we used a diverse group of participants. However, in order to be of added value, the participants had to be an expert in the energy industry, and have an understanding of blockchain technology, or an expert about blockchain technology, and have an understanding of the energy industry. Hence, although all the participants are employed at different institutions, their fields of expertise were similar.

Second, in a focus group there are always participants who are more at the forefront, and participants who act more at the background. To hear every expert's opinion during the discussions, an external agency served as moderator (Jester). However, it was insurmountable that some participants were heard more than others. In both groups this happened to some extent. For group 1 this resulted in an extreme version of scenario four. In group 2, the result was a strong focus on energy technology at the beginning of the discussion of scenario two. However, after an intervention by the researcher of this project, the participation of all experts improved. Additionally, during the discussions, it is possible that individual thoughts were influenced by the discussion. Therefore, the individual interviews with some of the focus group participants were used as counterpart for the focus group.

Third, the choice for the key driver for change 'incremental vs. radical technological developments' as axis for our scenario framework was questioned by a few of the participants during the focus group. Additionally, the axis appeared to be difficult to understand for some of the participants. Looking back at the process, there are other possible axes thinkable. However, this axis was chosen because based on the impact and uncertainty analysis and the cross-impact analysis: it was ranked as the most important and most uncertain trend. Although a different combination of trends for the scenario framework would likely have resulted in different outcomes, it is questionable whether this would have been 'better' outcomes, or if there even is a 'right or wrong' in this case.

Fourth, it appeared to be difficult to get the participants out of their comfort zone. The participants were selected based on their extensive knowledge on the energy industry and/or blockchain technology, to get as much valuable information as possible. For some of the participants, however, it was difficult to be open-minded towards ideas about future, because of their experience or their way of thinking. A comment that was sometimes heard during the discussions was 'today things are arranged and regulated this way, hence, your thoughts about the future are impossible'. To overcome this way of thinking, the two groups were compiled up front: we made sure that every group had at least one person we knew to be open minded, to keep the discussion open and bring new ideas into the discussion. Secondly, during the discussions we intervened now and then in an attempt to open up the discussion again.

Lastly, during the focus group only the general directions for the four scenarios had been outlined. For scenario one and two, the experts provided many ideas. This meant that we had to decide to not include some of the ideas, to derive a logical scenario from all these ideas and expectations. Hence, we mainly had to bring focus into these scenario narratives. For scenario three, the experts were unanimous and gave a clear direction and convincing causes which could have led to this scenario. Hence, we decided to follow the direction of the experts. Scenario four on the other hand was a challenging scenario because of the extreme assumptions provided by the experts. The main challenge was to make this scenario a plausible scenario. However, for all of the scenarios the assumptions based on blockchain were minimal. Hence, the biggest job during the scenario narrative development process was to develop viable blockchain cases for each of the four scenarios. We decided to use the discussions of the focus group as starting points, and developed the use of blockchain with the knowledge we gained from chapter 4. During the interviews we tested whether the experts thought the way blockchain would be used in the scenarios would fit with the developments described in the scenario narratives, and whether the experts thought the blockchain cases could be possible and could work. Additionally we discussed the overall scenarios to be able to include more detail each time we had an interview. Hence, although we were a bit disappointed at first about the limited discussions about blockchain technology during the focus group, after a good search through the results of the focus group we did indeed find some good starting points to develop a viable and plausible blockchain case for each of the scenarios. The interviews were of good help to get more detail and to test the way we thought blockchain could be used.

8.4.3 Theoretical Concepts

For this research project, we used two theoretical concepts. First of all, we used the business ecosystems theory to be able to describe and analyse changes the energy industry. Business ecosystems theory was found to be very useful to map the existing ecosystem of the energy industry and provide the guidelines of which parts of the industry to include in the ecosystem, and which not. However, multiple other theories were needed to be able to complete our theoretical framework around a business ecosystem model for the energy industry. For example, we used Network Value Analysis to analyse the types of relationships between members of the ecosystem, and Social Network Analysis to analyse the structure of the ecosystem. The ecosystem member roles concept (keystones, dominators, and niche players), which is a typical concept of business ecosystems theory, was found to be less useful in the end. These roles helped to analyse which members are important for the ecosystem, which members could be harmful to the others members of the ecosystem, and which members of the ecosystem found ways to remain their position in the ecosystem. Therefore, we argue that the real potential of the use of these member roles is in research by members of the ecosystem to develop their future business ecosystems, but the usability of the member roles concept was limited for this research. To conclude, the concept of business ecosystems was useful, but it had to be complemented by other network concepts to increase its usability.

Secondly, we used transaction cost economics to find how blockchain technology could change the energy ecosystem. This theory appeared to be extremely useful for our research, as it provided us a different perspective on the potential of blockchain technology for the energy industry. However, it was challenging to use this perspective, as not much articles have appeared yet viewing blockchin blockchain technology from this perspective. We do however think that the use of this new institutional economics perspective in other studies on the potential of blockchain technology will increase their usability.

8.4.4 Blockchain Development Assumptions

Blockchain technology still is an immature technology. Therefore, during this research we have used the theoretical possibilites and concepts of blockchain technology to assess its potential impact on the energy ecosystem in the Netherlands. The scenarios in chapter 7 of this research are based on the functionalities blockchain in theory could provide, but are not yet possible in practice. Hence, they are based on the assumption that blockchain technology has been developed further and has overcome its inconveniences: technological and regulatory constraints have not been taken into account. Therefore, it must be emphasised that in order for the scenarios to become reality, blockchain technology should be developed further. In the interviews, the main challenges that have to be overcome in order to implement blockchain technology at such a large scale as in the scenarios of this research are:

1. The high transaction costs which are currently concerned with blockchain transactions. These are mainly the result of the current consensus mechanisms. If we want to use blockchain at a large scale, these transaction costs should drop dramatically.
2. Blockchain are slow, because of the current consensus mechanisms. In cases where fast transactions

are important, current blockchains are inappropriate because they are too slow. Hence, the consensus mechanisms would have to be developed to enable fast transactions.

3. The blockchain has to be able to manage the amount of transactions. The capacity of current blockchains is not big enough. Additionally, the size of the transactions in the blockchain have to be decreased in order to be able to store all the transactions that have taken place.
4. People who do not want to, or have difficulties with digitalisation. Think of elderly, or people who are against digitalisation because of privacy or other reasons. Hence, the interface of blockchain applications has to be as user friendly as possible and privacy and security issues have to be taken care of. People using these applications do not have to be aware of the fact that they are using a blockchain-based application.
5. The costs of setting up a blockchain system. Someone will have to pay for the initial costs of the system, and set the first step. In one of the interviews it was mentioned that it could be that the government would set up different blockchain infrastructures. Other parties will only do this if they will benefit from it.
6. In scenario one, a permissioned blockchain is used. The way this blockchain is used, the parties setting up the blockchain, the energy companies, could use this blockchain to make pricing agreements. Hence, if this scenario would become reality in the Netherlands, it is likely that there has to be a supervising authority (for example ACM, or the government) to prevent this kind of behaviour.

8.5 Recommendations for Future Research

Based on the conclusions and limitations of this research discussed in previous section, we provide several recommendations for future research:

Research concerning the business ecosystem model

The ecosystem developed for this research project provides a new perspective to view the energy industry. In future research, this model should extended to increase the usability. For example, in this research, only the electricity market is included. In future research, the gas market or new energy carriers could be included in the ecosystem. Furthermore, in our research we only included the physical, monetary, and informational flows as the exchange processes in our version of the ecosystem. In future research this could be extended, by including more exchange processes, or including more detail into the type of exchanges taking place. For example, the sort of data that is exchanged could be included in the model. Additionally, the energy ecosystem could be simulated using computer models.

Research concerning the scenario planning methodology

Scenario planning has existed and been used for a while now, but mostly this methodology is only used in practice. Many different methodologies and tools exist, but often scenario planning is for a large part based on intuition. Scientific research on scenario planning is needed to improve the credibility and validity of this method and the resulting scenarios. This is needed, because especially in changing and complex environments like the energy industry, this methodology could be a useful method for scholars. We suggest that more research should be done to structure the scenario planning process and to create a consistent methodology.

Research concerning the scenarios

The scenarios that have been formulated in this research provide a starting point to explore the possible implication of blockchain technology on the energy ecosystem. The experts that have been interviewed were asked about the plausibility of each of the scenarios. The general conclusion of these interviews is that each of the four scenarios are plausible. In future studies, the scenarios should be studied in more detail to test the viability of the scenarios, and the viability of the blockchain cases in particular. Additionally, interviews with other experts inside and outside the industry could be held to validate the scenario narratives and conclusions. Also, the scenarios could be modelled quantitatively, and simulations of the scenarios could be developed to test the scenarios.

Furthermore, in future research other scenario frameworks can be tested to see if this will lead to a different outcome than the results of this study. This will increase the robustness of the scenarios, hence, increase their usability.

Research concerning the use of blockchain

This research explored how blockchain as an institutional technology could be used in the energy ecosystem. This provides a good basis for at least four different types of implementations. Future research will be needed to study the potential of blockchain technology and to develop the blockchain use cases in more detail. It should be studied which functionalities should be included into the blockchains, how the applications should be modelled and should work, what the interface of blockchain applications should look like, etc. Furthermore, it should also be studied which regulatory changes are needed before a particular blockchain case could be realised.

On a more general level, more research on blockchain technology is needed to increase the efficiency of the technology, lower the transaction costs, increase the capacity of blockchains, and increase the security of blockchains. Only if these challenges have been solved, blockchain technology will be used on large scale.

Research concerning business models in the energy ecosystem

Lastly, the scenarios constructed for this research project should be used for research on future business models for current energy ecosystem members. The scenarios provide a framework of possible extremes to which the energy industry could move. It is unlikely that there will be an energy ecosystem in the Netherlands in the year 2030 which is exactly like one of our scenarios. However, it is likely that there will be an energy ecosystem somewhere within the boundaries of this framework described by our four scenarios, including elements or combinations of the scenarios we have developed. Energy companies should open up to these scenarios and use the scenarios to prepare their business models for the future. This way, the companies will not be surprised when there is a sudden move in the energy ecosystem, making their current businesses redundant. Based on our results, we would especially advise the data facilitator, the energy suppliers and the market operator to revise their current business model. However, as became clear from our scenarios, the position of all ecosystem members is likely to change in the future.

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Appendix A - Participants Focus Group

List of participants of the focus group participating the workshop on Wednesday May 24th, 09.00-12.00.

1.	Jeroen van Hoof	PwC- *Chief Technologist, (Co)creator Blockchain Experience, Blockchain Technologist*
2.	Jan-Peter Doomernik	Enexis- *Sr Business Developer*
3.	Theo Fens	TU Delft- *Senior Research Fellow Economics of Infrastructures at the faculty of TPM and consultant in energy markets and IT*
4.	Gaston Hendriks	Energy 21- *CTO* Quantoz- *Co-founder*
5.	Egbert-Jan Sol	TNO- *CTO TNO Industry*
6.	Eric van der Laan	ICT Group- *Business Development Manager Energy*
7.	Minke Goes	Ecofys- *Consultant Urban Energy Infrastructure*
8.	John Post	Topsector Energie- *Programme Director Digitalisation Agenda*
9.	Wim Bouman	Alliander- *Strategy Consultant exploring and developing blockchain initiatives*
10.	Joris Bontje	OneUp- *CTO*

Appendix B - Interview Protocol

1. Introduction
    1.1 How did the respondent experience the workshop during the focus group?
    1.2 Structure of the interview
(Because all respondents have participated in the focus group, an official introduction by the respondent and of the objective of this study is deemed unnecessary)

Each respondent will receive a version of the scenario narratives that will be discussed during the interview, and is asked to read the scenario narratives before the interview. The narratives will be send by email, at least 2 days before the interview takes place. After each interview, the scenario narratives will be adapted, with the use of the results of the interviews.

All scenarios will be discussed separately. The questions described below will therefore be asked for every scenario. Because the interviews are used to extent the results of the focus group results and for more detail in the scenario, the exact questions asked will differ per respondent as each respondent has a different field of expertise. Generally, the following structure will be followed per scenario:

<u>Questions regarding the scenario narrative</u>

2. Do you agree with the way the scenario narrative has been described?
    2.1 Does the scenario fit with your view on this scenario during the workshop?
    2.2 Has the scenario narrative logically been derived?
    2.3 Are there parts missing? Do you have something to add to the narrative?

<u>Questions regarding a particular part of the scenario narrative</u>

3. What does X look like in this future world?
(X will depend on the expertise of the respondent, and the unclarities of the scenario that are left)

<u>Questions regarding the ecosystem described for the scenario</u>

4. Are the implications for the ecosystem correct?
    4.1 Is it true that function X disappears?
    4.2 Who or what is likely to take over function X?
    4.3 Are there other functions that could potentially change/disappear/emerge in this scenario?

<u>Questions regarding the characteristics of the scenario</u>

5. Is the scenario described a plausible scenario?
6. Is the scenario sufficiently extreme/provocative?

<u>Questions regarding the use of blockchain in this scenario</u>

7. Is this application of blockchain technology disruptive for the ecosystem and ecosystem configuration?

Questions regarding the obstacles for this scenario

8. What are the obstacles that have to be overcome in this scenario?

Important to note is that the questions above are used as guidelines for the interviews. In some interviews however, the focus will be on different topics than in other interviews and some of the topics will not be discussed. This is a result of the field of expertise of the respondent and the status of the scenario narrative at the time of the interview.

Appendix C - Cross-Impact Matrix

!!!	Aantal respondenten: 22

#	Trendcluster	Impact	Onzeker-heid	1 The emergence of new developments in energy technology	2 Increasing need for flexibility	3 Increase in decentralised energy production	4 Increase in large scale sustainable energy production	5 Increasing governmental steering in the energy market	6 Aging	7 Increase in customer awareness and involvement in the energy market	8 Increasing sustainable energy use	9 Increase in energy service and service providers	10 Increase in energy cooperations	11 Acceleration of technological breakthroughs	12 Increasing importance of data	Mate van invloed op andere trendclusters	Gemiddelde	Afwijking van gemiddelde
1	The emergence of new developments in energy technology	4,3	3,5		2	3	3	1	0	2	3	2	1	1	2	1,8		0,1
2	Increasing need for flexibility	3,7	2,6	3		1	1	2	0	1	1	3	2	2	2	1,6		-0,1
3	Increase in decentralised energy production	3,7	3,0	2	3		2	2	0	2	3	2	2	1	2	1,9		0,2
4	Increase in large scale sustainable energy production	3,5	2,7	2	2	3		2	0	1	2	1	2	1	2	1,6		-0,1
5	Increasing governmental steering in the energy market	3,6	3,3	2	0	2	3		0	2	3	2	1	2	1	1,6		-0,1
6	Aging	2,4	2,4	0	0	0	1	1		0	0	2	1	1	0	0,5		-1,2
7	Increase in customer awareness and involvement in the energy market	3,4	2,6	2	2	3	3	3	0		3	3	3	2	2	2,4	1,7	0,7
8	Increasing sustainable energy use	3,6	2,8	2	3	3	3	1	0	2		2	2	2	1	1,9		0,2
9	Increase in energy service and service providers	3,3	2,8	1	1	1	2	2	0	2	3		2	1	3	1,6		-0,1
10	Increase in energy cooperations	2,4	2,6	2	1	3	3	2	0	2	2	2		0	1	1,6		-0,1
11	Acceleration of technological breakthroughs	4,4	3,9	3	2	3	2	2	2	1	1	2	1		3	2,0		0,3
12	Increasing importance of data	3,9	3,3	2	2	1	1	3	0	2	2	2	1	2		1,6		-0,1
		3,5	2,9															
	Mate waarin trendcluster wordt beinvloed			1,9	1,6	2,1	2,2	1,9	0,2	1,5	2,1	2,1	1,6	1,4	1,7			
	Gemiddelde								1,7									
	Afwijking van gemiddelde			0,2	-0,1	0,4	0,5	0,2	-1,5	-0,2	0,4	0,4	-0,1	-0,3	0,0			

Toelichting op CIM

De cross-impact matrix analyseert de mate van onderlinge afhankelijkheid tussen trendclusters. Deze "cross-impact" wordt bepaald door de mate waarin een trendcluster andere trendclusters beinvloed te scoren op een schaal van 0 tot 3.

Scoring: 0 = geen invloed, 1 = beperkte invloed, 2 = gemiddelde invloed, 3 = veel invloed

Toelichting op scores

Mate van invloed	*Mate van afhankelijkheid*	*Type trendcluster*
Hoog	Laag	Kernonzekerheid (key change driver)
Laag	Laag	Autonome trendcluster
Laag	Hoog	Afhankelijke trendcluster
Hoog	Hoog	Links (linking pin met andere trendclusters)

Appendix D - Summary Results Focus Group

Scenario 1 – 'Power Play'

- Central energy production
- Incremental technological developments

Causes

- Power play between the incumbent energy giants and new entrants, technologies and substitutes.
- Large companies, like Shell for example, lobby for central energy production at a European level.
- There is little to no political urgency to change.
- Incumbent firms defend their own interests, polder a lot and make compromises.
- There are no pricing breakthroughs for decentral energy storage. Central energy storage appears to be more stable. Therefore, decentral energy storage is not attractive.
- Energy production via solar panels appears to be insufficient to meet energy demand. Energy can also not be supplied back to the grid, because this burdens the energy grid.
- Energy is centrally stored.
- Much scale-ups.
- Large companies, like Shell and the Albert Heijn build hydrogen plants. Due to safety issues at the global level this serves as a strategic reserve in an insecure world.
- Consumers can easily switch between energy suppliers. Consumers also switch a lot, this keeps prices low, which makes competition less attractive.

Ecosystem

- The ecosystem is similar to the current ecosystem.
- Data is centrally stored via smart meters.
- Blockchain is not used much. Consortia use blockchain mainly to create entry barriers ('cartel blockchain': think of IBM's Hyperledger as an example of a 'centralised' blockchain.)
- Data is controlled and send via Facebook, Google or another large technology firm. They form a central trusted third party.
- P2P energy trade is restricted as a result of the lobby of the energy giants.
- Google and Amazon could potentially become intermediaries to buy centrally produced energy to sell to clients, or invest in a large scale wind or solar farm themselves to provide energy to the consumers.
- The government does not restrict the above mentioned.

Scenario 2 – 'Power to the Devices'

- Central energy production
- Radical technological breakthroughs

Causes

- Technological breakthroughs make sustainable energy cheaper than fossil energy. Energy can be transported over large distances, even continental. This creates room for large scale, central energy production through the use of solar and wind energy and gas (which can also be used for storage), while using the current infrastructure. The wholesale market offers sufficient flexibility.

- Geopolitical instability encourages West-Europe to become self-sufficient.
- Blockchain enters the wholesale market: clearing and settling becomes unnecessary.
- Wholesale market offers sufficient flexibility.
- Central energy production and power-to-gas solutions allow for the usage of the current energy infrastructure.

Ecosystem

- Free, but traditional energy market: the current energy infrastructure is used intensively.

Critical breakthroughs

- Technological developments make blockchain transactions (close to) zero.

Scenario 3 – 'Power to the People'

- Decentral energy production
- Incremental technological developments

Causes

- Much optimisation of technologies at the consumer level. Small scale energy production and storage becomes more efficient.
- Central systems have become too vulnerable, for example due to cyber-attacks: driver for decentralisation.
- 'Saldering' has been abolished. This makes it less attractive to supply energy back to the grid. As a result, people want to become more self-sufficient: driver for decentralisation.
- More bottom-up initiatives.
- Blockchain has a decentral role: direct transactions between decentral parties/communities.

Ecosystem

- Blockchain is used at a local level. Conditions for energy trade are captured in smart contracts.
- Central rules (or market rules) are captured in smart contracts.
- Blockchain is used to check of people honour their commitments.
- The market model encourages sharing.
- Transparency resulting from blockchain gives opportunities to new entrants: for example multi-utility facilitators, service providers to optimise energy usage.

Critical breakthroughs

- Decentral energy production capacity and flexibility are sufficient to meet energy demand.
- New service providers emerge to optimise the new technologies for energy production, storage and trade.

Scenario 4 – 'Land of Plenty'

- Decentral energy production
- Radical technological breakthroughs

Causes

- Solar energy follows Moore's Law: it becomes cheap and enables to produce an overcapacity. We shift from scarcity to abundancy.
- Breakthroughs in energy storage (does not need to be batteries per se)
- A 'mobile' ecosystem emerges in which cars and drones produce and store energy to supply energy at their arrival at a particular destination. Everywhere in the environment, energy can be produced.
- Everything is direct current: there is no need for balancing anymore.
- Disasters or accidents occur at central power plants. Governments, consumers and firms are anxious to invest in central grids and central production sites.
- Machines and technology become an income for the consumer.

Ecosystem

- There is a shift from economy of scale to economy of networks.
- Machines/robots make established companies less relevant.
- Production and storage takes place decentral and local, and are exchanged P2P.
- Many large, close networks emerge, with many sorts of suppliers.
- The IT network is made as user friendly as possible, consumers are digitally taken care of.
- The blockchain is integrated, open and accessible to everyone to facilitate between demand and supply.
- The blockchain protects data against abuse, big data is used to optimise the open blockchain's efficiency.
- The grid connection monopoly is removed from law: the consumer is free to switch between the local and national grid connectiveness.

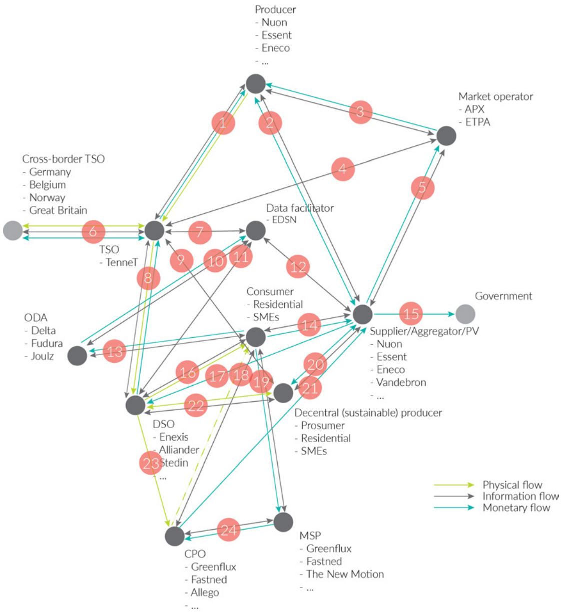
Critical breakthroughs

- There is a 'fool proof' blockchain.
- Today's energy producers and asset and infrastructure owners are under pressure, this results in changes in the energy value chain.
- Energy technology firms play a more important role.
- The infrastructure and regulations allow free choice and switches between the scale of the consumers grid/connection.

Appendix E - Ecosystem Structure Analysis

Current Dutch energy ecosystem

Density

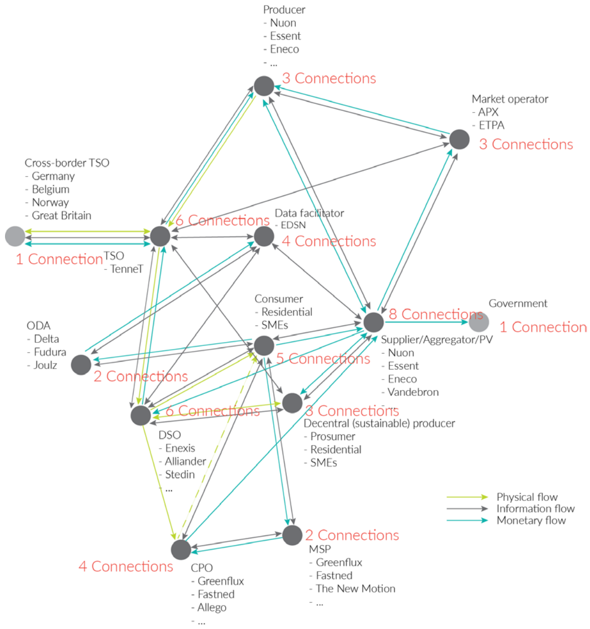


Total ties: 24

Possible ties: 13*12 = 156

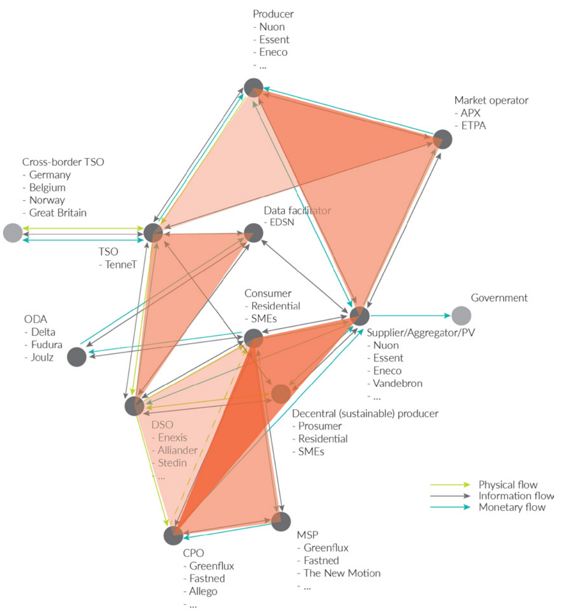
Density: 24/156 = 0,16

Centrality



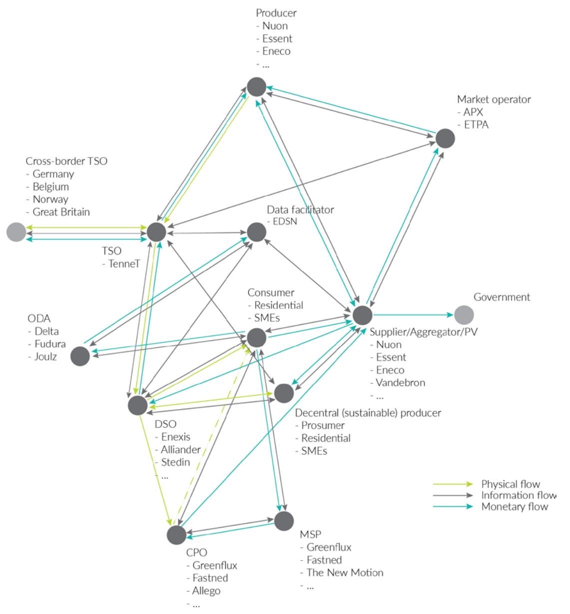
The energy supplier is the most central actor, with 8 connections within the ecosystem. The TSO and DSO are also quite central.

Cliques



Cliques: 6

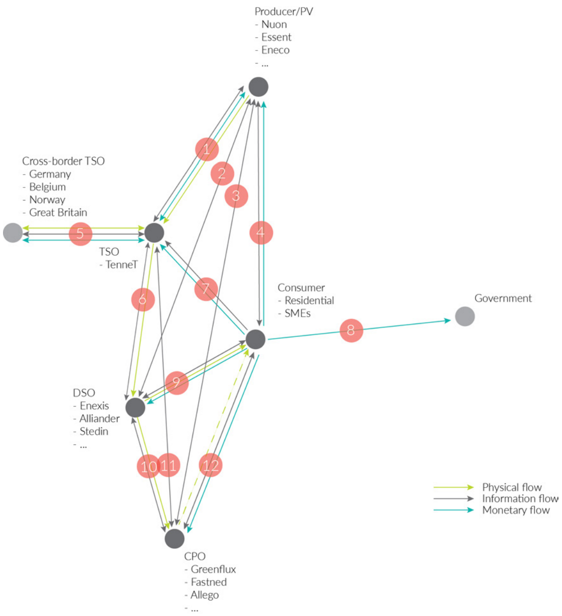
Diversity



Nr. of different functions: 13

Density

Scenario One- Power Play

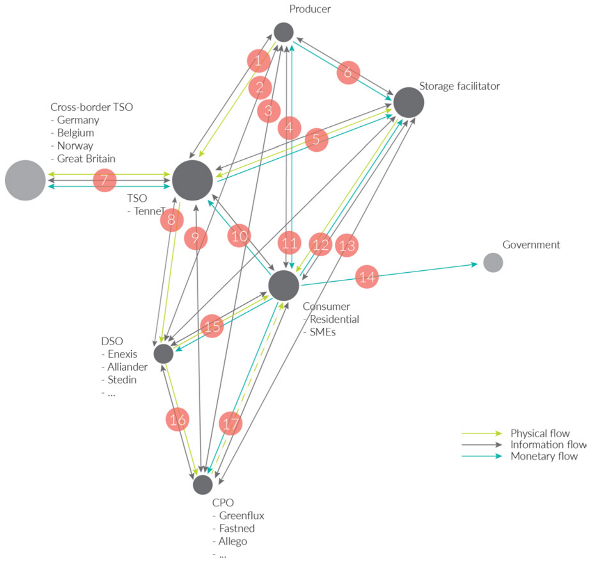


Total ties: 12

Possible ties: 7*6 = 42

Density: 12/42 = 0,29

Scenario Two- Power to the Devices

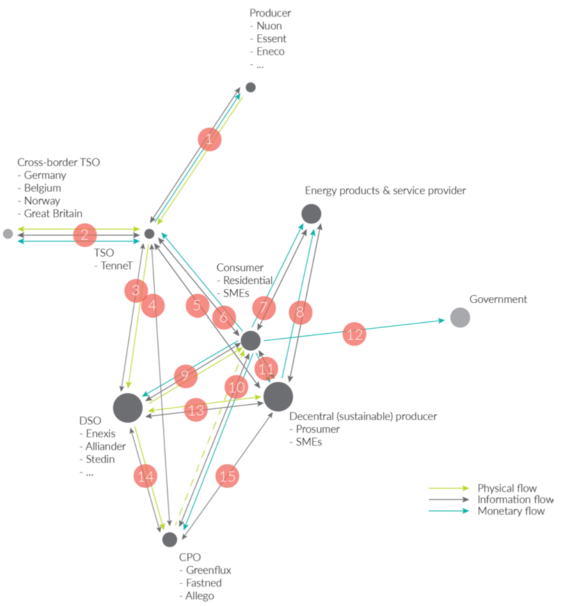


Total ties: 17

Possible ties: 8*7 = 56

Density: 17/56 = 0,30

Scenario Three- Power to the People

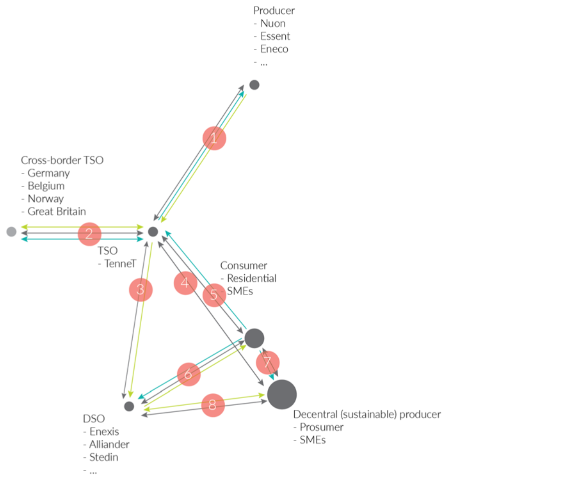


Total ties: 15

Possible ties: 9*8 = 72

Density: 12/42 = 0,21

Scenario Four - Land of Plenty



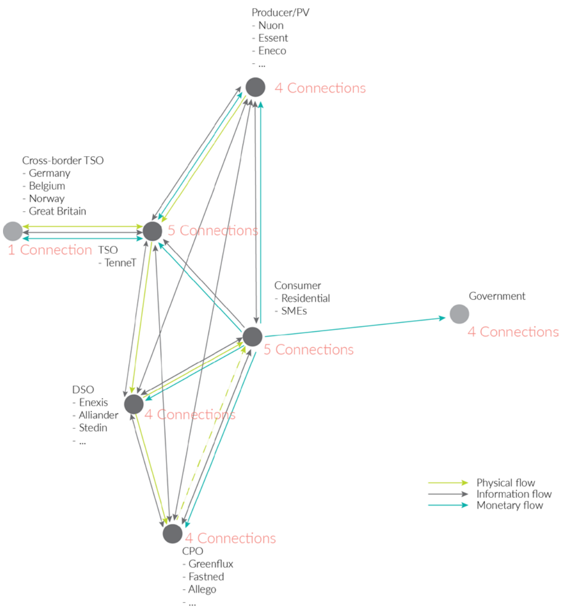
Total ties: 8

Possible ties: 6*5 = 30

Density: 17/56 = 0,27

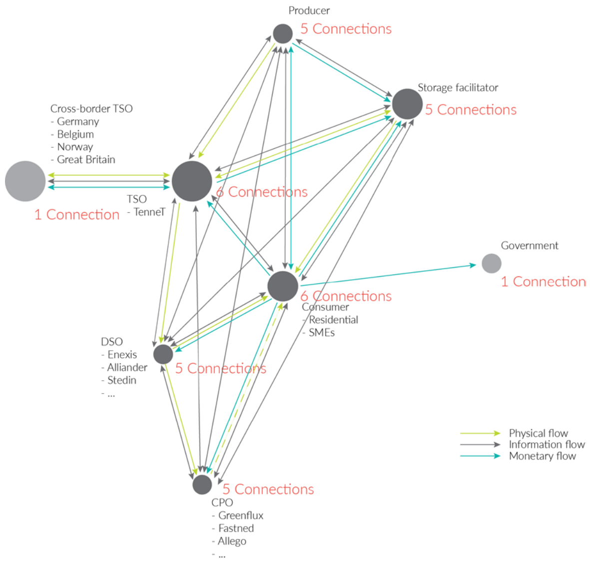
Centrality

Scenario One- Power Play



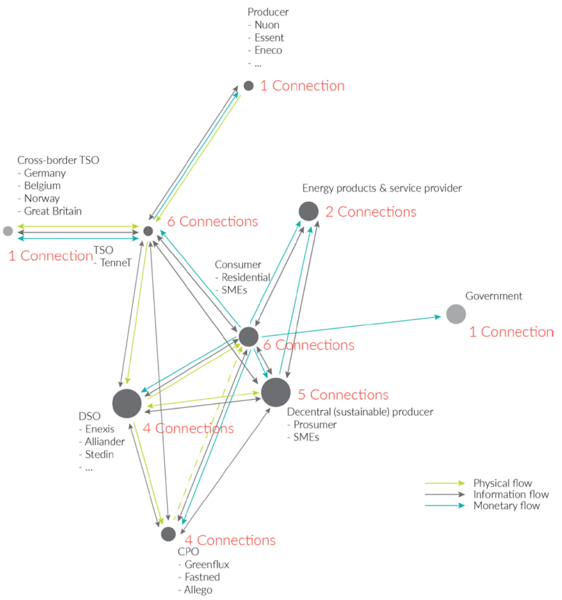
The TSO and the consumer have the most connections, however this is because of their link with the cross-border TSOs, resp. the government. Hence, all nodes can be considered to be equally connected and there is no real central actor in the ecosystem.

Scenario Two- Power to the Devices



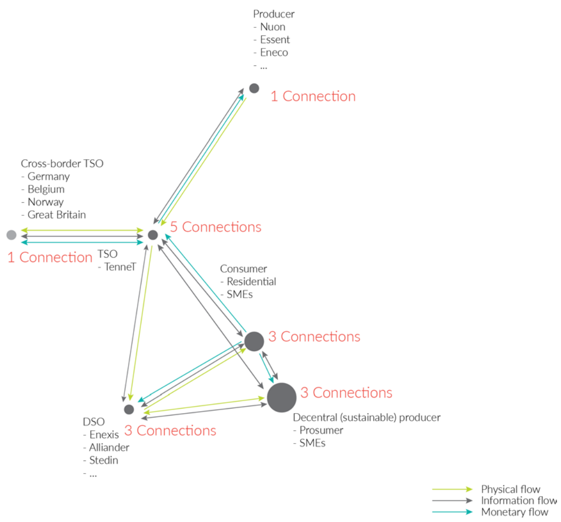
The TSO and the consumer have the most connections, however this is because of their link with the cross-border TSOs, resp. the government. Hence, all nodes can be considered to be equally connected and there is no real central actor in the ecosystem.

Scenario Three- Power to the People



The consumer is slightly more central because of its link with the blockchain network, the government, and the energy products & service facilitator. The TSO has the same amount of connections, but is not seen as central because of its decreased importance .

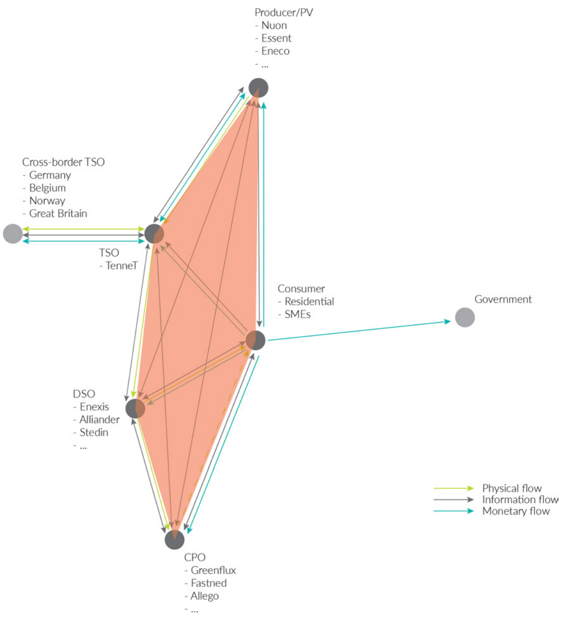
Scenario Four - Land of Plenty



From the model, the TSO can be seen as a central node. However, its importance has decreased in this scenario.

Cliques

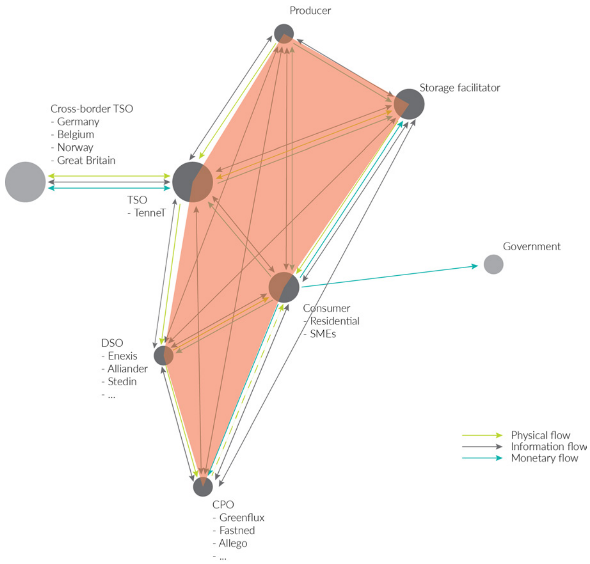
Scenario One- Power Play



Cliques: 1

There is one clique visible, covering all main members of the ecosystem: they are all directly connected with each other.

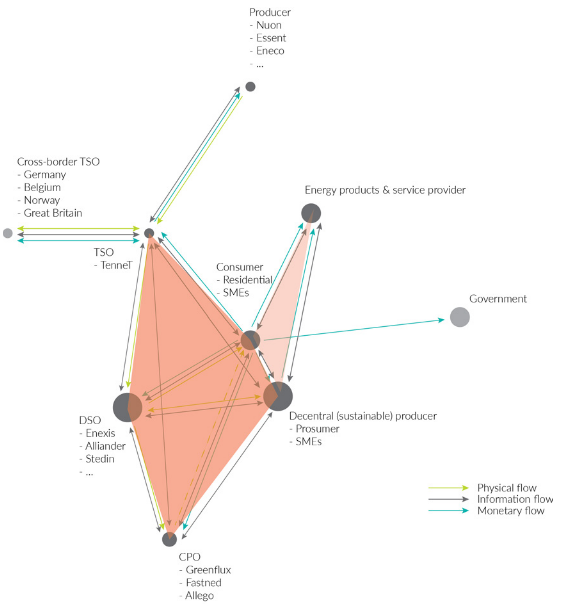
Scenario Two- Power to the Devices



Cliques: 1

There is one clique visible, covering all main members of the ecosystem: they are all directly connected with each other.

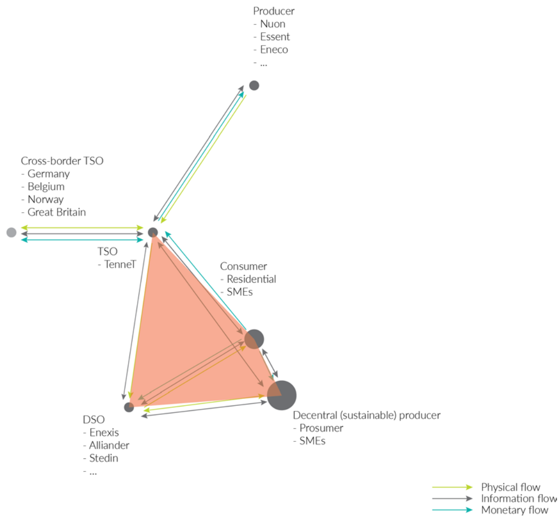
Scenario Three- Power to the People



Cliques: 2

There is one clique covering all main members of the ecosystem, and there is one clique consisting of the consumer, the decentral producer, and the energy products & services facilitator.

Scenario Four - Land of Plenty

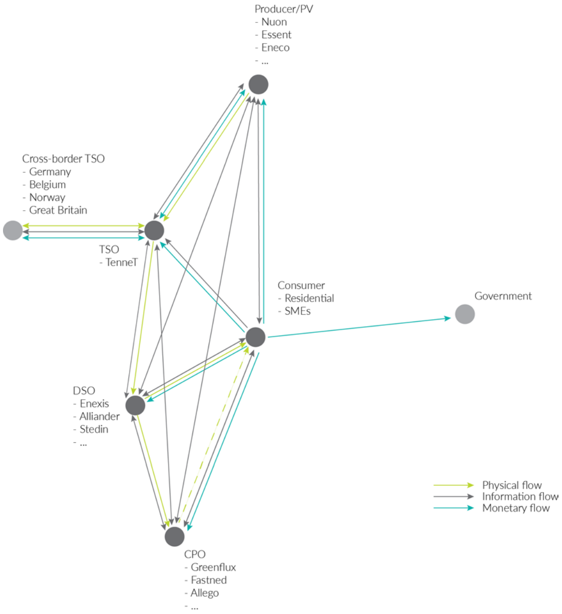


Cliques: 1

There is one clique visible, covering all main members of the ecosystem: they are all directly connected with each other.

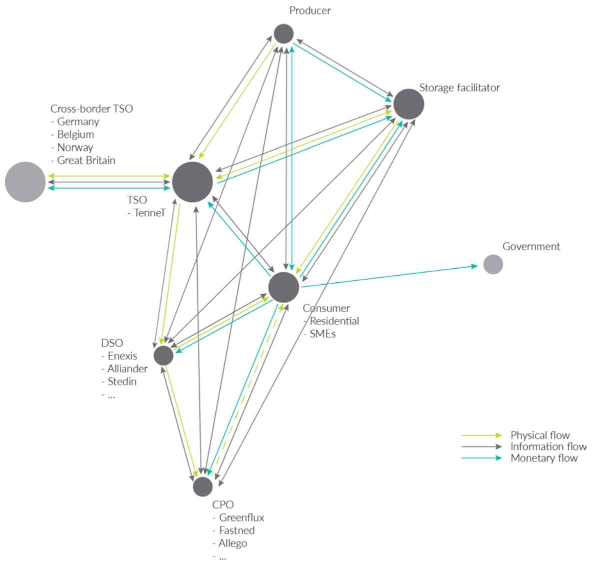
Diversity

Scenario One- Power Play



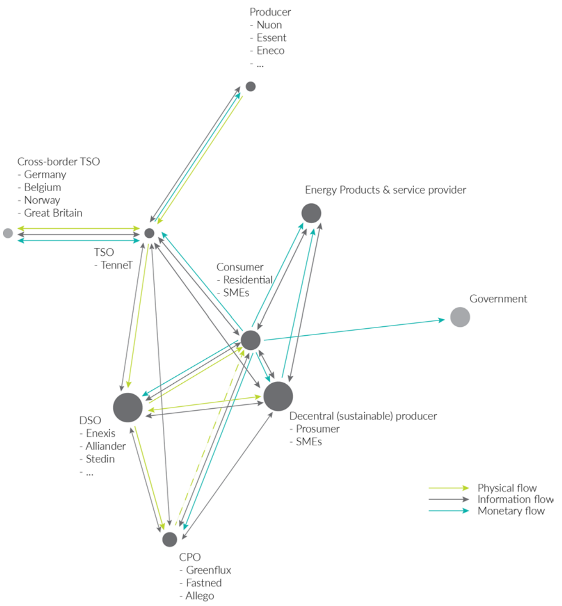
Nr. of functions: 7

Scenario Two- Power to the Devices



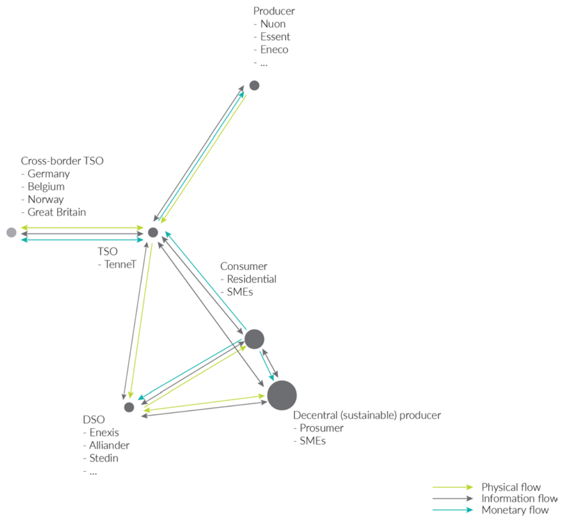
Nr. of functions: 8

Scenario Three- Power to the People



Nr. of different functions: 9

Scenario Four - Land of Plenty



Nr. of different functions: 6