Blockchain as a Solution for Collective Servitization

A case study on Bundles washing machines
and the Circular Service platform

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Master Thesis

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Preface

As a bachelor student in Industrial Design Engineering at the TU Delft, I learned about the design, mechanics, and production methods of products. During those years, what struck me, is that many day-to-day products are made with planned obsolescence in mind. Manufacturers deliberately shorten the lifespan of products to force consumers to buy replacement quicker. A famous example is Apple's deliberate slowing down of older iPhone models with software updates. I also witnessed the destruction of new products at a recycling facility in Eindhoven. I visited the facility on behalf of my internship at KPN. The facility destroyed new printers (from one of the major brands) as they released a newer version on the market. They did not want the older versions to compete with the newer model.

In our current economy, companies have little interest in what we as consumers do with the products. Companies make products to persuade us to buy them. Marketing and striking packaging designs are used to sell a (fake) image of the product. The linear economy has succeeded in making processes from material to product as cheap and efficient as possible. At times, at the cost of harsh labor conditions. Materials are extracted from our earth as if our resources are infinite. The resulting damages to natural habitats and pollution are not paid for by companies.

The moment I realized the unsustainability of our current economy and the mismatched need of consumers and companies, I became passionate about the circular economy. I chose a master that focuses on sustainability; Industrial Ecology. This master thesis explores the topic of collective servitization. It is an idea that aims to change the linear mindset of all the companies within a value chain to a more circular one—a mindset where the goals of the company and the consumer are more aligned.

I want to express my gratitude to Jacky Bourgeois, with whom I have had the pleasure of discussing the topics of collective servitization and blockchain technology. Thanks to Conny Bakker, who suggested this topic to me in the first place and who provided valuable perspectives and feedback. At last, thanks to Rene Kleijn, who without, this thesis would not have been possible.

List of Abbreviations

Circular Service Platform (CiSe)

Collective Servitization (CS)

Product-Service System (PSS)

Circular Economy (CE)

Distributed Ledger Technology (DLT)

Sustainable Finance Lab (SFL)

Business to customer (B2C)

Sustainable Finance Lab (SFL)

Ellen MacArthur Foundation (EMF)

Community of Practice (COP)

If This Than That (IFTTT)

Peer-to-peer (P2P)

Industrial Ecology (IE)

Internet of Things (IoT)

Abstract

The circular economy is an economic system that aims to replace the linear economy and the accompanying take-make-dispose mindset. It is an economic system that decouples economic growth from finite resource consumption. The Sustainable Finance Lab (SFL) identified two requirements for a high state of circularity. 1) Products are serviced instead of sold and 2) the entire life-cycle of products must be considered. As a solution, the SFL came up with the idea of collective servitization (CS). It meets the previous requirements by aligning the incentives of all the value chain participants involved in a product-service system by compensating each of them as long as the product is in working condition. However, the SFL predicted four implementation barriers related to CS. The SFL expects 1) a need to share innovation costs, 2) high administration costs, 3) increasingly complex devision of ownership, and 4) a need to directly handle micro-transactions. To help overcome CS challenges, the SFL conceptualized the Circular Service (CiSe) platform. It is an administration tool for collectively serviced pay-per-access and pay-per-use products. It uses the novel technologies blockchain, cryptocurrency, and smart contracts to overcome three out of the four challenges. 1) The CiSe platform reduces transaction costs by automatically handling product use and access payments without an intermediary. 2) The CiSe platform stores the transactions of use and access in a distributed database that is publicly accessible. By viewing all the payments and costs, the SFL expects that companies can better decide on responsibilities. At last, 3) micro-transactions are made possible with the Micro-Euro.

From an IE perspective, the use of blockchain technology is fascinating. Engineering, environmental, and social perspectives are crucial for the successful and sustainable implementation of new technologies. These technologies (combined) have a wide range of technical applications. The question is if these technologies are effective in overcoming CS. In order to get initial insights into the effectiveness of blockchain technology in implementing collective servitization, this master thesis focuses on the company Bundles and their combined pay-per-access and pay-per-use washing machines. The following research question will be answered:

"How effective could the Circular Service platform implement collectively serviced Bundles washing machines?"

To address this question this thesis used a threefold structure. It consisted of a literature study that identified 51 blockchain designs in the literature and multiple papers oriented on both blockchain and the circular economy and blockchain and product-service systems. These provided insights into the problems and need for CS, insights into the solutions of the CiSe platform and their technical viability, as well as insights into additional challenges for the CiSe platform. Moreover, a business analysis identified 32 blockchain companies. These provided more insights into the technical viability of the CiSe platform. Finally, a case study explored collectively serviced Bundles washing machines on the CiSe platform. The primary stakeholder Miele and Vonk en Co were included in the CS business model. The case study helped identify additional opportunties and challenges of CS and the CiSe platform.

The results of this study are not straightforward and mainly raise questions for additional research. This is largely because of the conceptual nature of CS and the CiSe platform. There are some promising results and some challenges related to the effectiveness of the CiSe paltform.

There is some economic potential as the transactional relationship, the cost for added value, and the administration cost for revenue disappear. By spreading the initial investments amongst multiple stakeholders the barrier for entry for Miele and Vonk en Co can become lower.

However, It is improbable that a collectively serviced Bundles washing machine with Miele and Vonk en Co will happen. It is for three reasons. Bundles will lose their role as risk-taker, and Bundles does not provide any additional value. Furthermore, Miele has the resources available to do the washing machine service themselves. Finally, Miele and Vonk en Co currently have a profitable collaboration with Bundles without long-term risks.

Additional challenges are related to the use of blockchain technology. First of all, there is a problem with the flexibility of blockchain systems. Once live, blockchain systems and their smart contracts can not be altered. It can become problematic with a collectively serviced washing machine that is intended to be long-term. Moreover, the vulnerability of the system moves to the sensors. Due to the autonomous and automatic nature of the CiSe platform, a faulty or hacked sensor can wrongfully activate transactions. Furthermore, blockchain systems can generally only handle low transaction volumes. The CiSe platform's scale is dependent on the number of products and the types of products that are going to be serviced.

The main limitation of this study is in its conceptual and explorative nature. It is due to four reasons. Firstly, there is no support of the definition of CS in literature. Secondly, no direct comparison could be found of the CiSe platform concept either. Moreover, the results from the two systemic literature reviews were mainly conceptual papers. Finally, the case study is explorative. All in all, this means that these results are not final. They are indicative and more research is necessary to determine the effectiveness of the CiSe platform in overcoming CS barriers.

To move the development of the CiSe platform forward, it is essential that the need for and problems of CS are researched more thoroughly. The case study revealed that CS is not for every value chain. If there is no need for CS, then the CiSe platform is irrelevant. If the CiSe platform does not address the right barriers of CS, the same fate awaits. It is advised to prioritize research into CS before developing the CiSe platform further.

Table of Contents

Introduction

Chapter 1

Introduction

In this chapter, I will provide the context of this master thesis. I will introduce the concept of collective servitization and the Circular Service platform. I will describe the problem definition on which I based my research questions and describe the research approach.

1.1 Context

Industrial Ecology (IE) is a scientific discipline that takes a systemic approach to sustainability problems. It regards engineering, social, and environmental perspectives to be essential for sustainable development. The circular economy (CE) is a concept that touches on all three perspectives of IE. CE is an economic system that aims to replace the linear economy and the accompanying take-make-dispose mindset. It is an economic system that decouples economic growth from finite resource consumption (EMF, 2013). Besides economic sustainability, the CE promises social and environmental sustainability (Korhonen et al., 2018).

To achieve a high state of circularity, the Sustainable Finance Lab (SFL) identified two requirements:

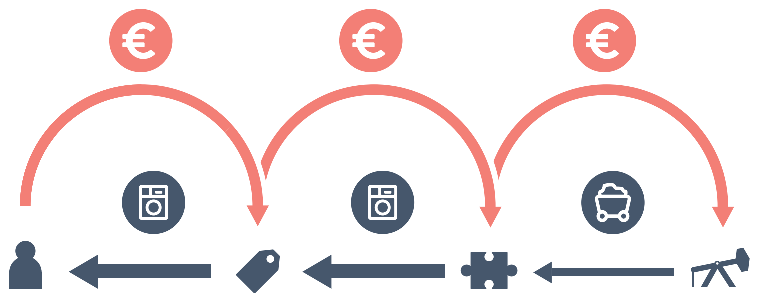
1. Products are serviced instead of sold.
2. The entire life-cycle of products must be considered.

Servicing products are referred to in the literature as product-service systems (PSS). They are a mix of tangible products and intangible services. Examples of PSS business models are pay-per-use and pay-per-access (a detailed explanation will come later). With these business models, service providers retain ownership of the product and receive revenue for as long as the product is in working condition. It stimulates circular behavior, such as resource-efficiency and product longevity.

Regarding the second requirement, companies must consider a product's circularity during each phase of its life cycle for a truly circular economy. During pre-use, products have to be designed optimally for the CE (such as the use of recyclable materials, durable materials, and design for repair). During the use-phase, companies should extend the useful life of products for as long as possible. Finally, products have to re-enter the system at the end-of-life (waste is food).

To address these requirements, the SFL invented collective servitization (CS). The goal of CS is to integrate as many stakeholders of a service within a PSS business model. When more stakeholders are stimulated to be resource-efficient and extend product longevity, the SFL expects a high state of circularity. The more stakeholders that are incentivized to think circular, the better. Different stakeholders also have different roles within the value chain and different influences on a product's life-cycle. The SFL expects that CS improves the recycling, repair, and remanufacturing of products. These processes are necessary to have products re-enter the system. While CS is likely to stimulate collaboration, it is not the same as collaborative servitization. Collaborative servitization is characterized by collaboration with customers and external partners through knowledge, capabilities, and resource sharing. (Polova & Thomas, 2020). CS is distinct in how stakeholders invest and receive and share revenue. An additional benefit of CS is that companies share the initial capital investment costs, which reduces risk.

To better understand how the SFL expects CS to provide circular benefits, I illustrated and compared a linear business model with a pay-



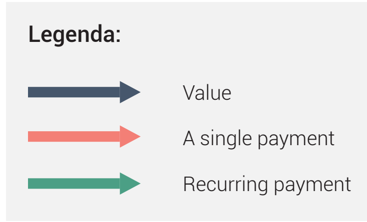


Figure 1.1a

A linear sales business model
Starting from the right, the material supplier harvests materials and sells these to the manufacturer. The manufacturer pays the material supplier an amount depending on the quality and type of material. The manufacturer adds value (indicated by a thicker arrow) by constructing and assembling a washing machine from these materials. Following, a retailer sells the washing machine to a consumer. The consumer pays the full price for the product in return for complete ownership of the product. Within such a linear sales model, all the value chain stakeholders only receive revenue when they sell products. It incentivizes them to sell as many products as quickly as possible. It is in sharp contrast to the principles of the circular economy.

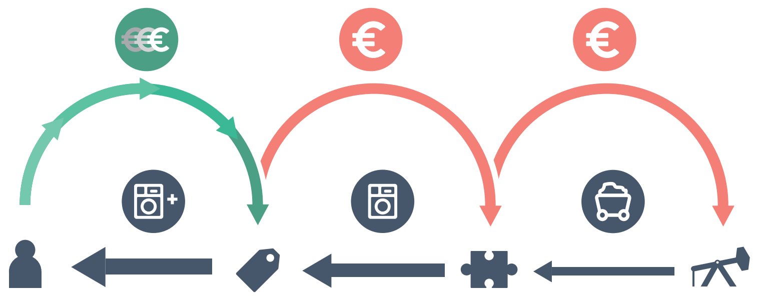


Figure 1.1b

A pay-per-use or pay-per-access business model
The service provider adds services along with the product, creating a PSS. Examples of such intangible services could be a working product guarantee and 24/7 customer service. These services add even more value to the product (indicated by a thicker arrow). In this example, the service provider receives recurring payments from the user, as long as users can access or use the washing machine. As long as the product is in working condition, the service provider can make a profit. This notion incentivizes the service provider to extend the working life of their products. The mindset shifts from a linear sell fast sell mindset to a circular one. However, with pay-per-use and pay-per-access business models, stakeholders in the value chain still follow a linear sales model and are stimulated to sell as much as possible. Ideally, these stakeholders are stimulated to behave circular as well.

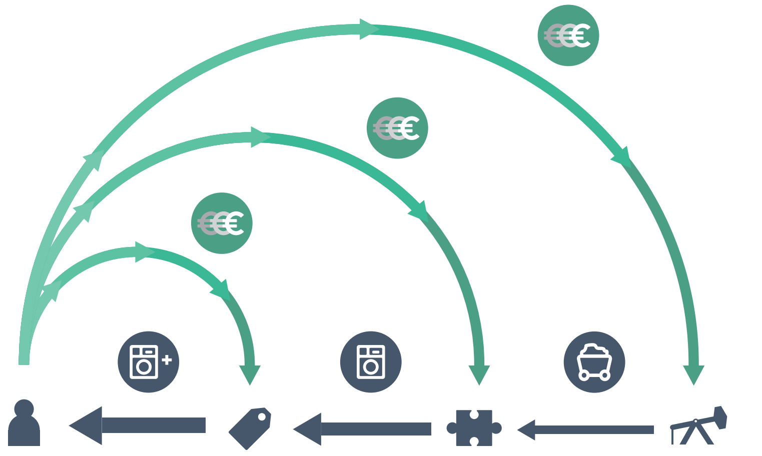
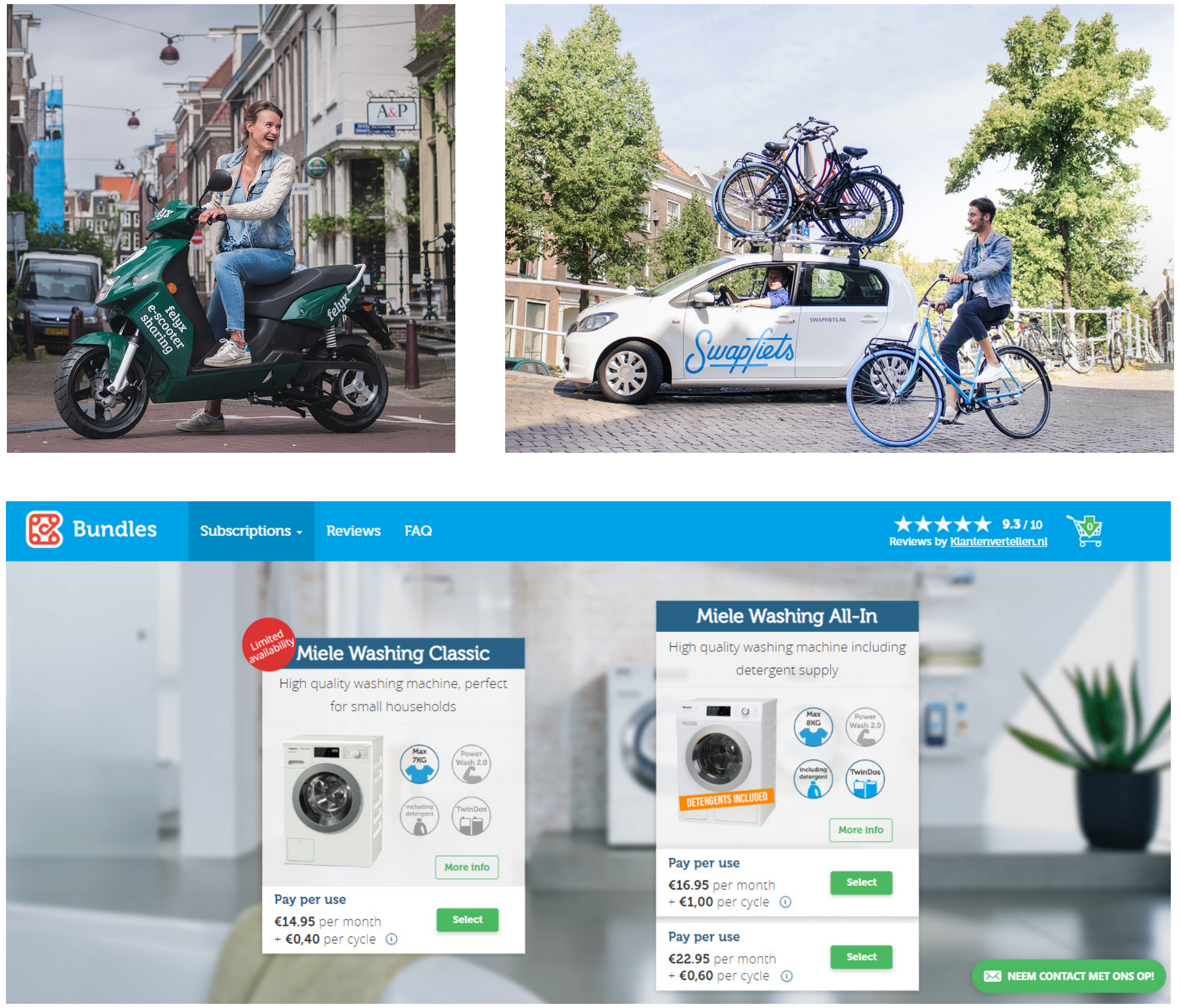


Figure 1.1c

A collective servitization business model
With CS, the linear sales model disappears for each of the companies that join the collective business model. Companies still provide components, materials, and services related to the PSS. However, with a CS business model, the service provider and other stakeholders receive recurring revenue for as long as consumers have access to- or use the product. Companies are not incentivized to sell fast and sell more. Instead, the SFL expects that each of the participants in a CS business model behaves circular.

per-access/pay-per-use business model and a CS business model (figure 1.1). An example of a pay-per-use and pay-per-access business model are the washing machines from the company Bundles. Bundles sells convenient high-quality laundry experiences. They add care-free services on top of the washing machine, such as home delivery, installation, and pick-up. The washing machines are both pay-per-use and pay-per-access. With pay-per-access, consumers pay for access to a product, often in periodic (weekly, monthly, and yearly) payments (another example is the company Swapfiets and their pay-per-access bicycles). As long as users of the service have access to the washing machines, they pay a monthly fee to Bundles. With pay-per-use products, consumers pay the service providers an amount related to how much they have used it (Another example is the company Felyx and their pay-per-use electric scooters). Additionally, users of Bundles washing machines pay a small amount for each time they use the washing machines. With such business models, the service providers (Bundles, Felyx, and Swapfiets) only receive revenue for as long as consumers have access to- or use the product. This notion incentivizes companies to maintain the product in working condition for as long as possible—decoupling economic growth from resource consumption.

Figure 1.2: Felyx's electric pay-per-use scooters (top left), Swapfiets' pay-per-access bicycles (top right), and Bundles' combined pay-per-use and pay-per-access washing machines (bottom)



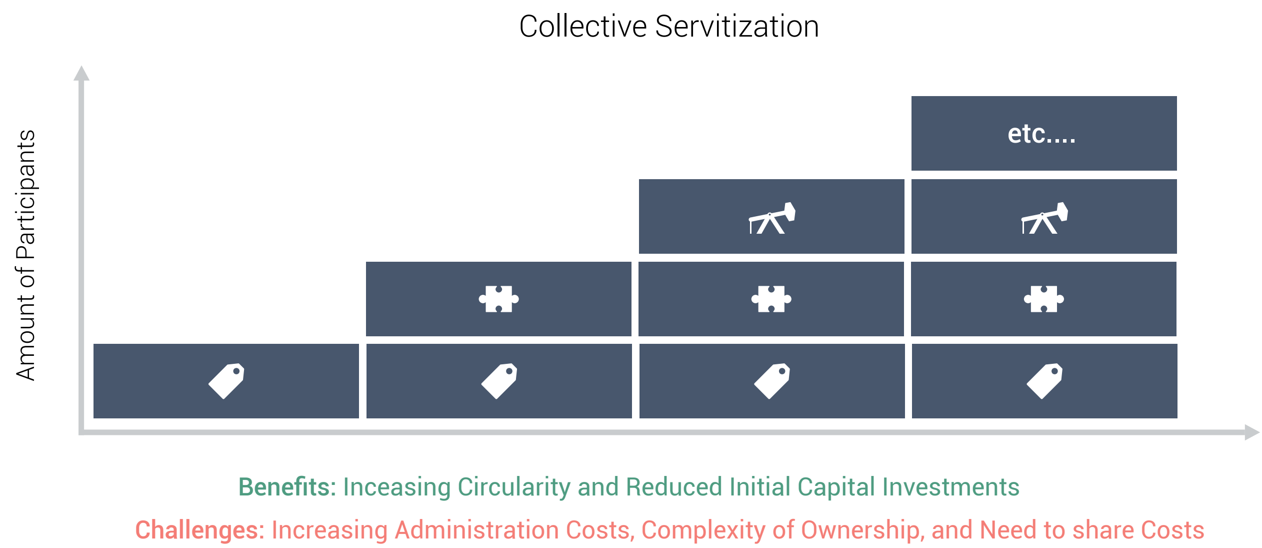
However, stakeholders in the value chain still follow a linear sales model (see figure 1.1b). Their purpose remains to sell as much as possible. For example, the manufacturer in a value chain only receives revenue when they sell a product (a washing machine, bicycle, or scooter) to the service provider (Bundles, Swapfiets, and Felyx). It still incentivizes these manufacturers to have a linear sell fast sell more mindset. This mind-set stimulates companies to use more resources to get more revenue.

With CS, the SFL hopes to include as many companies into the same "circular" mindset. CS achieves this by incorporating multiple companies into the PSS business model. The linear sales model disappears for each of the companies that join the collective. Companies still provide components, materials, and services related to the PSS. However, with a CS business model, the service provider and other stakeholders receive recurring revenue for as long as consumers have access to- or use the product (see figure 1.1c).

The SFL predicts four problems that will hinder the implementation of CS:

1. The SFL argues that there is a need to share innovation costs. A successful innovation by one stakeholder, who takes the risk of paying for the innovation, will result in a better product or service and more revenue for all collective participants.
2. With more participants, the complexity and costs of administration will grow too.
3. The SFL emphasizes that the responsibilities become increasingly complicated when more members join. Instead of one service provider who has full ownership over their products, multiple members become part of the service and are partially responsible.
4. The SFL expresses a need for micro-transactions in the case of short moments of use (for instance, paying for a minute of lighting). It is preferred to handle micro-transactions directly instead of using a costly intermediary, such as a bank, who handles the transactions in bundles.

Figure 1.3:
Collective Servitization: increasing benefits and challenges with more participants in the business model



As a solution to these problems, the SFL conceptualized the Circular Service (CiSe) platform. In its current design, the SFL claims to solve three out of the four identified problems. The platform is still in ongoing development, and changes and additions are expected to happen. The next two paragraphs will explain the CiSe platform design as it currently stands (October 2020).

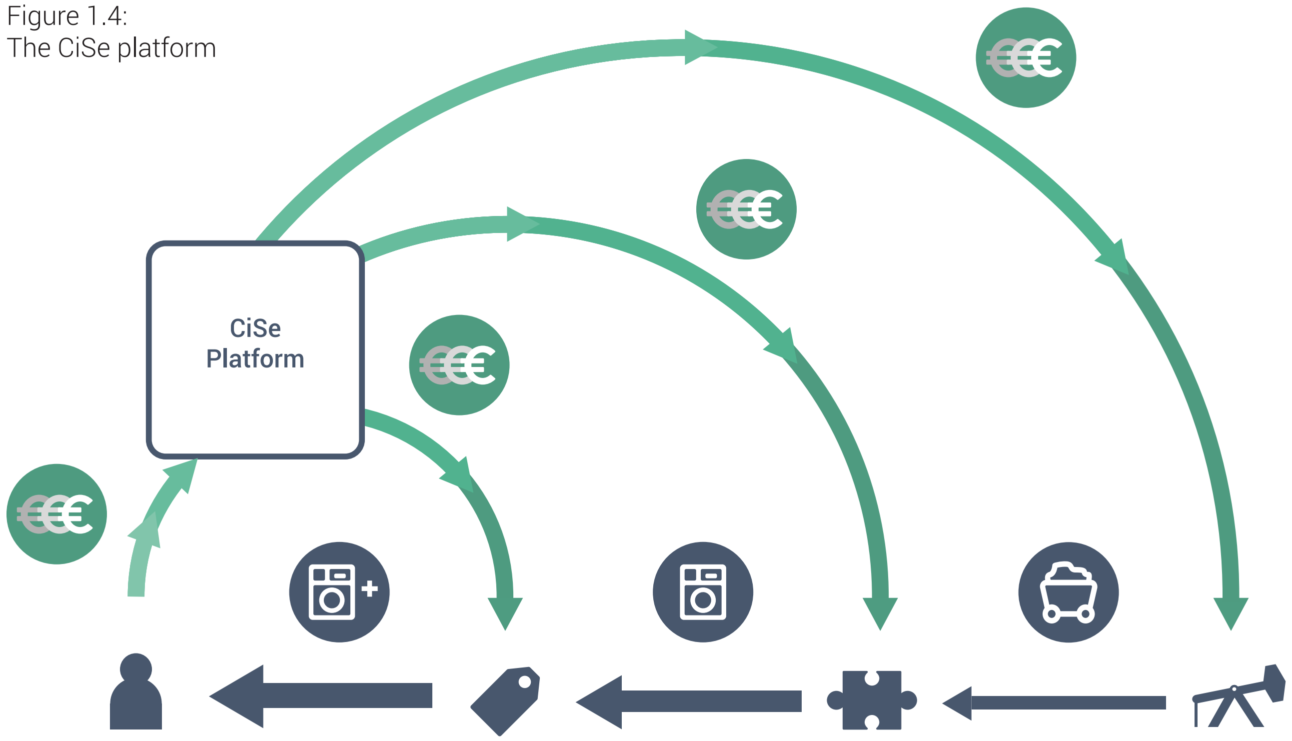
The SFL describes the CiSe platform concept as an administration tool for collectively serviced pay-per-access and pay-per-use products. The SFL mentions several benefits:

1. The CiSe platform reduces transaction costs by automatically handling product use and access payments without an intermediary.
2. The CiSe platform stores the transactions of use and access in a distributed database that is publicly accessible. By viewing all the payments and costs, the SFL expects that companies can better decide on responsibilities.
3. Micro-payments (below 0.01 cents) are possible. A digital currency called Micro-Euro is used and allows for individual micro-payments without a costly intermediary.

The CiSe platform uses the novel technologies blockchain, smart contract, and cryptocurrency. The blockchain stores transactions of use and access securely and transparently. Smart contracts store the rules and conditions of how the collective members want to divide these transactions. When a product senses use or when paying for access is due, the smart contracts trigger a transaction and distribute it to the different CS stakeholders. Unique is that these technologies do not need an intermediary "controlling" party. SFL expects that this drastically reduces administration costs. The blockchain database is publicly accessible and simultaneously secure and immutable (changing stored data is almost impossible). Because of this, anyone can confirm that they received or paid what they agreed on. For the collective members, the SFL expects this will help in deciding on responsibilities. The CiSe platform uses the cryptocurrency micro-euro as the digital medium for exchange. It can be divided into infinitely small amounts.

Figure 1.3 illustrates the CiSe platform within a CS business model. When a product senses use or when paying for access is due, the CiSe platform automatically triggers a transaction from the users' digital wallet. It divides the transaction amongst different members in the CS business model that have contributed to the PSS.

Figure 1.4:
The CiSe platform



Users experience the CiSe platform as a web or phone application. While still in development, the CiSe platform's goal is to provide consumers and service providers with different interfaces. The CiSe app will likely have an online shop with various collectively serviced products to choose from for consumers. When they opt for a service, they can link the product to their account by scanning its barcode. Attached to their account is a digital wallet that displays their micro-euro balance and an overview of their payments. Due to the use of blockchain technology, consumers have a transparent overview of where their money goes. Service providers will have access to a dashboard with information related to all their serviced products. Blockchain technology provides a detailed overview of every serviced product, how much it made, and who earned what.

Overall, the CiSe platform concept is a solution to the implementation barriers of CS. Figure 1.5 illustrates an overview of the origin of the CiSe platform. The CiSe platform and CS are both a concept and idea that need research. It is uncertain if the CiSe platform can overcome CS implementation barriers. If companies are willing to start a CS business model is not yet sure either. The next chapter explores such questions and other alike.

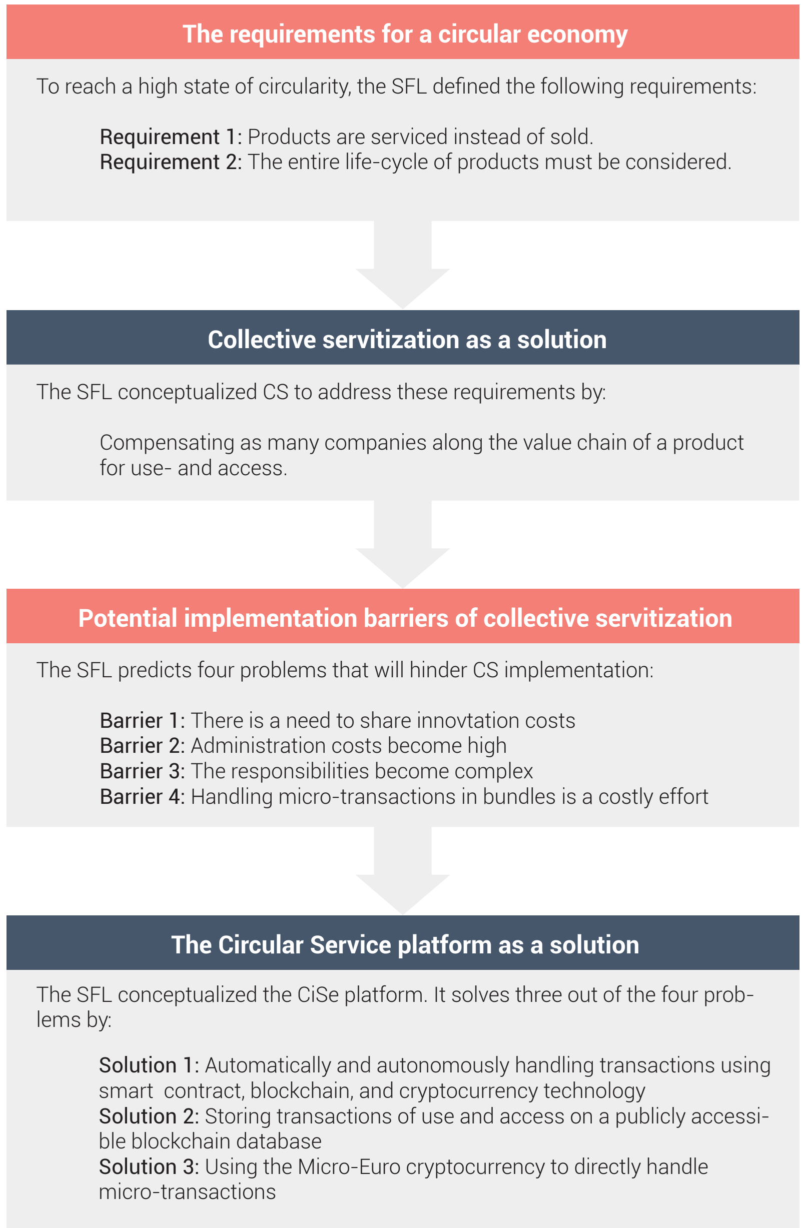


Figure 1.5:
The origin story of the CiSe platform

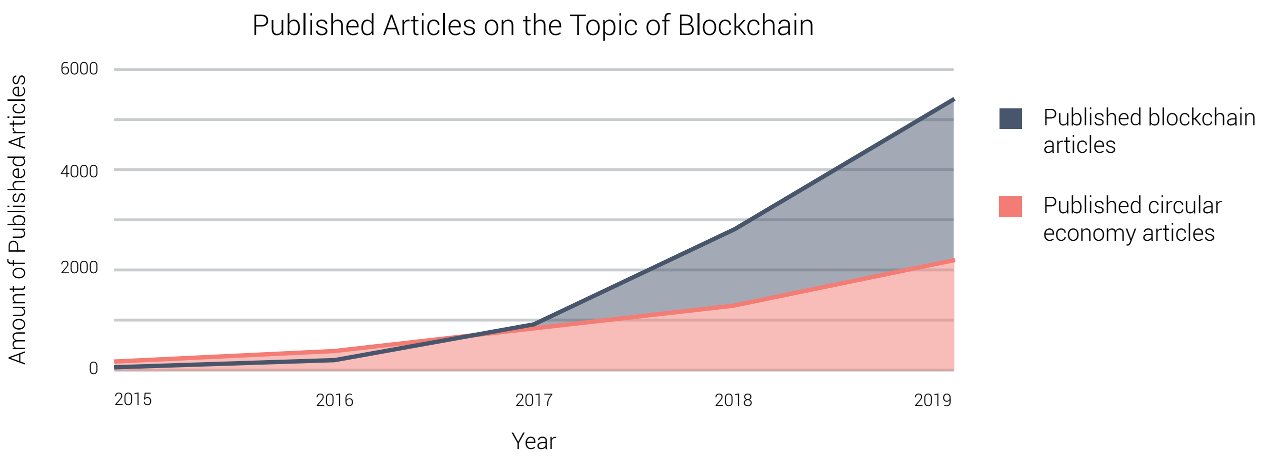
1.2 Problem Definition

From an IE perspective, the use of blockchain technology is fascinating. Engineering, environmental, and social perspectives are crucial for the successful and sustainable implementation of new technologies (Lifset & Graedel, 2002). There is an increasing amount of attention on blockchain amongst companies and scholars. For instance, IBM has invested over $200 million in the technology and hired 1000 staff members in blockchain research (Carson et al., 2018). Large companies such as Walmart, Alibaba, Toyota, and UPS are experimenting with blockchain technology (Kouhizadeh et al., 2020). Figure 1.6 shows the number of blockchain articles published from 2015 to 2019 compared to CE articles. The keywords "blockchain" and "circular economy" were used in the scientific search engine Scopus. The total number of published papers on blockchain technology is significant and was well over 10,000 as of April 2020. Scholars have researched blockchain technology in many different subject areas, such as digital payments, supply chain management, transport, logistics, and voting (Hughes et al., 2019).

Research of blockchain technology into the CE and PSSs is scarce. While there are many potential use-cases for blockchain within the CE, Kouhizadeh et al. (2019) emphasize a need for more research. According to Paschou et al. (2020), blockchain technology has not been addressed in digital servitization literature, even though it has relevant potential. Similarly, Huang et al. (2019) mention that blockchain has much promise in PSSs and that more research is necessary. Regarding PSS and CE literature, research into the CiSe platform can contribute valuable information.

For the CiSe platform to be widely adopted and sustainable, it has to have positive results in each of the IE perspectives. It means that the CiSe platform has to be both technically and socially sound. It raises questions such as; can the CiSe platform reduce transaction costs? Can it provide a secure and transparent database? Can it directly handle micro-payments? The technology also has to work within the current technological landscape and has to be scalable and interoperable with other systems for significant impact. Other questions are related to the social acceptability of such technologies. Can the CiSe platform be adopted and be used by people? Regarding CS, does it significantly stimulate circularity (compared to normal PSS or linear sales business models), and are companies open to starting a CS business model? Figure 1.6 shows the different IE perspectives with each of the previously mentioned questions in the corresponding perspective. For the CiSe platform to be viable and sustainable, it must have positive results in all three areas.

Figure 1.5:
Published articles on the topic of blockchain techology and the circular economy

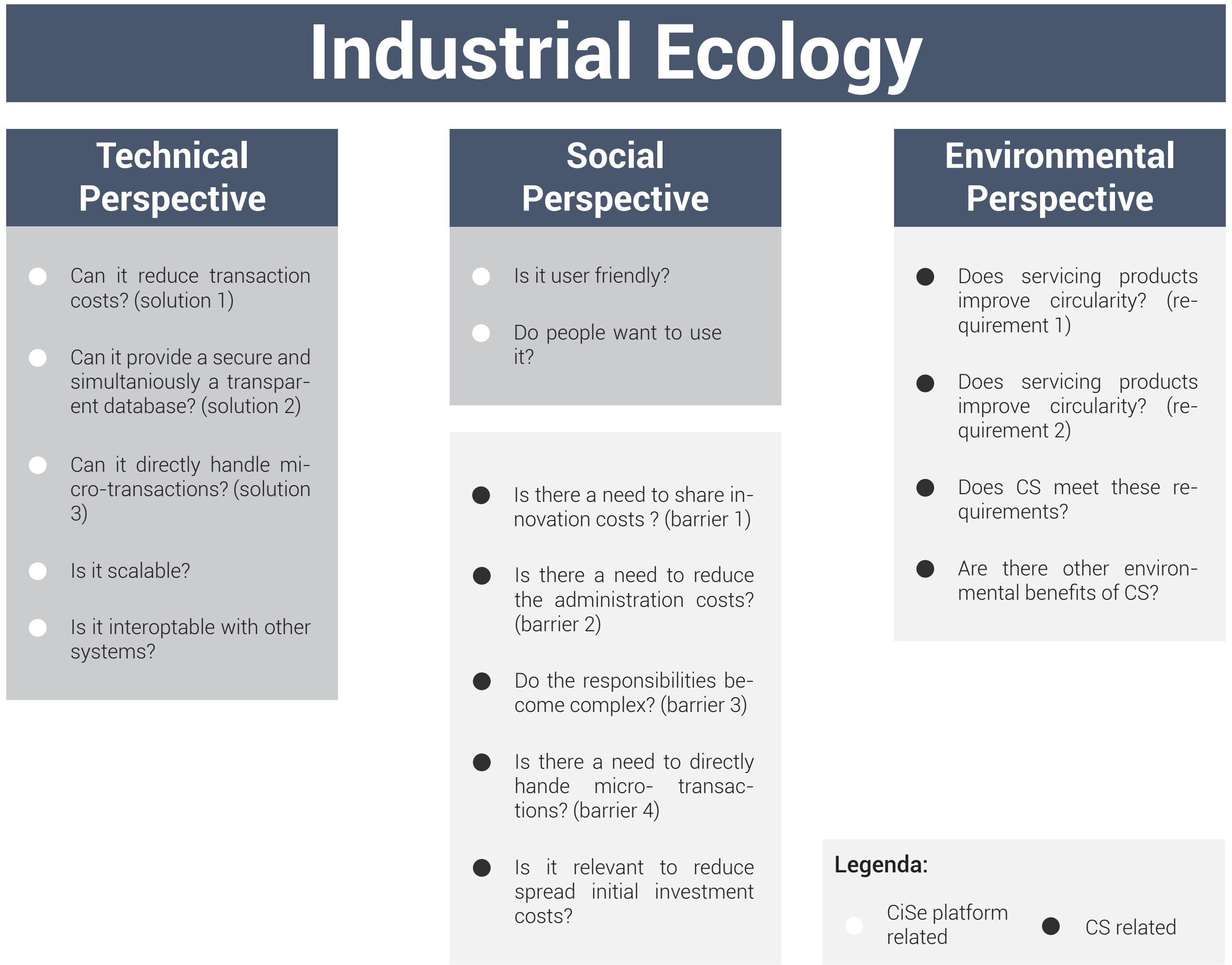


Research into the CiSe platform can provide valuable information on how blockchain can stimulate circularity. Since the platform and CS are still conceptual, it is necessary to get more information. This results in the following problem definition:

"The Circular Service platform uses technologies such as blockchain, smart contract, and cryptocurrency to overcome implementation barriers in collective servitization business models. However, success of the Circular Service platform will remain on its technical and social viability and the social and environmental need and benefits of collective servitization."

To address this issue requires research into the state/development of blockchain in other scientific fields. These might provide valuable information. Research into companies can also provide information on how blockchain applications are implemented and how successful and mature blockchain technology is. An exploratory case study can also help define questions and hypotheses for future research and provide more in-depth insights on how CS and the CiSe platform might be implemented. The pay-per-use and pay-per-access washing machines of Bundles can function as an interesting case study. The Bundles washing machines have been used to test software demos of the CiSe platform. This notion should make it easier to research and validate the case with the SFL as they are already familiar with the company. The next few sub-chapters (chapter 1.3 to 1.6) will explain the research questions, scope, and the thesis approach and methods.

Figure 1.6: Questions related to each IE perspective



1.3 Research Questions

In order to give insights into the previously defined problem, this thesis focuses on the implementation of the CiSe platform and CS in the context of Bundles' pay-per-use and pay-per-access washing machines. This results in the following research question:

"How effective could the Circular Service platform implement collectively serviced Bundles washing machines?"

To answer this research question, the statements made by the SFL regarding the requirements for a high state of circularity, the challenges of and need for CS, and the solutions of the CiSe platform will be researched. These are each related to the three perspectives of IE. The following sub-questions are formulated:

1. How are the Sustainable Finance Lab's defined circularity requirements and collective servitization problems described amongst the product-service system and circular economy literature?
2. How do the Circular Service platform's solutions compare to blockchain designs in literature?
3. How are the Circular Service platform's solutions described amongst blockchain and circular economy- and blockchain and product-service systems-oriented literature?
4. How do companies' blockchain designs compare to that of the Circular Service platform?
5. How do the Circular Service platform and collective servitization affect the Bundles' washing machine service?

1.4 Research Scope

To address the research questions, this thesis will explore blockchain, CE, and PSS literature, study a range of blockchain companies, and perform a case study on the Bundles washing machine service that includes the primary stakeholders Miele and Vonk en Co.

1.5 Cooperation with the Sustainable Finance Lab

Through April and May, I had an internship at the SFL. Due to the surge of COVID-19, I could not physically attend the SFL office and meetings. The internship was also made part-time. Despite these circumstances, the internship provided useful information. It provided a great opportunity to discuss the latest developments of the CiSe platform with the SFL and attend several meetings to discuss new ideas. This master thesis was conducted independently of SFL.

1.6 Thesis Approach

This study follows four steps:

1. A **literature study** on blockchain technology, the CE, and PSS
2. A **business analysis** of companies and start-ups that focus on blockchain-based applications
3. A **case study** on a collectively serviced Bundles washing machine with Miele and Vonk and Co
4. An **evaluation** of the research that includes a discussion, conclusion, and recommendations

Figure 1.6 provides an overview of these four steps and their corresponding chapters.

Figure 1.6: Outline of this master thesis

I. Literature Study
Goal: to provide background information on the CE, PSS, and blockchain technology, compare blockchain concepts in literature with the CiSe platform, and to review blockchain literature related to the CE and PSS
- Chapter 2: Background study — *Answer to sub-question 1*
- Chapter 3: Literature Review — *Answers to sub-question 2 & 3*

II. Business Analysis
Goal: to provide background information on the maturity of blockchain technology, to understand how companies use the technology, and to understand how successful they are
- Chapter 4: Blockchain Desk Research — *Answer to sub-question 4*

III. Case Study
Goal: to assess the viability of introducing CS and the CiSe platform in a specific case
- Chapter 5: Bundles Case Study — *Answer to sub-question 5*

IV. Evaluation
Goal: to present final discussions, conclusions, and recommendations
- Chapter 6: Discussion
- Chapter 7: Conclusion — *Answer to main research question*
- Chapter 8: Recommendations

I. Literature Study

The goal of this step is to answer the first three sub-questions. These will give insights into a need for CS (social perspective), the occurrence of CS problems (social perspective), and the viability of the proposed CiSe platform solutions (technical perspective).

The literature study consists of a background study (chapter 2) on blockchain technology, the CE, and PSS and a literature review (chapter 3) on blockchain concepts and papers that focus on blockchain technology in the context of the CE and PSS.

Chapter 2 answers **sub-question 1**:

"How are the Sustainable Finance Lab's defined circularity requirements and collective servitization problems described amongst the product-service system and circular economy literature?"

The background study followed the snowball method and keyword searches in scientific search engine Scopus such as "blockchain", "distributed ledger technology", "circular economy, "PSS", "product-service system", "product service system", and "servitization".

Chapter 3 answers two sub-questions. Firstly, the **sub-question 2** is answered:

"How do the Circular Service platform's solutions compare to blockchain designs in literature?"

To answer this question the systemic literature review process of Hagen-Zanker & Mallet (2013). The process is transparent and reduces bias as much as possible by using a set of predefined standards. The protocol consists of inclusion and exclusion criteria, search strings used, and the means of retrieval. The literature review is confined to scientific knowledge of blockchain technology and will only research scholarly articles through the scientific search engine Scopus. The search string "blockchain" OR "block chain" AND ("platform" OR "concept" OR "application" OR "system") has been used in Scopus to find the existence of blockchain concepts. Papers are analyzed based on their titles and abstracts and are read through if the paper focuses on blockchain and if it discusses an application/concept of it. Proposals are considered a blockchain platform, concept, application, or system if they function as an interactable medium and provide a certain result and solution using blockchain technology. Papers that fall outside of this definition are ignored. For instance, applications aimed at enhancing blockchain performance, such as smart contract performance or the amounts of transactions per second, are not considered a blockchain application and are left out of this literature review. The vast majority of research done in recent years, see figure 1.4. Thus, papers have only been selected from the years 2019 and 2020. From my experience, earlier papers on blockchain tended to be less valuable. All papers found and that matched these criteria are included in the systemic review. The result is several concepts that use blockchain technology to solve problems in certain fields.

Secondly, chapter 3 answers **sub-question 3**:

"How are the Circular Service platform's solutions described amongst blockchain and circular economy- and blockchain and product-service systems-oriented literature?"

The same systemic literature review process is used by Hagen-Zanker & Mallet (2013). However, the protocol is different. The search strings contain "blockchain" AND "block chain" AND ("circular economy" OR "PSS" OR "product-service system" OR "product service system" OR "servitization"). Papers are analyzed based on their titles and abstracts. They are read through if the paper mentions blockchain and either CE or PSS at least once. The systemic review does not include papers that do not significantly contribute to either blockchain, CE, and PSS literature. For instance, if an article only mentions blockchain briefly as one of many technological opportunities for the CE, the paper is not included in the literature review. All papers found that match the described criteria were included in the systemic review. The result is several papers that contribute to blockchain technology, CE, and PSS literature.

II. Business Analysis

The goal of this step is to answer the fourth sub-question. It will provide insights into how companies are implementing blockchain technology and how successful they are.

The business analysis consists of desk research (chapter 4) on the maturity of blockchain and different blockchain companies and start-ups compared with the CiSe platform.

Chapter 4 answers **sub-question 4**:

"How do companies' blockchain designs compare to that of the Circular Service platform?"

The desk research used the Google search engine and relevant keywords such as "blockchain", "company", "start-up". It resulted in several companies that have designed different blockchain applications to fulfill certain needs.

III. Exploratory Case Study

The goal of this step is to answer the final sub-question. It will provide insights into how CS and the Circular Service platform could affect the Bundles washing machine proposition.

The exploratory case study consists of the Bundles case study (chapter 5) that explores a collectively serviced Bundles washing machine and includes Miele and Vonk en Co in the CS business model. I chose the Bundles washing machine service as it has been servicing washing machines seemingly successful since its foundation in 2014. Washing machines are relatively simple products and allow for a good first case study. Bundles and CiSe are also already familiar with each other. Bundles' washing machines have been used for technical testing with the CiSe platform.

Chapter 5 answers **sub-question 5**:

"How do the Circular Service platform and collective servitization affect the Bundles' washing machine service?"

will be answered. The Bundles case study follows the case study methodology of Yin (2017). To be specific, the Bundles case study is an exploratory single-case study. Exploratory case studies are aimed at defining questions and hypotheses for future research. Since the CiSe platform is still in the demonstrative phase, an exploratory approach seems fitting to discover potential unforeseen barriers and opportunities related to blockchain technology and CS. It can help define issues that need more research. A single-case approach is chosen instead of a multi-case approach to provide more in-depth insights and knowledge.

The case study has four steps. The first step described the case context. It uses secondary research of Nilesh Nahar's and Julieta Bolanos's master theses. These contained detailed business model analysis and field research at Bundles, Miele, and Vonk and Co. Additionally, qualitative interviews have been done with Nahar and Bolanos to answer any remaining questions. The next step addresses the case through a qualitative risk analysis. A service blueprint maps the phases of the washing machine service. Since the CiSe platform focuses on transactions related to use and access, the service blueprint included the monetary flow between different stakeholders for each step. It gives insight into the financial risk related to each stakeholder. The next step discusses the results. In the final step, the results are evaluated. It was done by interviewing Nahar, Bolanos, and Henk Kuijpers from SFL and presenting the results.

IV. Evaluation

The goal of this step is to finalize the research. Chapter 6 provides a discussion. Chapter 7 provides the conclusion of each sub-question. It also answers the **main research question**:

"How effective could the Circular Service platform implement a collectively serviced Bundles washing machines?"

Finally, chapter 8 describes the recommendations for future research.

I. Literature Study

Chapter 2

Background Study

In this chapter, I will describe the results of the background study. I focussed on three fields that are relevant to collective servitization and the Circular Service platform. These are the circular economy, product-service systems, and blockchain technology. This chapter answers the first sub-question: ***How are the Sustainable Finance Lab's defined circularity requirements and collective servitization problems described amongst the product-service system and circular economy literature?***

2.1 The Circular Economy

The consumption of finite resources, together with ever-growing demands, increases the risk of volatile resource prices and supply disruptions (EMF, 2013). The linear economy is unsustainable. The CE is a new economic system that aims to decouple economic growth from finite resource consumption. The CE promises economic, social, and environmental sustainability (Korhonen et al., 2018). Some of the principles to transition to a CE are as follows:

1. Restoring products, components, materials at end-of-life
2. Using renewable energy sources
3. Regenerating natural systems
4. Designing out waste (waste is food)
5. Think in systems

The CE distinguishes between two separate cycles; the technical and biological cycle (figure 2.1). Different from technical nutrients, biological nutrients can re-enter the biosphere. The CiSe platform serves products that are on the technical cycle. These consist of materials that are unsuitable for the biosphere, such as metals and plastics. A shift away from the take-make-dispose mindset is necessary. Instead, the CE prioritizes to return products at end-of-life. Different recovery methods such as repair, refurbishment, remanufacturing, and recycling recover value left within products and components.

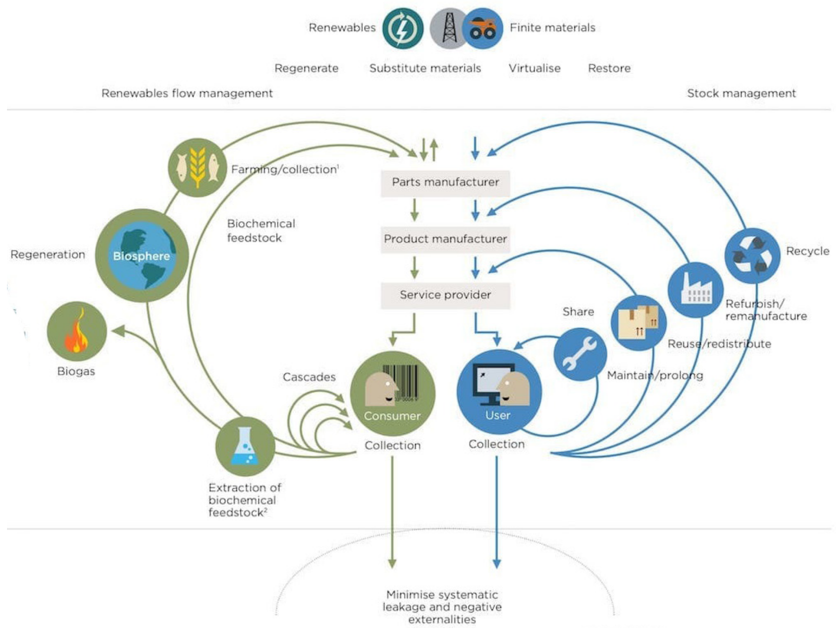


Figure 2.1: Outline of a circular economy, *source: EMF (2015)*

The value hill (figure 2.2) represents the technical lifecycle of products within a CE. During the pre-use phase, material suppliers, manufacturers, assemblers, and service providers create value (a product, a service, or both). During this phase, with thoughtful circular design, products can be optimized for durability and value recovery. While in use, the product is at its highest value. It is preferred to keep products in use for as long as possible. Post-use, value recovery strategies can capture the remaining value. Achterberg et al. (2016) also defined four core circular strategies related to these three phases; circular design, optimal use, value retention, and network support.

The CiSe platform's efforts to stimulate the servitization of products are in line with the optimal use strategy. The CiSe platform further stimulates circular business through its code of conduct. To join the platform, participants have to comply with the following criteria:

1. Practice at least one of four circular strategies (figure 2.2)
2. Avoid the use of materials that cannot be recycled or which are not bio-degradable
3. Reduce energy and material use

How compliance with the code of conduct is approved is not yet clear and is still in development.

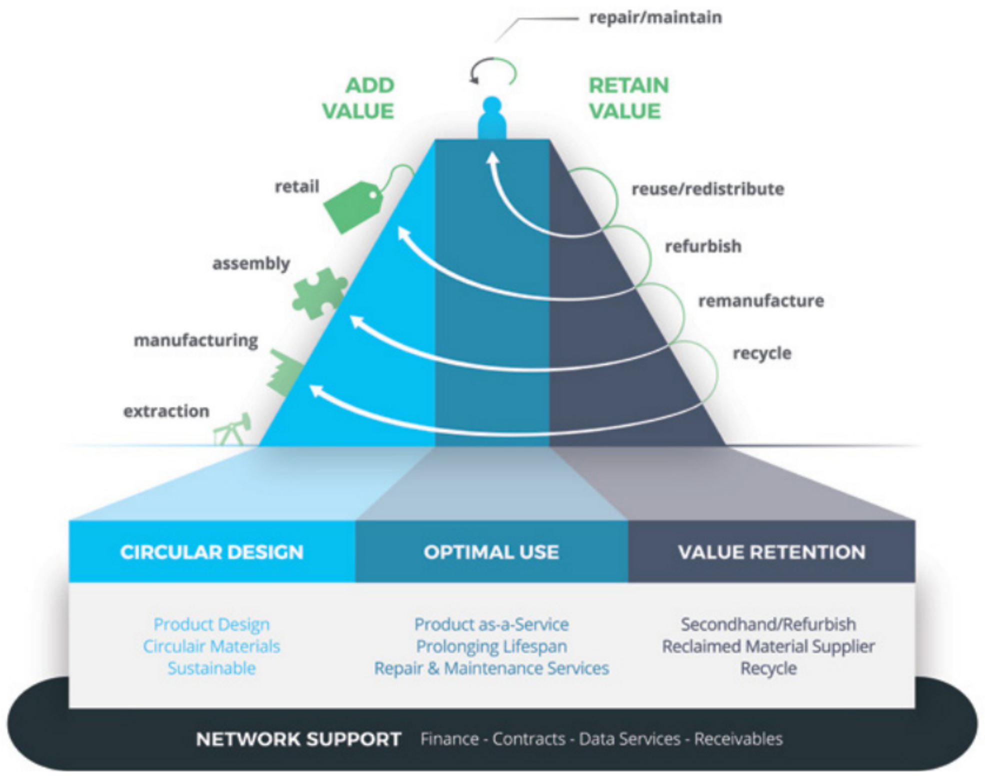


Figure 2.2: The value hill & circular strategies, *source: Achterberg, E., Hinfelaar, J., & Bocken, N. (2016)*

2.2 Product-Service Systems

To stimulate a CE, the EMF (2013) advocates the need for more service-oriented business models where providers retain product ownership. With a similar circular goal in mind, the CiSe platform aims to overcome administrative challenges in collectively serviced pay-per-access and pay-per-use products. The latter are subcategories of PSS. A specific definition of PSS is "*a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs*" (Tukker & Tischner, 2006).

Tukker (2004) classified PSS into three main categories; product-oriented, use-oriented, and result-oriented (figure 2.3). They differ in the level of tangible products and intangible services. The CiSe platform focuses on **use-oriented PSS**. Here, the product remains central to the business model. PSS can help companies create more value and improve competitiveness by being able to fulfill customer needs in an integrated and customized way, build unique relationships that improve customer loyalty, and innovate faster by being able to follow better the customer's needs (Tukker, 2004).

The literature regards PSSs as useful tools for moving towards a resource-efficient CE (Tukker, 2015). The circular benefits are mainly due to the shift in ownership to the service provider. It is the case with use- and result-oriented business models. Use- and even more so result-oriented business models promote the execution of circular activities by companies such as extending the useful lifetime of products, maximizing product utilization, making products as cost- and material-efficient as possible, and re-using as much as possible after product end-of-life (Tukker, 2015). Product-oriented PSSs do not provide a profound

Product-oriented services

Product-oriented PSSs have business models geared towards selling products. Extra services add benefits to consumers.

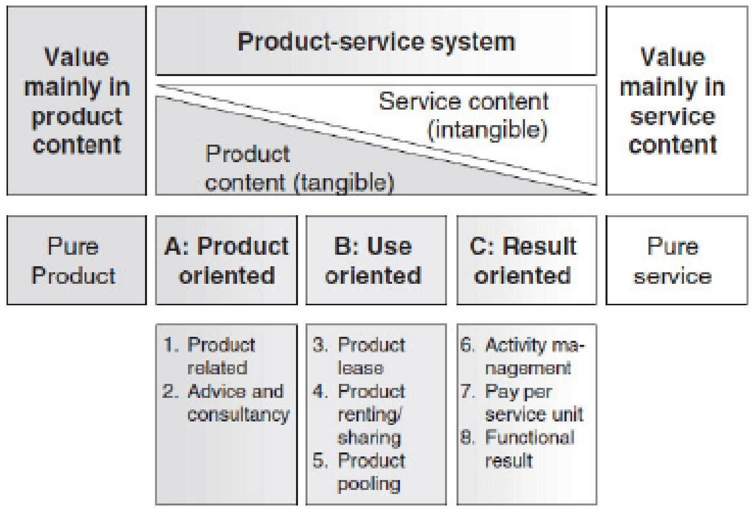
Use-oriented services

Use-oriented PSSs also have products central to the business model. However, instead of selling the product, they are serviced. The product stays in ownership of the provider.

Result-oriented services

With result-oriented PSSs, consumers and service providers agree on a result. The product is not central to the business model.

Figure 2.3: Product-Service Systems, source: Tukker (2004)



circular improvement. It is because the consumer is responsible for the product. The focus of the provider remains on selling as much as possible. Overall, the more service-oriented a PSS, the better this is from a CE perspective.

Collaboration is crucial for successful and innovative PSS (Polova & Thomas, 2020). Scholars outline a need for trust and holistic commitment (Aarikka-Stenroos & Jaakkola, 2012). Wiesner et al. (2013) mention a need for openness and the need to share knowledge, capabilities, and resources to collaborate effectively with clients and external partners. CS is likely to stimulate collaboration and cooperation amongst members that join the collective. However, it does not mean the same as collaborative servitization. CS is distinct in how revenue becomes shared and incremental for every participating member contributing to the PSS. With CS, every member earns revenue as longs as the product is in working condition. It is likely to align the incentives and mind-set (think long-term and circular) and stimulate collaboration and cooperation.

2.2.1 Digital Servitization

Since the start of PSS literature, scholars include software and digitalization in its research (Kohtamäki et al., 2019). However, only recently have PSS and digitalization been converged into one definition (Bustinza et al., 2018). The following definition categorizes digital servitization: *"digital servitization is the transition towards smart product-service-software systems that enable value creation and capture through monitoring, control, optimization, and autonomous function"* (Kohtamäki et al., 2019).

Digital servitization may open up new opportunities or move traditional PSS benefits to new levels. Entirely new businesses are made possible by capitalizing on big data, cloud technologies, and augmented or virtual reality. These technologies can accelerate the transition to a CE by increasing resource efficiency, extending product life, and improving value recovery (Bressanelli et al., 2018). The CiSe platform is an interesting case of using blockchain technology to digitalize servitization. While blockchain has potential in the realm of servitization, scholars have not addressed it in the literature (Paschou et al., 2020).

2.2.2 PSS Challenges

The literature mentions a lack of broad adoption of use- and result-oriented PSS (Tukker, 2015). This is particularly the case in a B2C context. The following paragraphs describe the PSS implementation barriers that are most relevant to this thesis' research question.

Costs of PSS are often expensive (Tukker, 2015). It is due to three reasons:

1. PSSs tend to have an extensive network of companies, which results in high transaction costs (Tukker & Tischner, 2006).
2. Labor and material costs are often expensive.
3. The responsibility of the product can result in higher costs down the road due to unforeseen problems.

Companies perceive use- and result-oriented PSS as riskier than product-based business models (Mont, 2004). It is because use- and result-oriented PSS require medium- to long-term investments. The initial capital investments are high, while the return of investment is incremental. Companies tend to prefer short-term profits over long-term profits (Dallas, 2011)

For specific PSS offerings, providers have developed systems for monitoring and managing the product's condition. For some customers, this might be a sensitive issue (Vezzoli et al., 2015).

Finally, companies fail to collaborate (Vezzoli et al., 2015). Scholars mention three reasons:

1. There is a conflict of interest in PSS between the PSS provider and the "linear-thinking" stakeholders. The latter aims to sell as much as possible. The PSS provider conflictingly aims to be resource-efficient and extend product lifetime.
2. Companies fear sharing sensitive information on their processes and technologies.
3. Increased collaboration can have negative effects on a companies' influence

Answer to sub-RQ 1:

"How are the Sustainable Finance Lab's defined circularity requirements and collective servitization problems described amongst the product-service system and circular economy literature?"

The results are mixed. To the best of my knowledge, the SFL's definition of CS, "aligning the incentives of all the value chain participants involved in a service by compensating them for performance or output", or anything similar, is not mentioned amongst CE, PSS, and servitization literature. Vezzoli et al. (2015) mention that the conflict of interest within the value chain hinders collaboration. By compensating stakeholders within the value chain for performance or output, the incentives and mind-set are likely to become more aligned, thus stimulating collaboration. The literature can further help clarify the existence of CS implementation barriers and, thus, the relevance of the CiSe platform. I will first discuss the requirements and implementation barriers that are confirmed by the literature. Finally, I will discuss those that are refuted or not mentioned at all.

Confirmed Requirements, Implementation Barriers, and Benefits

The literature supports both of the SFL's circularity requirements. This indicates that CS is likely to significantly improve circularity compared to PSS and linear business models.

Scholars regard PSS as promising in stimulating companies to behave more circularly (confirming requirement 1: *Products are serviced instead of sold*). By compensating multiple stakeholders only for as long as the product is in working condition, each become incentivized to increase resource-efficiency and product longevity. By incorporating more stakeholders in this mind-set, the PSS is likely to reach an overall higher circular state.

There is also support for the second circularity requirement of the SFL: *The entire life-cycle of products must be considered*. Within a circular economy, the pre-use, use, and post-use phase must be optimized to retain value (Achterberg et al., 2016). With CS multiple stakeholders will likely work more closely and adapt and integrate business processes. Each stakeholder has unique perspectives, expertise, and roles within the system.

Furthermore, the benefit of spreading initial capital investments amongst multiple members and the implementation barrier of high administration costs seem both relevant. Mont (2004) mentioned that the high initial investment costs and incremental returns are perceived as risky (Mont, 2004). Tukker & Tischner (2006) mentioned that PSS is generally associated with high transaction costs.

There is some mild support in favor of the following implementation barrier for CS: the need to share innovation costs. Collaborative servitization literature mentions a need for trust and holistic commitment (Aarikka-Stenroos & Jaakkola, 2012), as well as a need for openness and sharing knowledge, capabilities, and resources

(Wiesner et al., 2013) for effective collaboration and innovation. Generally, transparency and sharing resources will improve the overall PSS. However, this barrier's origin does not stem from a need to improve collaboration but stems from a need to receive compensation for the contributed innovation. With conventional PSS, the service provider would pay more for an improved product. In a CS business model, the innovator will have to be compensated differently, for instance, by getting a larger cut of the incoming revenue or sharing the costs of innovation.

Unconfirmed Implementation Barriers
As far as I am aware, the literature does not mention an increasing complexity of ownership and the need for micro-transactions or the need to handle micro-transactions directly. Regarding the first comment, this problem might be unique to CS. The lack of research into the phenomena of CS points to a need for more research. It might be that there are different and unforeseen problems of CS we do not yet know. These problems might make the CiSe platform irrelevant. More research in CS is essential for knowing the CiSe platform's viability from a social perspective (is there a need for CS).

2.3 Blockchain Technology

2.3.1 Confusion in Terminology

There is some confusion around the terminology of blockchain technology. Before diving into how blockchain technology works, it is useful to clarify the definitions used in this thesis. First of all, Bitcoin is not blockchain. Instead, Bitcoin is the first application of the technology. Secondly, blockchain can mean several things. It can refer to the specific data structure, an algorithm, a technology, or a system/application as a whole (Drescher, 2017). Finally, scholars often use distributed ledger technology (DLT) to describe blockchain, which is not entirely correct (Bashir, 2017). Instead, DLT is a larger family of blockchain technology (Aste, 2017). While both have a lot in common, blockchain is unique in how information is stored.

To understand the benefits of blockchain technology, I will first describe the unique data structure of blockchain technology, the algorithm behind it, and the various blockchain applications. For a more detailed overview and a step-by-step guide, see Appendix A.

2.3.2 How it Works

Blockchain is a distributed ledger or shared database across a computer network. Every computer (also referred to as a node) in the network runs software to directly communicate with other computers (peer-to-peer) who run the same software. The consensus protocol is an algorithm that allows nodes to agree on new information entries into the shared database. This process is often called mining. The consensus protocol is unique in that it eliminates the need for an intermediary "verifying" party. Drescher (2017) mentions that the ability of blockchain technology to disintermediate, without giving into data security and integrity, is the main reason for its excitement.

Blockchain systems store information in bundles called blocks. Each block of information receives a corresponding cryptographic hash value. These are digital fingerprints that uniquely represent a set of data. Each block refers to the most recent stored block with yet another hash value. As a result, these hashes create a chain of blocks, all the way to the genesis block (figure 2.4). The genesis block is the first block in the chain and is hardcoded into the system. When a malicious user wants to change a piece of information in the blockchain, the hash value changes, breaking the chain. Since the ledgers are shared and transparent, other users can compare their version of the ledger and identify the broken chain. This makes blockchain systems almost immutable. To change a piece of data that is stored on the blockchain requires possession of over 50% of the computers within the blockchain network.

Blockchain also uses assymetric cryptography. This allows users to confirm transactions and data entries with their own unique private key. With the corresponding public key, which is mathematically linked to a specific private key, everyone can digitally confirm that a certain piece of information is signed. Assymetric cryptography is considered to be very safe and secure.

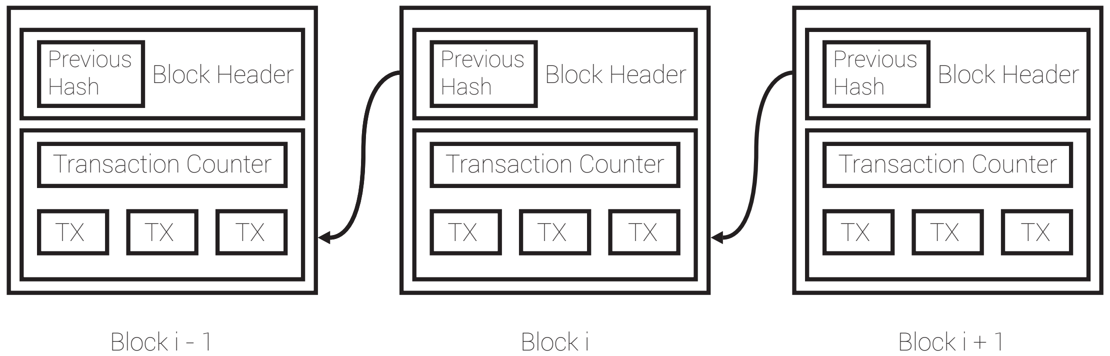


Figure 2.4: A sequence of blocks, *source: Zheng et al. (2017)*

The core advantages of blockchain systems are:

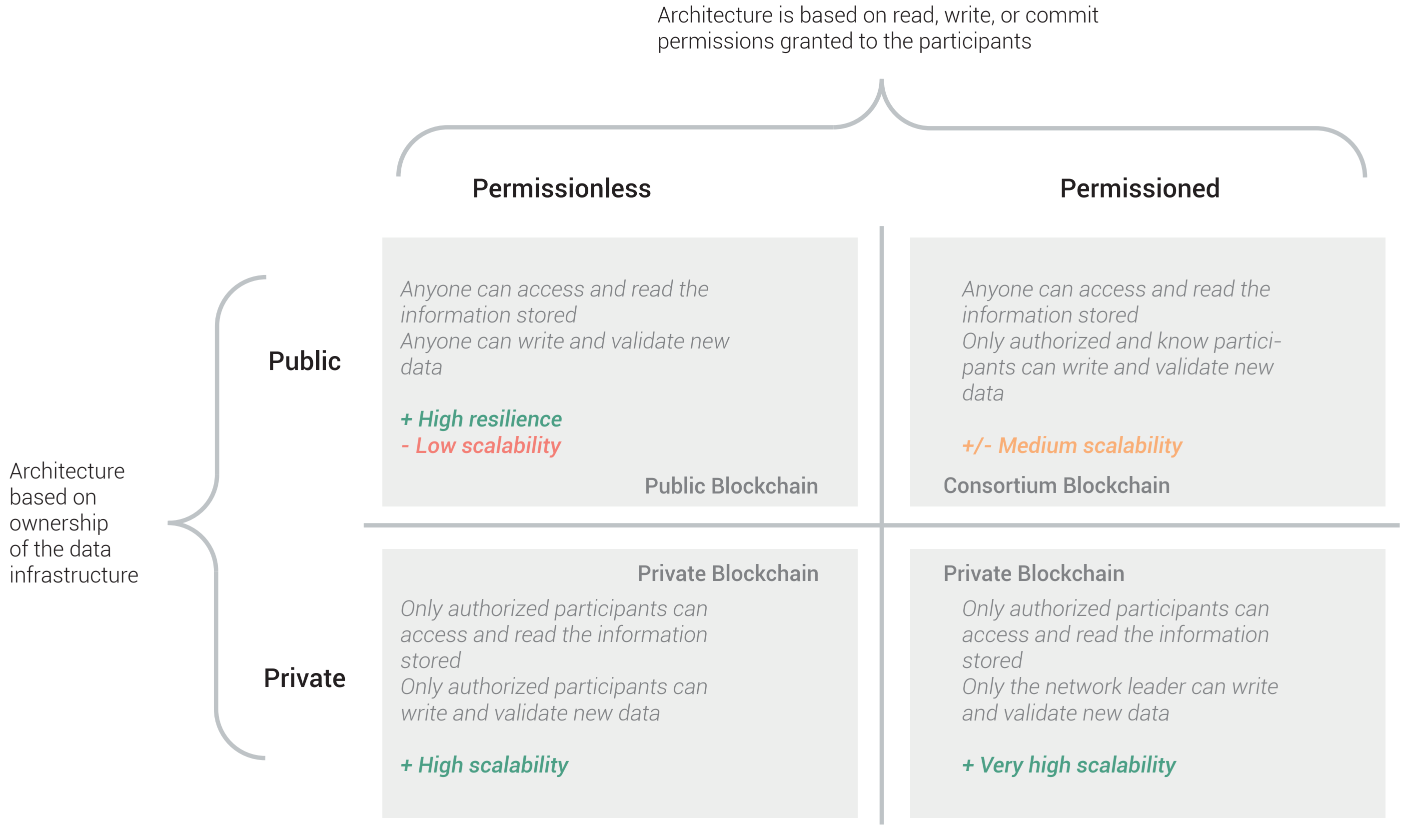
1. Disintermediation
2. (cryptographic) Security
3. Transparency
4. Immutability

Smart contracts are programmed on the ledgers. These execute transactions when certain conditions are met. For example, smart contracts can automate loans or insurance-claim payouts without the need for an intermediary. As a result, smart contracts can significantly reduce turnaround time and transaction costs of business processes (Zheng et al., 2020).
Blockchain technology can be configured in several ways to meet different needs. Different consensus protocols have trade-offs between throughput, scalability, and security (Makhdoom et al., 2018). The literature also distinguishes between three types of blockchain systems. These are public blockchains, consortium blockchains, and private blockchains, and they vary in the accessibility of information (public vs. private) and who are allowed to validate and write data to the blockchain (permissioned vs. permissionless) (Zheng et al., 2017). Blockchain systems do not have to be decentralized, even though the computers within the system share the ledgers. One or a few organizations can control the computers that validate and add data to the ledgers. More centralized blockchain systems tend to have improved processing time, throughput, and less overhead but deliver security and tamper resistance (Rauchs et al., 2018). The SFI designed the CiSe platform as a **consortium blockchain** (public and permissioned). Only the computers of companies that service their products through the CiSe platform can add and validate data to the shared database. However, the database itself is publicly accessible.

2.3.3 Blockchain Challenges

There are some issues with blockchain technology. First of all, blockchain systems are generally not capable of scaling up and handling high volumes of transactions or new data entries (Maull et al., 2017). Bitcoin can handle up to seven transactions per second. Quorum is the blockchain software the CiSe platform currently aims to use. It performs better than Bitcoin with a throughput of 150 transactions per second. Still, this pales compared with the 65000 transaction VISA can handle per second (USA VISA, 2017). The limited throughput raises questions regarding the types of products and the number of products that can be serviced through the platform.

Figure 2.5: different blockchain types, *source: Zheng et al. (2017)*



Furthermore, blockchain systems are not very flexible (Drescher, 2017). There is no procedure to change major components of a blockchain once it is in operation. Blockchain systems are built to last for their entire lifetime. For instance, it is currently impossible to change the smart contract code stored on the blockchain (Zheng et al., 2020). The inflexibility can become problematic for the CiSe platform's smart contracts that store the revenue distribution agreements. A company might innovate a lot, requesting a more massive cut in the revenue distribution. For this to happen, the smart contract would need to be changed.

With blockchain systems, every user has a unique private key. Users use the private key to authenticate and authorize a transaction or data change. If a user loses his or her private key, the security of the account is broken. Often there is no additional safety net. Key management can be quite tricky and requires technical proficiency (Rauchs et al., 2018). Key management to third-party services. For the CiSe platform to remain accessible, it aims to use a third-party key manager. However, outsourcing key management can come with extra costs and slower transaction speeds (Pal et al., 2019). Centralized key management can also make the system vulnerable to data breaches. For the CiSe platform, it is crucial to understand if the reduced administration costs outweigh the key manager's risks and costs.

In IoT and Computer Science, there is an expression; garbage in, garbage out. It is the concept that nonsense data input will result in nonsense data output. With blockchain systems, this expression changes; garbage in, garbage forever. Data stored on the blockchain will remain on the blockchain forever. It could become problematic for the CiSe platform. A domino effect could occur when sensors wrongfully trigger use due to an error or malicious intent. Smart contracts will automatically and autonomously initiate transactions. Once initiated, these transactions cannot be changed or reversed.

2.4 Takeaways

First of all, there is no mention of the definition of CS. However, this chapter identified some support for the SFL's defined requirements, solutions, needs, and benefits of CS. Four positive takeaways have been identified from the literature:

1. It is **likely that CS significantly improves circularity** compared to PSS or linear business models.
2. The problem of **high administration cost is relevant**
3. The problem of **high-risk perception of PSS is relevant**
4. The **need to share innovation costs seems relevant**

This chapter identified a lack of support for some of the CS barriers. Some additional limitations of blockchain technology were identified as well. These can be summarized as follows:

1. The **process of bundling micro-transactions is likely not relevant**
2. There is **no support for complexity of ownership** in PSS found (might be unique to CS)
3. The use of **blockchain limits scalability** of the CiSe platform
4. The use of **Blockchain limits flexibility**
5. Private **key management is problematic** and might require a costly intermediary
6. Wrong data i**nput will remain on the blockchain forever**

To address this issues, a systemic literature review has been done. The results will be described in chapter 3. First, different blockchain use-cases are defined. These use-cases help compare different blockchain designs, found through a systemic literature review, with the CiSe platform. Finally, a systemic literature review will explore papers on blockchain and the CE and blockchain and PSS.

Chapter 3
Literature Review

In this chapter, I will describe the results of the literature reviews. I will first describe the four use-cases of blockchain systems I identified. Following, I will apply the use-case framework on different blockchain designs found in literature and compare them with the CiSe platform. Moreover, I will discuss the results from the literature review regarding blockchain and the circular economy. Finally, I will discuss the results from the literature review regarding blockchain and product-service systems. This chapter answers two sub-questions. It answers the second sub-question: ***How do the Circular Service platform's solutions compare to blockchain designs in literature?*** *It also answers the third sub-question:* ***How are the Circular Service platform's solutions described amongst blockchain and circular economy- and blockchain and product-service systems-oriented literature?***

3.1 Blockchain Use-cases

A literature review identified several blockchain designs amongst literature (see chapter 3.2). I designed a blockchain use-case framework to help compare different blockchain concepts with the CiSe platform. The framework consists of four use-cases. Each blockchain use-case can contain different types of information. Information can be both or either endogenous (internal) or exogenous (external) to the system. Blockchain designs can fall under multiple use-cases. The next paragraph describes the types of information. The following paragraphs describe each blockchain use-case.

Blockchain systems can contain three data types; **endogenous** and **exogenous** information and a combination of both; **hybrid**. Cryptocurrency is an example of an endogenous type of information. Cryptocurrencies are digital pieces of information that exclusively exist within the system's boundaries. Any type of data that references information extrinsic to the system is considered exogenous. It can be almost any digital data types, such as patients' healthcare records, word documents, sensor measurements, and many more. The sky is the limit. Finally, hybrid information is a combination of both endogenous and exogenous types of information. These occur in two ways; reference data and tokens. Reference data are hashes of a piece of exogenous information. Instead of storing a large file, such as a patient's health record, reference data only stores the hash value of said data—the hash value functions as a proof of existence. The hash value is a hybrid information type as it is created within the boundaries of the system and references information external to the system. Another form of hybrid information are tokens. Here assets are represented by digital tokens. Tokenizing the asset improves its liquidity (ability to trade the asset). Fully endogenous systems have the benefit that they are resilient and independent. Using exogenous information makes the system more vulnerable. However, it also allows for unique opportunities. Many digital information types can benefit from the disintermediary and secure properties of blockchain systems. Using Reference data and tokens is a compromise that allows blockchain systems to store exogenous information more efficiently. Since the actual files are not stored on the blockchain, they deliver in security.

At its core, every blockchain system is a **distributed database**. It has specific properties that are prevalent amongst every blockchain design. Blockchain databases can conclude on new information entries without an intermediary party, are cryptographically secure, are transparent (for the permissioned nodes), and the data is (almost) immutable. An example of a blockchain design that I consider a "distributed database" is Bitcoin. The Bitcoin blockchain keeps track of the ownership of Bitcoins. However, the process of transferring Bitcoins is manual. Other examples of "distributed databases" are the storage of healthcare records (Medchain, see chapter 3.2) and vehicle registration, (BVD, see chapter 3.2)

Blockchain's asymmetric cryptography allows users to **authenticate** or sign a piece of data using their unique private key. With the corresponding public key, everyone can digitally confirm that a specific person or entity signs a particular piece of information. This notion could potentially improve and simplify identification processes. For example, Sproof is a blockchain concept that allows universities to grant educational certificates (Brunner et al., 2019). These universities can sign the documents with their unique private key that only they possess. Combined with blockchain's secure and immutable dataset, people can quickly, reliably, and digitally verify claims (such as an identity or a certificate) without the need for an intermediary.

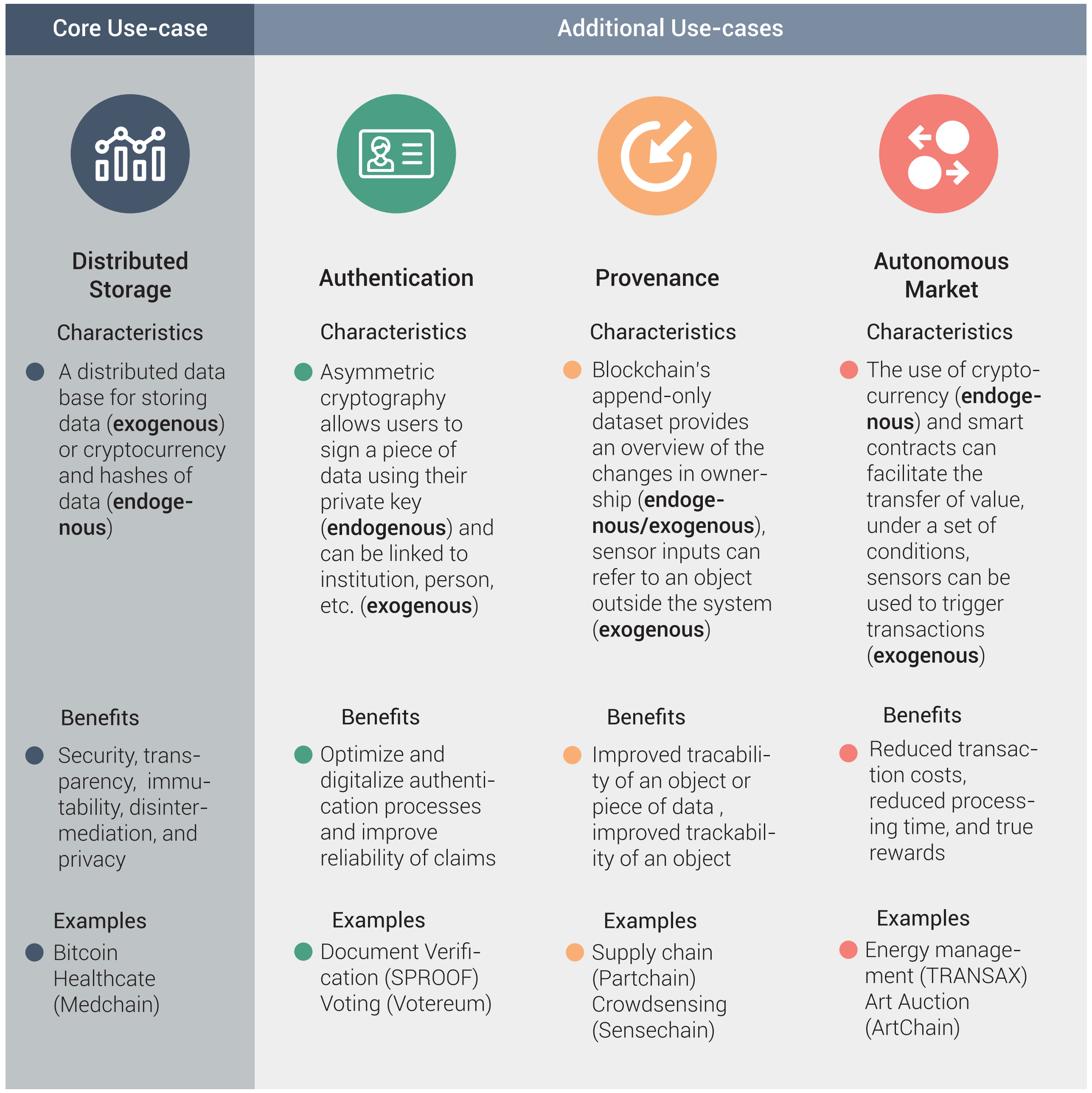


Figure 3.1: The use-cases of blockchain technology

Another use-case of blockchain systems is
Another use-case of blockchain systems is
provenance. This use-case predominantly uses exogenous information. Using sensors (RFID tags, QR scanners, and many more), the whereabouts of an object external to the system can be tracked and traced. This use-case is useful in supply chains (Partchain, see chapter 3.2). The provenance use-case can also track the reputation of something or someone. For example, a sensor could directly send and store its measurements on the blockchain (Sensechain, see chapter 3.2). From it, the complete history of measurements can be viewed and assessed on their reliability. Blockchain can also be useful for reputation systems (Khaqqi et al., 2018). An example of a reputation system is the driver score of an Uber driver. Blockchain can help provide reliability here. The literature mentions improved traceability and trackability of an object or a piece of information. The literature also mentions improved reliability of information and real-time updates.

The use-case **autonomous market** is always defined by the use of smart contracts. Quite often, these involve cryptocurrencies as well that have a monetary value. Smart contracts can efficiently trigger transactions or change ownership of a piece of data. The main benefits are reduced transaction fees and processing time. Since there is no intermediary, monetary rewards can be directly sent to people/contributors. Some blockchain designs mention a unique opportunity by providing more rewards for contributors or incentivizing people to do specific actions. It is possible since there is no costly intermediary necessary to validate the transaction. Examples of this use-case are blockchain auctions (Artchain) and energy markets (BIJLI).

At its core, the CiSe platform is a **distributed database** for payments related to the use of- and access to products. An additional use-case that the CiSe platform is characterized by is that of **autonomous market**. The CiSe platform uses smart contracts to automatically and autonomously translate product use and access into payments and divide the money towards the related companies. Furthermore, the CiSe platform uses both **endogenous** and **exogenous** information. Information about product use is external to the system. Smart contracts use this data to trigger transactions. Micro-Euro's, which are internal to the system, are sent to different collective members. The CiSe platform is not limited to these use-cases and, during development, might adopt others as well. For instance, the SFL has mentioned that they are looking into incorporating consumers' identity management into the CiSe platform. It is related to the use-case authentication.

3.2 Blockchain Designs in Literature

The literature review identified 51 different blockchain designs in various areas (for the complete protocol, read chapter 1.6). Table 3.1 shows an overview of all these designs and their respective fields. The search string “blockchain” AND “block chain” AND (“application” OR “concept”) identified 5410 articles. I screened the articles down to 3872 papers based on their scope (2019, 2020). Titles and abstracts were screened and assessed if they were a concept or application. Articles were considered if they mentioned a concept, application, system, or design that uses blockchain technology. The result was a selection of 51 papers. Many articles have been excluded based on the abstract and title.

Blockchain has a wide range of applications. It is not a surprise why there are so many published papers on the topic (See chapter 1.2). According to this literature review, the field of healthcare sees the most attention regarding blockchain technology. Scholars propose blockchain to provide a more secure, privacy-preserving, and unified database of health records. In the field of supply chains, scholars mention blockchain designs that strongly relate to the provenance use-case. For instance, HIDALS aims to increase the track- and traceability of parcel and assess the parcel's condition with sensors (such as the temperature and force) in real-time during transit. In video streaming, blockchain is proposed to provide content creators with maximized returns by cutting out the intermediary (Aurum). Blockchain is also proposed to enable digital voting by having users digitally confirm their identity and make it (almost) impossible to falsify votes or double-vote (Votereum). There are many more and different examples. For a short description of all the designs, see appendix B.

Only one blockchain design mentioned a focus on the CE, namely PlasticCoin. PlasticCoin is a cryptocurrency that aims to encourage plastic recycling. Rewarding PlasticCoin tokens incentivizes people to reduce their plastic waste. People can receive PlasticCoin's in three ways:

1. Bringing plastic to a partner who rewards users or not
2. Attending an event related to plastic waste (such as collecting plastic waste)
3. Completing quizzes related to the topic.

The first methods require human verification, while with the latter, rewards are handled with smart contracts. The CiSe platform and PlasticCoin are very different. PlasticCoin focuses on giving people coins that are representative of their efforts to reuse plastic. PlasticCoin is less reliant on the use of smart contracts to reduce transaction costs. The main goal is incentivizing green behavior. PlasticCoin is not judged as an Autonomous Market as it does not significantly focus on the automation and autonomation of transaction processes. PlasticCoin is not related to the administration of- and triggering transactions of use and access to products in any way.

BIJLI and TRANSAX operate in renewable energy, which is one of the principles of the CE. BIJLI is a platform where producers can directly (no intermediary) sell renewable energy to consumers. Blockchain provides security and transparency of the transaction processes. TRANSAX is a blockchain-based energy exchange for microgrids, resulting from the growth in renewable energy and improvements in battery technology. It aims to connect producers of energy with consumers in a privacy-preserving manner. Out of the two, TRANSAX is probably best compared with the CiSe platform. TRANSAX uses smart contracts and blockchain to securely and efficiently trade energy. It also mentions the use of storing smart contracts on the blockchain to stimulate trust. Similarly, the CiSe platform aims to store smart contracts that contain agreements on revenue distribution and the transactions of use and access to stimulate trust in the administration.

All the selected designs are explorative and demonstrative. It is a limitation to the current viability of blockchain. A trend amongst the articles is that they identify a problem in their respective field, propose blockchain as a potential solution, and provide a particular design. Some designs are more extensive than others. Some articles perform feasibility analysis, minimal-viable-product tests, and simulations. However, there is no final design. It is not surprising as it is not in the interest of scientists to implement these designs. That is more suitable for entrepreneurs and investors. Additional research into companies is necessary to provide insights into its maturity and implementation barriers.

Figure 3.2: Flow diagram of selection of blockchain designs

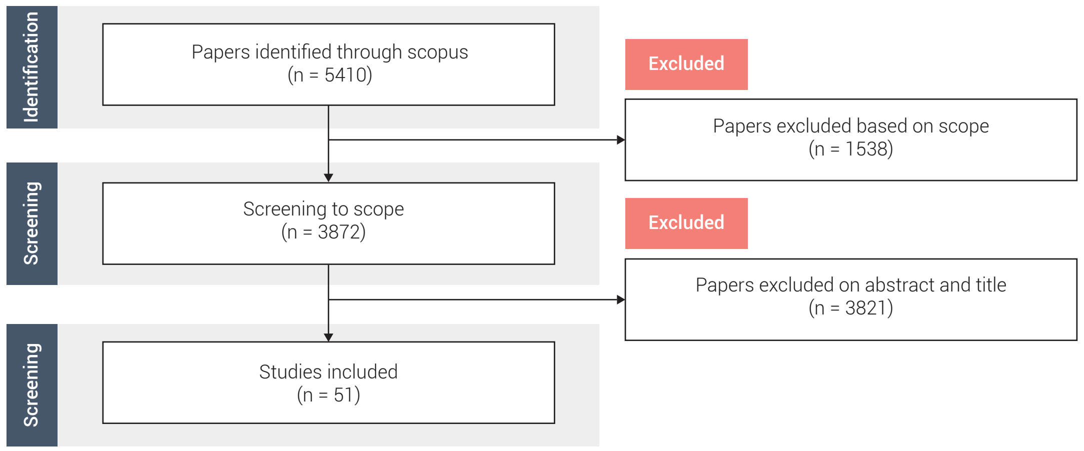


Figure 3.3: Identified use-cases amongst the literature

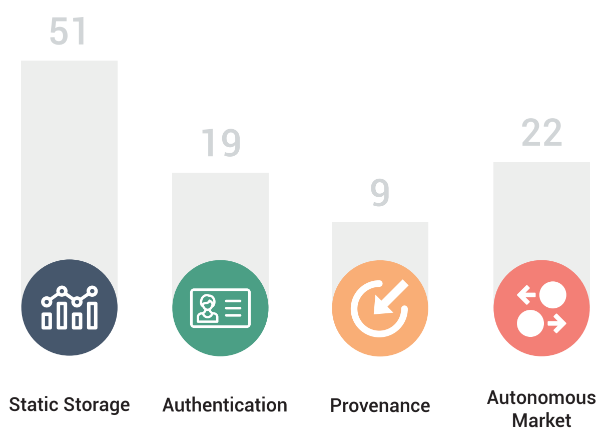


Table 3.1: Blockchain designs in literature

Blockchain Design	Area of Operation	Blockchain Use-case
1.BlocHIE	Healthcare	-
2.B4Health	Healthcare	-
3.Clinicappchain	Healthcare	Au
4.CUREX	Healthcare	-
5.MedBloc	Healthcare	Au
6.MedChain	Healthcare	-
7.MedibChain	Healthcare	-
8.TrialChain	Healthcare	Au
9.ABcrowd	Crowdsourcing	AM
10.CrowdBC	Crowdsourcing	AM
11.Fluid	Crowdsourcing	AM
12.Vizsafe	Crowdsourcing	AM
13.zkCrowd	Crowdsourcing	AM
14.CrowdBLPS	Crowdsensing	-
15.DMap	Crowdsensing	AM Au
16.SenseChain	Crowdsensing	DP
17.SPIR	Crowdsensing	AM Au
18.AdvoCate	Data	Au
19.BCSolid	Data	Au
20.Hyperprov	Data	DP
21.PrivySharing	Data	AM Au
22.Ambient	Social media	-
23.Tawki	Social media	Au
24.HomeChain	Smart homes	Au
25.JobChain	Job application	Au
26.Eureka	Scientific literature	AM Au
27.PlasticCoin	Plastic Reuse	-

Blockchain Design	Area of Operation	Blockchain Use-case
28.BCEdge	PC resource management	AM
29.CollabChain	PC resource management	AM
30.Nebula	PC resource management	AM
31.BIJLI	Energy management	AM
32.TRANSAX	Energy management	AM
33.LicenseChain	Licensing	AM Au
34.BVD	Vehicle registration	-
35.SPROOF	Document verification	Au
36.Genesy	Genomic data	AM Au
37.GenVote	Voting	Au
38.LaT-Voting	Voting	DP Au
39.Votereum	Voting	DP Au
40.Aurum	Video streaming	AM
41.Red5	Video streaming	AM
42.ArtChain	Art marketplace	AM DP
43.Cryptober	Car rental	AM Au
44.EVChain	EV charging	AM
45.Legacy Fish Farm	Farming	-
46.VegIoT	Farming (supply chain)	DP
47.WARP	AR	-
48.Smart Dam	Water rights	AM
49.BRUSCHETTA	Supply chain	DP
50.HIDALS	Supply chain	DP
51.PartChain	Supply chain	DP

Legenda:

Distributed Storage*
Provenance DP
Autonomous Market AM
Authentication Au

** At its core every blockchain system is a database*

Answer to sub-RQ 2:

How do the Circular Service platform's solutions compare to blockchain designs in literature?

The results are mixed. First of all, there was no design directly comparable with the CiSe platform when using the definition by the SFL; "A tool that automatically and autonomously processes payments related to collectively serviced pay-per-access and pay-per-use products". The literature review did not find any designs that focus on PSS, and only one design mentioned the CE, PlasticCoin. However, this concept's focus is mainly to incentivize plastic reuse and less on automation and autonomization. The blockchain use-case framework identified 22 designs that could be categorized in the "Autonomous market" use-case. I will first discuss the confirmed solutions. Next, I will discuss the unconfirmed solutions.

Confirmed Solutions of the CiSe platform

It is very likely that blockchain technology, combined with smart contracts, can reduce administration costs related to payments of use- and access to products. Multiple designs in the "Autonomous market" category mention reduced transaction costs (see figure 3.3). For instance, Cryptober mentions that blockchain can provide cost-optimal car rentals. Aurum uses blockchain to provide video content creators with maximized rewards by skipping the intermediary. ABcrowd and zkCrowd mention reduced transaction costs related to paying workers in crowdsourcing.

It is also likely that administration can be done transparently. ABcrowd proposes blockchain and smart contracts to provide autonomous and transparent executions of transactions. Similarly, zkCrowd stores transaction "transparently" on the blockchain. Dmap mentions they store all their transactions and interactions related to online mapping "transparently" on the blockchain as well.

One article mentions micro-payments. Eureka uses micro-payments to provide authors, editors, and reviewers of scientific articles with small rewards for their contribution to article submissions.

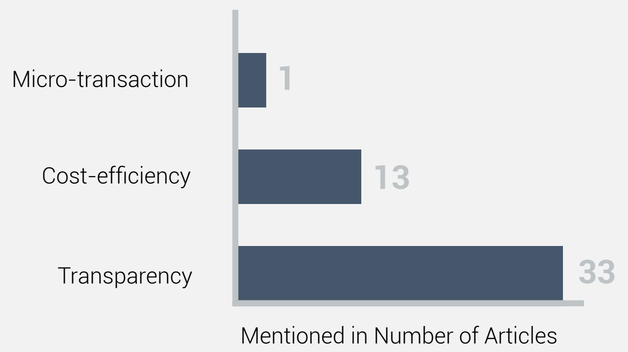


Figure 3.3: Solutions mentioned in articles

Unconfirmed Solutions of the CiSe platform
The solutions of CiSe are all mentioned in the articles, some more than others. However, the papers remain conceptual. While there is support that blockchain technology can improve transparency, reduce transaction costs, and allow for direct handling of micro-transactions, it is not sure if it is feasible on large scales and interoperable in the current infrastructure. The immature understanding of blockchain technology amongst the literature is a limitation to the technology's current viability.

Additional findings
Privacy is mentioned multiple times as a reason to use blockchain technology. For instance, Privysharing deploys blockchain allows people to share information without affecting their privacy negatively. Chapter 2.2 identified that users of PSS tend to be put off by extensive monitoring of products (Vezzoli et al., 2015). Blockchain might help to overcome these barriers by providing anonymity to users.

3.3 Blockchain and the Circular Economy

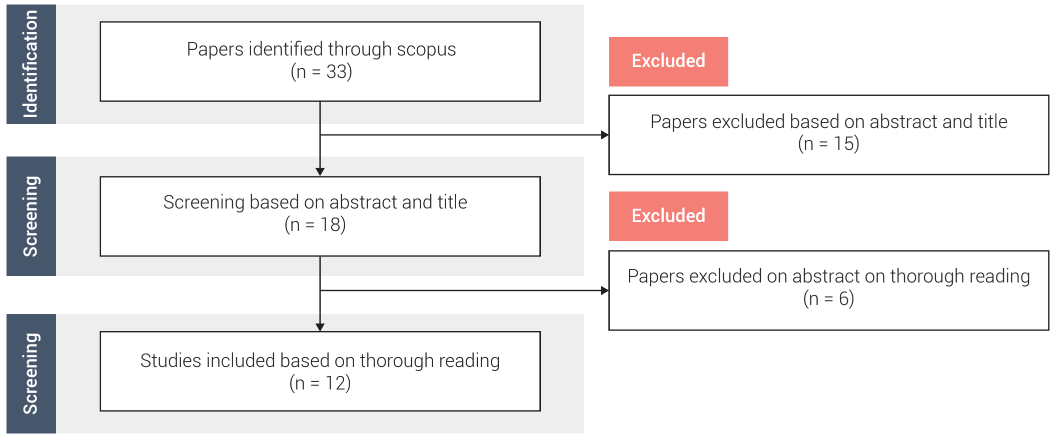
A literature review was conducted to understand how research in the CE and blockchain technology is developing (for the complete protocol read chapter 1.6). Using the search strings "blockchain" AND "circular economy" in Scopus resulted in 33 papers. Of each of these, the title and abstract were read through. If the title and abstract contained both the words blockchain and circular economy at least one time the paper was selected for further screening. This resulted in 18 papers. These were then thoroughly read which resulted in 12 papers that were included for this literature review. Papers were not included if they had no significant contribution to the CE and blockchain. For instance, some papers only mentioned blockchain and/or the circular economy once. This was deemed too irrelevant for this review. Table 3.2 has an overview of each of the selected papers including a short description of the paper's main findings, the type of paper, and the number of references. The following paragraphs will describe the papers and their findings that are most relevant to this thesis' research question.

Kouhizadeh et al. (2019) mention that blockchain technology can be of benefit for restoring at end-of-life and designing out waste. The ability of blockchain to reliably provide traceability, transparency, and a complete historical overview of materials, components, and products is crucial for value recovery methods. Here, authentication certificates can be used to assure the origin of a product. Blockchain can potentially also stimulate companies to trade their waste (industrial symbiosis), trade on secondary markets, and trade surpluses of energy (energy markets) by reducing transaction costs and processing time.

Various large companies, such as Walmart, Toyota, Alibaba, and ABB, are experimenting with blockchain technology and demonstrate CE related benefits (Kouhizadeh et al., 2020). Walmart is experimenting with blockchain to help prevent food waste and food fraud. Toyota is experimenting with the technology to enable shared autonomous vehicles, to help vehicle owners to monetize cargo space, a seat, or the use of their vehicle, and to improve value recovery assessment by tracking the history of a returned vehicle. Alibaba is working on a blockchain service that can inform consumers of the sustainable provenance of goods. ABB's blockchain platform aims to optimize smart grid markets. However, all these efforts have mainly been demonstrative. This is because companies still struggle with the stability, interoperability, and security of blockchain systems.

Other factors seem to be hindering blockchain implementation as well. One of these factors is regulation. Zhu et al. (2020) mentioned that a lack of regulation is the biggest

Figure 3.4: Flow diagram of selection of blockchain and CE articles



factor why blockchain is not gaining traction in China's energy sector. Similarly, Dindarian & Chakravarthy (2019) mention that regulatory and legal acceptance of blockchain is hindering developments in the waste management industry. Both papers also mention a lagging technological level of blockchain in their respective fields. Lähdeaho & Hilmola (2020) identified general skepticism against blockchain amongst companies in Finland and Russia.

Many kinds of solutions related to the CE are explored. For instance, Damianou et al. (2019) mentions the use of edge computing to increase the scalability of blockchain-based asset tracking networks. Koscina & Cluchet (2019) wants to use blockchain to incentivize plastic reuse. Alexandris et al., 2018 mentions blockchain to improve asset monitoring by tracking the location, condition, and availability. These parameters are necessary for effective value recovery. Narayan & tidström (2020) mention tokenization as a useful tool for coopetition (cooperative competition). Blockchain can be used to represent any asset into a token. By making the database publicly accessible, the barrier for companies to create value is not limited to the amount of information and knowledge available, but to the ability to use the information. Davidova & McMeel (2020) mention blockchain to improve cross-species bio-digital coliving. They philosophize questions related to the unique possibility of using blockchain to give species a digital wallet and cryptocurrency.

Overall, research in combined blockchain and CE literature is predominantly explorative/conceptual and the case studies mention a lack of actual implementation. This strengthens the notion that more research is necessary for how blockchain technologies can be actually implemented.

Table 3.2: Scientific papers on blockchain and the circular economy

Authors	Title	Type of Paper	Main Findings	Cited by
Kouhizdeh et al., 2020	Blockchain and the circular economy: potential tensions and critical reflections from practice	Descriptive multi-case study	Companies mention improved transparency, security, and accuracy of supply chian processes and a reduction in costs and processing time of transactions. However, efforts are mainly demonstrative.	17
Zhu et al., 2020	The development of energy blockchain and its implications for China's energy sector	Case analysis	The technological level of blockchain is still lagging in China's energy sector. However, the biggest obstacle is policy. China should loosen the regulatory environment.	3
Lähdeaho & Hilmola 2020	Business Models Amid Changes in Regulation and Environment: The Case of Finland–Russia	Case study (semi-structured interviews and a survey)	The majority of studied companies (region of Russia and Finland) remain skeptic of blockchain technology and do not aim to pursue its possibilities	7
Dindarian & Chakravarthy 2019	Traceability of Electronic Waste Using Blockchain Technology	Explorative multi-case study	Blockchain cases were in the experimental or pilot stage. The most succesfull blockchain applications are designed for specific use scenarios. The regulatory and legal acceptance of blockchain is lacking	1
Casado-Vara et al. (2018)	How blockchain improves the supply chain: Case study alimentary supply chain	Case study + concept paper	Blockchain model that improves shipment tracking, provenance of agricultural goods and efficiently processes transactions	166
Narayan & Tidström, 2020	Tokenizing coopetition in a blockchain for a transition to circular economy	Conceptual paper	Blockchain tokens can be used to represent information which can then incentivize companies to cooperate, which is necessary for the circular economy	3
Davidova & McMeel, 2020	Codesigning with blockchain for synergetic landscapes: the cocreation of blockchain circular economy through systemic design	Explorative paper	Explores questions how blockchain can improve cross-species bio-digital coliving. It raises the question of assigning value to to other species. What if beehives have a crypto-currency wallet and money where you had to pay the hive to harvest its honey? What if the hive paid locals who maintained flowerbeds?	0
Damianou, Angelopoulos, & Katos, 2019	An architecture for blockchain over edge-enabled IoT for smart circular cities	Conceptual paper	Edge computing can help reduce the storage capacity of IoT networks that run blockchain.	9
Koscina Lombard-Platet & Cluchet, 2019	PlasticCoin: an ERC20 Implementation on Hyperledger Fabric for Circular Economy and Plastic Reuse	Conceptual paper	Explores the potential of a cryptocurrency that empowers people to collect plastic waste	0
Kouhizadeh et al., 2019	At the Nexus of Blockchain technology, the circular economy, and product deletion	Explorative paper	The ability of blockchain to reliably provide tracability and transparency and reduce transaction costs and processing time is beneficial for areas related to the circular economy such as the service economy, industrial symbiosis, second hand markets, and energy markets	17
Alexandris et al., 2018	Blockchains as enablers for auditing cooperative circular economy networks	Conceptual paper	Provides a concept of a blockchain and smart contract design that can improve asset monitoring which is relevant for value recovery	4
Poberezhna 2018	Addressing water sustainability with blockchain technology and green finance	Discussion paper	Demonstrates how a sustainable future can be secured for our global water assets by combining Blockchain technology with green finance	8
Alexaki et al. (2018)	Blockchain-based electronic patient records for regulated circular healthcare jurisdictions	Conceptual paper	Proposed blockchain design that can provide data integrity, privacy, and higher efficiencies while sharing medical data	13

3.4 Blockchain and Product-Service Systems

A literature review was conducted to understand how research in PSS and blockchain technology combined is developing. Using the search strings "blockchain" AND ("PSS" OR "product-service system" OR "product service system" OR "servitization") in Scopus resulted in 13 papers. Of each of these, the title and abstract were read through. If the title and abstract contained the words blockchain and either PSS or servitization at least one time each, the paper was selected for further screening. This resulted in 8 papers. These were then thoroughly read. Papers were not included if they had a significant focus on PSS/servitization and blockchain. For instance, some papers only mentioned blockchain and/or PSS and servitization once. Others had the same abbreviation PSS that meant something else than product-service system. Table 3.3 has an overview of each of the selected papers including a short description of the paper's main findings, the type of paper, and the number of references. The next few paragraphs will describe the main findings relevant to this thesis' research question.

Out of the three, Huang et al. (2019) has the most holistic approach to PSS. He explores several ways how blockchain technology can solve major challenges found in PSS. Blockchain is proposed to be useful in three ways for PSSs. Firstly, the technology can be used to reliably track the whole lifecycle of serviced products and share the information with both the consumer and service provider. Furthermore, real-time important information of use can be collected and help service providers improve their PSS. Finally, this information can also trigger transactions between users and service providers that are fast and responsive. Huang et al. (2019) also mentions two challenges related to using blockchain in PSS. Firstly, smart contracts are irreversible. This means that a transaction for use, once issued, cannot be canceled. Similarly, blockchain's immutable properties prevent the correction of wrong data entries. Finally, all the information about product use can result in a lot of redundant data that has to be synchronized across all nodes. This can slow transaction processes.

Wenngren et al. (2020) explores how blockchain can support trust and decentralization in value chains. One of the problems that companies face when moving to PSS is difficulties to collaborate on equal terms and to create trust in large networks. The blockchain has three key features that are important in dynamic business collaborations, i.e., it provides transparency to all actors, it enables decentralized decision-making, and it ensures traceability of transactions. According to Wenngren et al. (2020) blockchain can serve as the trust mechanism that enables transparent collaboration between parties, and in which entries remain secured from alterations. By letting a distributed ledger verify that contracts between parties are being obeyed, more complex business ideas and agreements can be concluded because trust is integrated into the system. Using agent-based modeling this idea was tested. The model showed that trust can be established by having a win-win situation, having user behavior affect credibility in the network, and having a way of identifying and handling errors and cheating.

Wang et al. (2020) mentions blockchain is highly promising for maintaining mutual trust among stakeholders in PSS. A vehicle PSS is explored. By enabling the transparent and immutable properties of blockchain technology, vehicle conditions during use are easy to verify. This makes it easier to identify stage are made easier to be verified.

Figure 3.5: Flow diagram of selection of blockchain and PSS articles

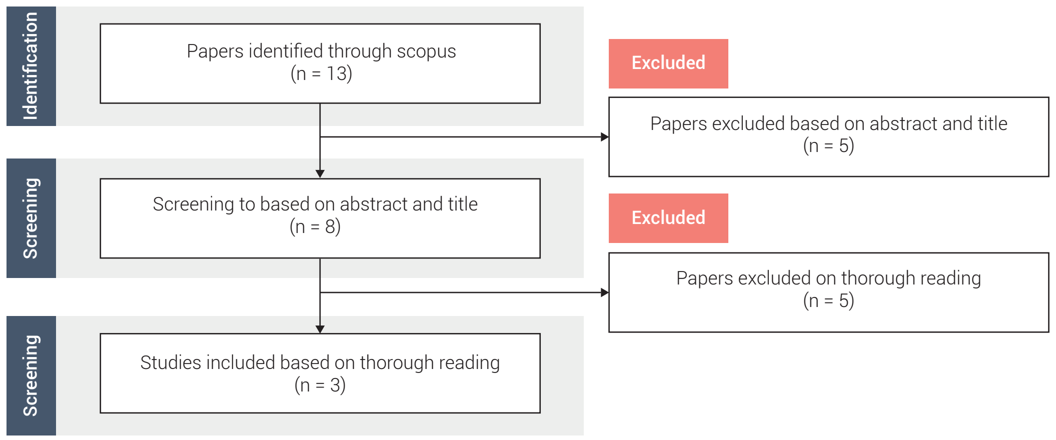


Table 3.3: Scientific papers on blockchain and the product-service systems and/or servitization

Authors	Title	Type of Paper	Main Findings	Cited by
Huang, Li, & Thürer (2019)	On the Use of Blockchain in Industrial Product Service Systems: A critical Review and Analysis	Review paper	Major challenges in PSS are product tracking and tracing, the triggering of service, and the delivery of service. Blockchain can potentially solve these issues by creating a synchronized database of all transaction at each node while smart contracts allow for responsive action. However, there are also challenges. For example, large amounts of redundant data, irreversible contracts and, consequently, reduced competition.	4
Wenngren, Lundgren, Ericson, & Lugnet (2020)	Distributed ledger technologies building trust in value chains?	Modelling study	This paper demonstrates how distributed ledger technology (DLT) can support trust and collaboration among decentralized actors in a value chain network through agentb-based modelling. By letting DLTs verify contracts between parties, more complex business ideas and agreements can be concluded because trust is integrated into the system. It also enables more actors to use the data and benefit from it.	2
Wang, Wang & Liu (2020)	Trust-Driven Vehicle Product-Service System: A Blockchain Approach	Conceptual study	This article deems blockchain as a highly promising technology for maintaining mutual trust among stakeholders in vehicle product-service system (PSS). The proposed framework in this paper consists of a blockchain-based data collection platform that enables all stakeholders update, verify vehicle information precisely. By increasing data immutability and transparency using blockchain technology, vehicle conditions during usage stage are made easier to be verified. This will likely shorten the time spent in identifying vehicle condition and service risks. As a result, mutual trust among stakeholders are maintained effectively.	0

Answer to sub-RQ 3:

"How are the Circular Service platform's solutions described amongst blockchain and circular economy- and blockchain and product-service systems-oriented literature?"

While research in CE and blockchain and PSS and blockchain is relatively minimal, there is quite some support for the CiSe solutions in the literature.

Confirmed CiSe Platform Solutions

Multiple scholars have explored blockchain as a tool for reducing transaction costs related to PSS. Kouhizadeh et al. (2019) mention the capability of blockchain to be used in the exchange for services versus products, and in doing so, reduce costs and processing time. Huang et al. (2019) specified that the technology is useful in triggering transactions between users and service providers in a faster and more responsive way.

Regarding transparent administration, Huang et al. (2019) mentions the technology can be used to reliably track the whole lifecycle of serviced products and share the information with both the consumer and service provider. Additionally, Wenngren et al. (2020) mentioned blockchain can serve as a trust mechanism that enables transparent collaboration between parties, and in which entries and agreements remain secured from alterations.

Unconfirmed CiSe Platform Solutions

There was no mention of a need for direct payment of micro-transactions in order to avoid a costly intermediary. This questions if this solution is relevant. What is further problematic is that most of these articles remain conceptual. While scholars support the ideas of reduced transaction costs and benefits from transparency, these are not validated through experiments. Kouhizadeh et al. (2020) and Dindarian & Chavrakavarthy (2019 researched several companies and identified a lack of successfull efforts. It makes it hard to judge the viability of the CiSe platform.

Additional Findings

Additional benefits CiSe might capitalize on is that the technology can be used to reliably track the whole lifecycle of serviced products and share the information with both the consumer and service provider. Real-time important information of use can be collected on a product level. This can help service providers improve their PSS.

Huang et al. (2019) also mentiond three problems. Firstly, smart contracts are irreversible. This means that a transaction for use, once put into motion, cannot be canceled. Similarly, blockchain's immutable properties prevent the correction of wrong data entries. Finally, all the information about product use can result in a lot of redundant data that has to be synchronized across all nodes. This can slow transaction processes.

3.5 Takeaways

First of all, the systemic literature review on blockchain designs identified no direct comparison with the CiSe platform. Categorizing blockchain designs into a similar use-case as the CiSe platform (Autonomous Market) identified three promising results:

1. Blockchain can **likely reduce transaction costs**
2. Blockchain can be **a usefull tool to provide a transparent and secure database**
3. Blockchain designs also mention **increased responsiveness**

The systemic review of blockchain technology, CE, and PSS literature also identified some limitations. Three challenges were identified:

1. Smart contracts are **irreversible**
2. Sensors can **wrongfully trigger** and store infomration that is immutable
3. Rendundant data can **limit system throughput**

The problem is that the majority of the literature is conceptual. It is a limitation for assessing the viability of the CiSe platform and blockchain in general. To move the understanding of blockchain forward, more research is necessary in the implementation of blockchain systems. The next chapter will describe the maturity of blockchain technology, and several blockchain companies found through desk research to get insights herein.

II. Business Analysis

Chapter 4
Blockchain Desk Research

In this chapter, I will describe the business analysis of blockchain technology. It was done through desk research. I will describe the maturity of blockchain and a range of blockchain companies and their blockchain use-cases. In this chapter, I will answer the fourth sub-question: ***How do companies' blockchain designs compare to that of the Circular Service platform?***

4.1 Blockchain Maturity

Companies are becoming increasingly interested in blockchain for its disruptive potential (Hughes et al., 2019). Kouhizadeh et al. (2020) mentioned several large companies, such as Walmart, Alibaba, Toyota, and UPS, who experiment with blockchain technology. IBM has even invested over $200 million in the technology and hired 1000 staff members in blockchain research (Carson et al., 2018)). Companies are aware of blockchain's potential. However, how is the business landscape developing? Are companies using it to stimulate PSS and the CE? Are their companies or start-ups with a blockchain application similar to the CiSe platform? Are they successful?

According to Gartner (2019), blockchain technology is within the Trough of Disillusionment phase (Figure 4.1). The Peak of Inflated Expectations has been passed with the bursting of the Bitcoin bubble in 2017. The hype has subsided and is replaced by more realistic expectations. Most blockchain projects are still stuck in the experimentation phase (Gartner, 2019). Gartner (2019) estimates that the market will climb out of the trough of disillusionment phase by 2021, whilst full technical scalability and operationality is expected until at least 2028. The technology is thought to see the feasibility of scale somewhere in 2021 to 2023 according to Mckinsey & Company (Carson et al., 2018).

One could argue that blockchain technology has already achieved success. The first application of the technology, Bitcoin, has a market cap of over 228 billion dollars, as of October 2020, and an average of over 37 million dollars being traded every day (coinmarketcap.com). However, Bitcoin is not yet able to be competitive with financial services such as VISA. The seven transactions that Bitcoin can process

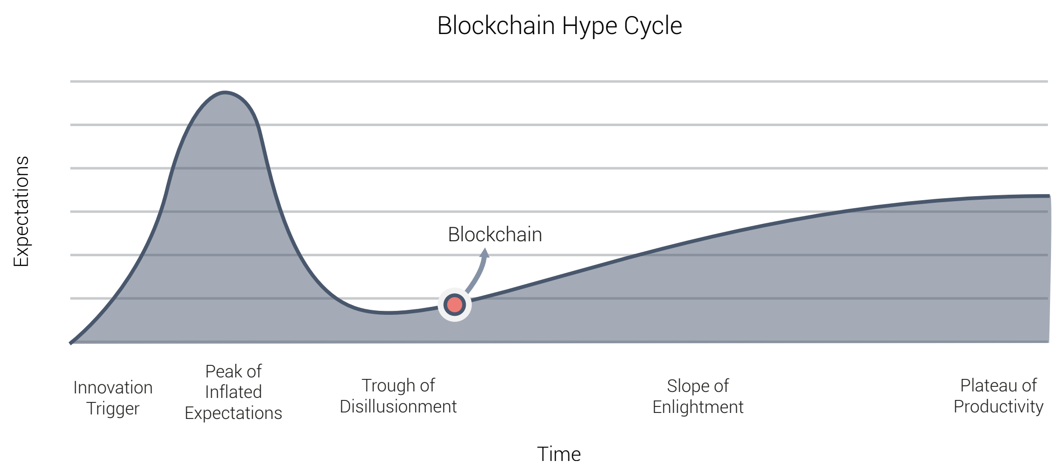


Figure 4.1: The blockchain Hype Cycle *source: Gartner (2019)*

per second pales compared to VISA's capability to process 65000 transactions per second (USA VISA, 2017).

In 2014, with the Ethereum cryptocurrency, Vitalik Buterin introduced a new generation of blockchain technology by finding a way to store and execute smart contracts on the ledgers. Smart contracts allowed for the design of decentralized applications called Dapps. Its most successful Dapp is Cryptokitties that has a valuation mark of over 4 billion dollars (Koscina et al., 2019). It is a game where players can collect, breed, and sell cats. It uses smart contracts to track the ownership of cats and determine how new cats are generated. It is a game that can hardly be considered "disruptive". Ethereum is the second most successful cryptocurrency with a market cap of almost 43 billion dollars and an average daily volume of almost 19 billion dollars (coinmarketcap.com).

Blockchain technology has many more opportunities than just a cryptocurrency. As pointed out by the literature review (chapter 3.2) there are many blockchain use-cases. Blockchain technology is proposed as a tool to provide transparency and real-time traceability in supply chains, provide security and privacy of healthcare records, and provide efficient and responsive transactions. The question is, how are companies/start-ups using blockchain? Are they performing well? Are they close to going live? Are there companies similar to the CiSe platform? Can they tell us anything about its viability?

4.2 Blockchain Companies

To answer the sub-questions desk research was performed in which 32 blockchain companies were identified (Table 4.1). Each of these companies has been evaluated based on the use-case framework (chapter 3.1). The desk research used the Google search engine. It should be noted that this method is prone to bias. Nevertheless, it resulted in quite a substantial amount of companies. The following paragraphs mention the most relevant and interesting findings.

Two companies, Circularise and Monochain, respectively, mention the CE. However, no company mentioned PSSs or servitization. Circularise states the following on their website *"transparency and traceability for a circular economy"*. Monochain mentions the following statement *"a blockchain platform empowering brands & retailers to adopt a sustainable circular economy-driven practice"*. They aim to improve transparency and traceability in supply chains, which corresponds with Kouhizadeh et al. (2019), defined blockchain opportunities for the CE.

It is worth mentioning that ten companies were found that focus on sustainability. These are CERA, Everledger, Omega Grid, PlasticTwist, Provenance, TraceMet, CarbonX, Ecocoin, Swachhcoin, and Recereum. Respectively, CERA, Everledger, Provenance, and TraceMet use blockchain technology to improve supply chains' sustainability. As an example, Provenance provides provenance of products to verify their sustainable sourcing. Omega Grid rewards users for using clean, local energy. Recereum incentivizes people to separate their waste using tokens.

One of the few companies that are live is Tradelens. It is a blockchain system that provides provenance of shipping goods and reduces the costs and processing time in shipping handovers. Multinational IBM and shipping conglomerate Maersk are behind it. It is currently operating live and, according to its site, has helped process over 25 million containers as of July 2020. They mention increased efficiency and faster document-handling by replacing manual processes. They also mention to securely share information that stimulates collaboration

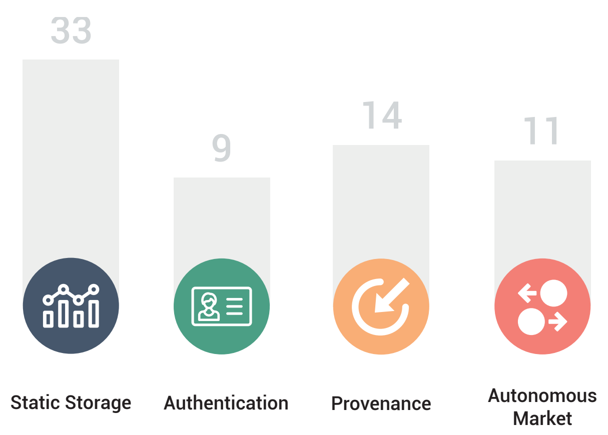


Figure 4.2: Use-cases amongst blockchain companies

Table 4.1: Blockchain Applications

Company	Area of Operation	Year Established	Blockchain Use-case	Live?
1.Bext360	Supply chain	2016	DP	No
2.CERA	Supply chain	2017	DP Au	No
3.Chemchain	Supply chain	2017	DP	No
4.Circularise	Supply chain	2016	DP	No
5.Everledger	Supply chain	2015	Au	No
6.Grain Chain	Supply chain	2013	AM DP	No
7.Minespider	Supply chain	2017	DP	No
8.Monochain	Supply Chain	2015	DP	No
9.Provenance	Supply Chain	2013	DP Au	No (almost)
10.Shipchain	Supply Chain	2017	DP	No
11.Tradelens	Supply Chain	-	AM DP	Yes (since 2018)
12.TraceMet	Supply Chain	-	DP Au	No
13.Factom	Data storage	2014	-	Yes
14.Filecoin	Data storage	-	-	No
15.PeerNova	Data storage	2013	-	No
16.Doc.ai	Healthcara	2016	-	No
17.Vital Chain	Healthcare	2018	Au	No
18.Omega Grid	Energy	2017	AM	No
19.Chronicled	Life science	2014		No
20.PlasticTwist	Plastic Reuse	2018	AM	No
21.Evernym	Digital credentials	2013	Au	Yes
22.Minds	Social media	2011	AM	Yes (sinde 2015)
23.Steemit	Social media	-	AM	Yes (since 2016)
24.Mediachain	Media	2016	-	No
25.TraDove	Trade	2012	AM	Yes
26.Medici	Land governance	2018	-	Yes
27.Voatz	Voting	2015	DP Au	No
28.Votem	Voting	2015	DP Au	No
29.CarbonX	Carbon trading	2018	AM DP Au	No
30.EcoCoin	Sustainable behavior	2015	AM	No
31.SpaceChain	Satellite network	2017	-	No
32.Swachhcoin	Waste management	2016	AM	No
33.Recereum	Waste management	2017	AM	No

Legenda:

Distributed Storage*
Data Provenance DP
Autonomous Market AM
Authentication Au

* *At its core every blockchain system is a database*

Answer to sub-RQ 4:

"How do companies' blockchain designs compare to that of the Circular Service platform?"

The results are mixed. First of all, there was no design directly comparable with the following definition of the CiSe platform: *A tool that automatically and autonomously processes payments related to collectively serviced pay-per-access and pay-per-use products*. Secondly, no design could be found in general that focuses on PSS. Two companies could be found that specifically mentioned the CE. Unlike the CiSe platform, these companies, Circularise and Monochain, focused more on the blockchain use-case provenance and aim to increase transparency and traceability in supply chains.

Confirmed Solutions of the CiSe platform
Tradelens is a company that is live and seemingly successful. It mentions improved and more efficient administration processes. This indicates that the CiSe platform might be able to reduce administration costs of pay-per-use and pay-per-access products. Tradelens also mentions their platform improves the secure sharing of information, which in turn stimulates collaboration. They also mention having processed over 25 million containers as of July 2020. Indicating that the technology well scalable.

Additional Findings
A lot of companies have been established for quite a while and still are not yet live. For instance, Provenance and PeerNova were established in 2013. After seven years of development these companies are still not live. This suggests that there are a lot of challenges related to implementing blockchain technology. It is likely that the CiSe platform will take quite some time before going live.

An additional note is that these companies are hard to assess on their success and specific design as they are less open about their design. More in-depth research into these companeis could better clarify their challenges and how they use blockchain technology.

4.3 Takeaways

One company, Tradelens, is live and can be compared with the CiSe platform. it mentions the following promising results:

1. Tradelens mentions blockchain as a useful tool to reduce transaction costs and
2. Tradelens mentions increased transparency.

However, there are some concerns. These are as follows:

1. Many companies have been in the running for multiple years without a product on the market. It is an indication that blockchain designs are tough to implement

Overall, the immaturity of blockchain technology is a limitation to its current viability. It is hard to assess if specific technical designs are possible on a larger scale. Technological challenges will likely take quite some time to overcome. Before putting many resources into realizing the CiSe platform, more detailed information into the specifics of the CiSe platform is necessary. The following chapter will cover a case study of a Bundles washing machine. It provides additional insights into the potential and problems of CS.

III. Exploratory Case Study

Chapter 5

Bundles Case Study

In this chapter, I will describe the case study of Bundles. First, I will describe the washing machine PSS. Following, I will describe the case context, which includes which stakeholders I take into the CS proposition and which not. Next, I will address the case. It consists of a service blueprint of the new CS proposition combined with a qualitative risk analysis. Finally, I will validate the case study through interviews with Henk Kuipers, Nilesh Nahar, and Julieta Bolanos. The fifth and final sub-question will be answered in this chapter: ***How do the Circular Service platform and collective servitization affect the Bundles' washing machine service?***

5.1 Bundles Washing Machine Offering

Bundles is a Dutch company that was founded in 2014 and is based in Amsterdam. They provide various use-oriented PSSs (figure 5.1). Their washing machines are available in a combined pay-per-access and pay-per-use fashion (figure 5.2). Users pay a monthly fee for access and an additional fee for each time they ran a cycle. The washing machines have a smart-plug, which tracks the power usage of the washing machines. From this data, Bundles can invoice consumers for use. Bundles offers two different washing machines from Miele, a basic model and a more expensive model with an automatic detergent dispensing system. Additionally, the more expensive subscription model comes with a convenient detergent service.

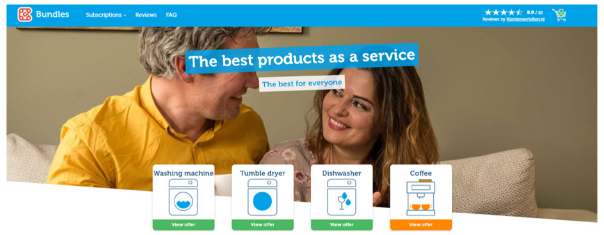


Figure 5.1: Bundles Washing service offerings, *source: bundles.nl*

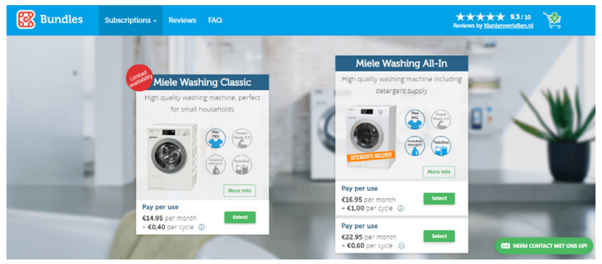


Figure 5.2: Bundles Washing Machine Subscription Models, *source: bundles.nl*

Bundles buys the washing machines from Miele and retains ownership of them. Bundles aims to keep their washing machines in use for as long as possible. They are responsible for their maintenance and repair, and, after consumers terminate their contract, Bundles is responsible for the pick-up and refurbishment of the washing machines for re-use. Bundles outsources these services to their logistics partner Vonk en Co. For extensive repairs, Bundles calls Miele.

The Bundles washing machine PSS provides consumers a high-quality washing machine. Users do not have to pay for the washing machine upfront. The PSS comes with convenient services such as installation, repair, pick-up, flexibility to terminate the contract at any time, and customer support through the Bundles app and customer helpline.

5.2 Case Context

Figure 5.3 shows a stakeholder map of the Bundles washing machine proposition from Nahar (2019). The primary stakeholders are in the central circle (within the dashed red circle). On the edge remain the secondary stakeholders. The image illustrates the different exchanges between every stakeholder. There are six interactions; data, monetary growth, product, service, customer relationship, and monetary compensation.

The exploratory case study only focuses on the primary stakeholders. I consider these stakeholders to be most crucial for the service.

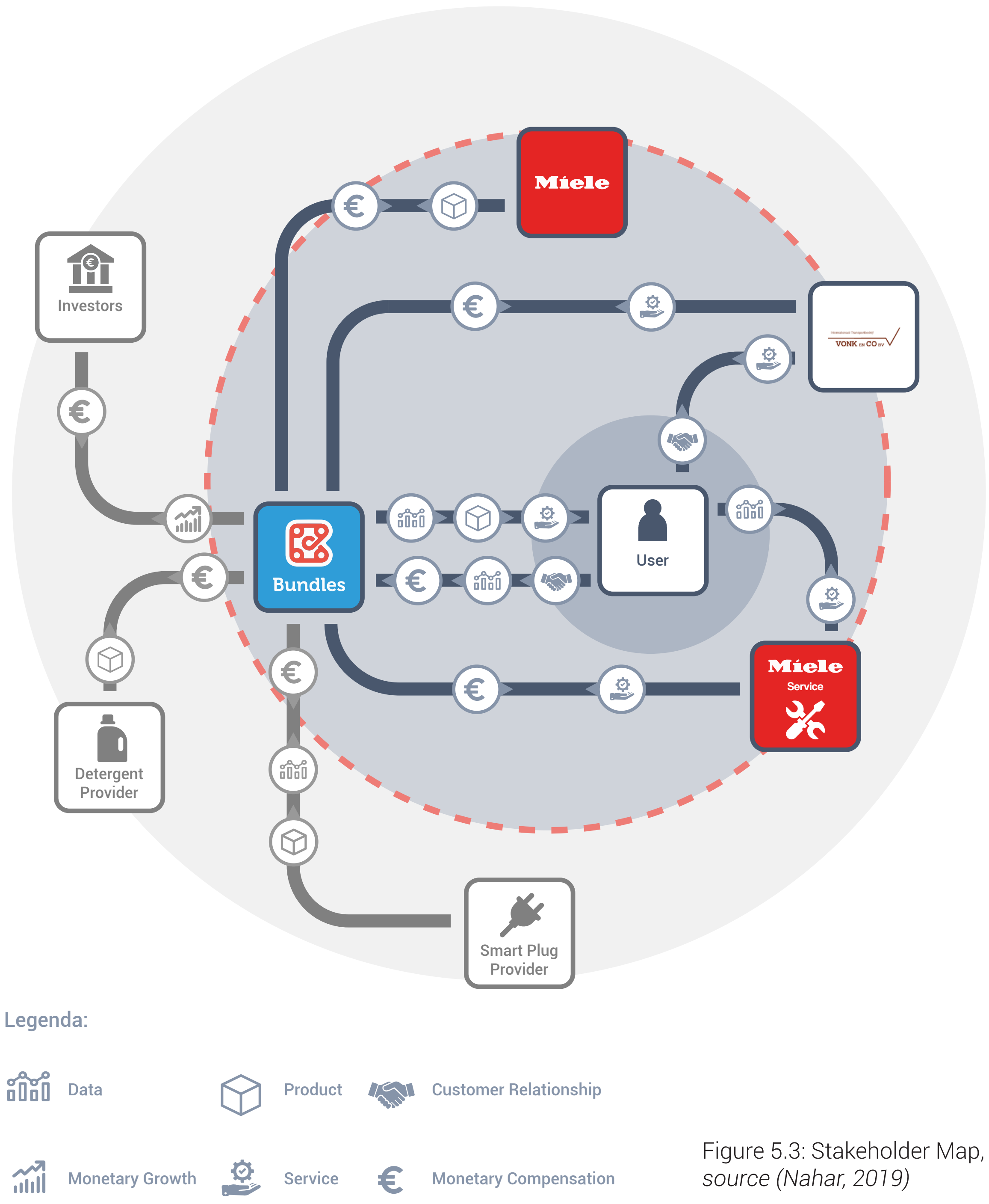


Figure 5.3: Stakeholder Map, *source (Nahar, 2019)*

5.3 Adressing the Case

Figure 5.4 illustrates the service blueprint of a collectively serviced washing machine. Eight distinct phases represent the steps necessary to provide the convenient washing experience described previously (chapter 5.1). The CiSe platform mainly impacts the flow of money. For this reason, each phase has a monetary flow related to each member's costs. Moreover, related to the costs, the risks are shown at the bottom of each phase. For comparison, I also made a service blueprint of the conventional Bundles washing machine proposition. It is in appendix D.

The start of the figure shows the required **initial investments (1)** for the service. In a CS business model, I assume Miele would pay for the costs related to the washing machine, and Vonk en Co would have to invest in warehousing and transport necessary to provide the pick-up, delivery, and installation services. There is a high risk involved here for Miele as the washing machines are expensive. Vonk en Co also has relatively high costs. As a result, Bundles vastly reduces its investment burden. The total initial investment costs might reduce compared to the conventional Bundles business model. It is because Bundles avoids the costs for added value. It is striking that during the following seven service phases, the transactional relationship disappears between Bundles, Miele, and Vonk en Co (see Appendix D for a comparison). When a **client purchases (2)** a subscription model and fills in the necessary details and payment method, Bundles receives a notification and sends a confirmation mail to the new customer. Following, Bundles checks on the availability of washing machines at Vonk en Co. If there are washing machines left, Vonk en Co prepares the washing machine for use and installation. Bundles contacts Miele for a new washing machine when there are no none left. Bundles used to pay Miele for the washing machine and Vonk en Co for their preparation services. However, with the CS business model, this does not happen anymore. The next step consists of **installation (3)** of the washing machine. Vonk en Co delivers the washing machine to the client and installs it in their home. Only in the fourth step, the **use (4)** phase, do Bundles, Miele, and Vonk en Co receive revenue. Each time a user runs a washing cycle, the CiSe platform directly compensates the CS members Bundles, Miele, and Vonk en Co. Every month users will pay a fee for access. **Maintenance (5**) comes mainly with costs for Vonk en Co and Miele. When clients **terminate (6)** the contract, Vonk en Co is called upon to pick-up the washing machine. Miele and Vonk enCo then **recondition (7)** the washing machine for another use cycle. Some additional **expenses (8)** are related to operational costs such as employees, ads, and websites.

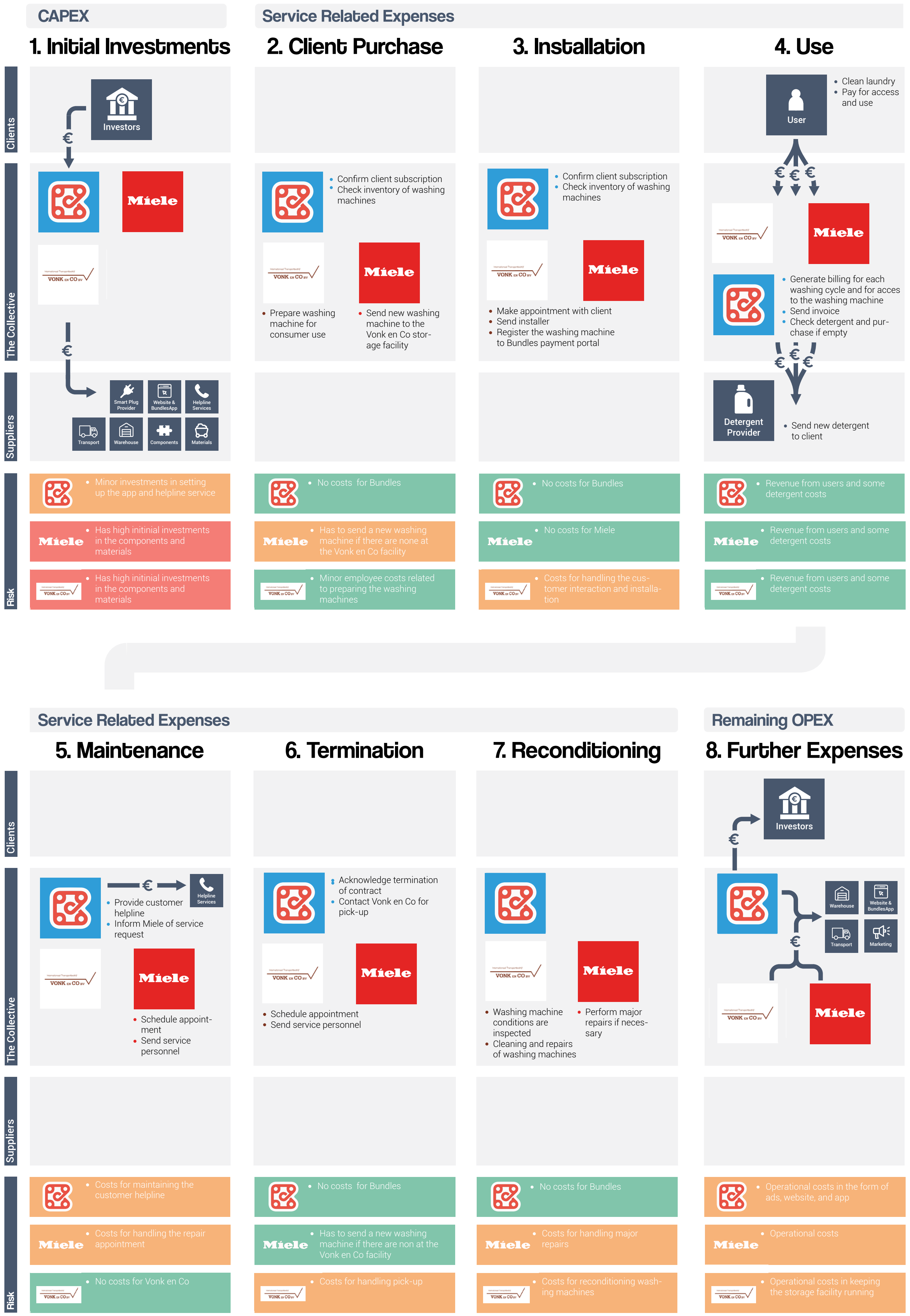
5.4 Results

The service blueprint helped discover and confirm several benefits and problems of CS. These benefits and problems are described in the next few paragraphs. The positive results will be discussed first.

There is some promise that the cost for added value and the transactional relationship disappears between Bundles, Miele, and Vonk en Co. Most of the administration centers at the moment users pay for use and access. It is then handled automatically and autonomously by the CiSe platform. With the CS business model, Miele now covers the manufacturing costs for the washing machines. Miele does not sell the washing machines to Bundles anymore with extra added value. Overall, this could mean that a CS washing machine's total initial investments become lower than the conventional Bundles business model. It might result in significant economic benefits. To better understand the significance of these benefits requires more quantitative research into the costs of Bundles, Miele, and Vonk en Co related to this service. Unfortunately, Bundles was not willing to provide this data.

Due to CS, the initial investment risks spread amongst the collective members. Miele takes up the burden of paying for the washing machines and extensive repairs. Vonk en Co becomes responsible for the costs related to repair, installation, and pick-up services. Reducing the risk could make a CS business model attractive for companies.

Figure 5.4: The money flow of a collectively serviced washing machine



However, it is not necessarily beneficial that the initial investments spread. Firstly, Bundles's role becomes minimal. In the original business model, Bundles has full ownership and responsibility for the washing machine. They pay for all the costs. With the CS business model, Bundles might be irrelevant. This is for two reasons. Firstly, Miele and Vonk en Co take over most of Bundles' responsibilities. Miele takes over the costs related to the washing machine and the costs for extensive repairs. Vonk en Co pays for the installation, pick-up, and minor repair services. Secondly, Bundles does not add any value to the washing machine. Apart from the smart plug, the washing machine is still the same. These reasons might make Bundles redundant. Miele is also a massive company with a revenue of over 4 billion dollars per year. It easily has the resources available take over Bundles' role.

Another problem is that the original Bundles PSS is profitable for Miele and Vonk en Co without any long-term risks. Miele and Vonk en Co receive revenue for each washing machine and service they provide. With a CS business model, a large portion of Bundles' risk shifts to Miele and Vonk en Co as they now also receive money in incremental steps over a long period.

5.5 Validation

For the validation, I interviewed Henk Kuipers, who works at the SFL, and Nilesh Nahar and Julieta Bolanos, who both wrote a master thesis on Bundles. I proposed my results to them. The following paragraphs will first cover the benefits of a CS Bundles washing machine.

Nahar and Bolanos agreed that CS through the CiSe platform might be beneficial for Bundles, Miele, and Vonk en Co for three reasons. Firstly, Nahar mentioned that Bundles has high administration costs related to their transactional relationship with stakeholders. It is because Bundles has to process and coordinate these processes manually, as there is a lack of automation. Secondly, Nahar mentioned that Bundles has high capital investments from having to buy all the washing machines, limiting scalability. A CS business model can reduce the risk and increase scalability by spreading the risks. Finally, Nahar and Bolanos mentioned a lack of collaboration that hinders the full potential of PSS. Compensating Miele and Vonk en Co, as long as the washing machine is working, might align their incentives and stimulate cooperation. Cooperation is currently minimal. Vonk en Co and Miele have unique information on the wear and tear of the washing machines. These are currently not shared (enough). By designing the Miele washing machines with the PSS could results in an overall beter product and possibly increased profits. Having Miele have insight into the washing machines' usage data could help them improve the washing machines specifically towards the PSS.

Nahar, Bolanos, and Kuipers agreed that there is quite some risk that makes it unlikely for Miele and Vonk en Co to start a CS business model. Especially since the current collaboration is are already profitable for them. Bolanos and Nahar mentioned that Bundles has high repair costs. It is due to four reasons:

1. The Miele washing machines can not handle multiple use-cycles very well
2. The washing machines are hard to repair
3. Labor costs for repair are expensive
4. Older machines become increasingly expensive to repair

Bolanos mentioned that costs could be up to 400 euros for a single repair. In comparison, the washing machines cost around 1000 euros new. Bundles also expects the washing machines to be useable for only ten years instead of Miele's twenty-year guarantee. It means they will have to buy new machines more often. Other costs are related to people that do not want refurbished washing machines and often request a new washing machine instead of a refurbished one. Nahar, Bolanos, and Kuipers agreed that these risks make it hard for Miele and Vonk en Co to join the CS business model.

Overall, Nahar, Bolanos, and Kuipers agreed that Miele would not need to join a CS proposition with Bundles. Bolanos and Kuipers mentioned that Miele is completely capable of servicing washing machines themselves. Bundles is just a small client for them. To put things into perspective, Bolanos mentioned that Miele produces over 2000 washing machines per day. It is the same amount as Bundles' complete washing machine inventory. Nahar added that Bundles does not add any value to the washing machines apart from the smart plug. It makes them not necessary in a CS business model with Miele and Vonk en Co. Nahar and Kuipers also mentioned that Miele had done service tests themselves in Germany. Kuipers and Nahar mentioned that Miele sees Bundles as a small part. Bolanos mentioned that for Vonk en Co the Bundles washing machines are a tiny part of their revenue. Kuipers mentioned that if Miele and Vonk and Co wanted to start a CS business model on the CiSe platform, then they would buy over Bundles.

5.6 Takeaways

There are some promising results and some concerning ones. The promising results are as follows:

1. The transactional relationship disappears
2. The costs for added value disappear
3. The risk spreads amongst multiple members

However, a **collectively serviced Bundles washing machine will likely not happen** this is for four reasons:

1. Bundles will lose their role as risk-taker
2. Bundles does not provide any additional value.
3. Miele has the resources available to do the washing machine service themselves.
4. Miele and Vonk en Co currently have a profitable collaboration with Bundles without long-term risks.

The next chapter will discuss all the results.

Answer to sub-RQ 5:

"How can the Circular Service platform and collective servitization be introduced in Bundles' washing machine offering and how does it affect the washing machine offering?"

The case study identified several benefits and some limitations. Overall, it seems that a collectively serviced Bundles washing is unlikely to happen. First, the benefits are presented, following the limitations.

Benefits of a Collectively Serviced Bundles Washing Machine:
The case study of a collectively serviced Bundles washing machine might be promising for three reasons. First of all, the total initial investments decrease by avoiding the costs for added value. The investments also spread amongst Miele and Vonk and Co. These two phenomena lower the barrier for entry and improve the scalability of the washing machine offering. Secondly, the transactional relationship disappears between Bundles, Miele, and Vonk en Co. This relationship comes with high administration costs for Bundles in their current PSS. By avoiding these costs and using the CiSe platform to handle the revenue distribution efficiently, the CS washing machine business model could see significant economic benefits. Finally, CS might stimulate collaboration, and this could result in a better product and more profits. There is much potential here as the current PSS sees a lack of collaboration. Data is fragmented, and the washing machines are not optimized for multiple use-cycles and repair. Miele and Vonk and Co also have a different role and expertise within the value chain and can provide unique value to the washing machine.

Limitations of a Collectively Serviced Bundles Washing Machine:
Even though there are some benefits, it is improbable that Bundles, Miele, and Vonk and Co will start a CS business model. It is for three reasons. First of all, Bundles will lose its role as risk-taker. Bundles also does not provide any additional value to the product. For this reason, their role in the CS business model becomes irrelevant when Miele and Vonk en Co join. Secondly, if Miele wants to, they can easily perform each of the service processes themselves. They are a large multinational with a yearly profit of over 4 billion. Finally, Miele and Vonk en Co currently have a profitable collaboration with Bundles without having long-term risks.

IV. Evaluation

Chapter 6
Discussion

In this chapter I will discuss potential problems related to the results of this study. First, is a general discussion. Following, I will discuss the results related to each of the reseach steps. These consists of the literature study, business analysis, and explorative case study.

6.1 General Discussion

When working on blockchain technology and CS, it was found to be hard to make definitive statements. Blockchain technology is still seeing much experimentation, and CS is an idea of which the concept has no mention in literature. As a result, this thesis is explorative of nature and qualitative. It has two intricacies. First of all, the interpretation of the qualitative data may be prone to bias. Moreover, most results of this thesis are not conclusive and mainly function as a basis for future research.

6.2 Literature Study

The barriers of CS, as defined by the SFL, were researched on their relevance by reviewing the barriers of PSS. It might be that there are more and different barriers in CS that are not reflected in PSS literature. The results remain inconclusive. The progress of CS is also limited by a lack of support of the definition of CS in literature. Overall, it emphasizes a need that more research is necessary. In order for the CiSe platform to be relevant, there has to be a need for CS.

Furthermore, the systemic literature review on different blockchain designs provided many results (for the search strings, see chapter 1.6). Even when using a limited scope of papers published in the years 2019 and 2020 resulted in 3872 papers. Eventually, the review only included 51 papers. These were considered a blockchain design. It is likely that, out of the 3872 articles, more papers fit the protocol. However, this literature review was limited to one person. With so many articles, some were likely overlooked. Another problem is that the blockchain papers could become quite technical. For instance, some papers focussed extensively on the specific codes and algorithms of their designs. It lies outside of my expertise as an Industrial Ecologist. It made it hard to retrieve relevant information and to categorize designs into the right use-case(s). Overall, it is evident that much research is being done into blockchain technology. It is likely due to the broad application of blockchain technology. What industries do not benefit from secure and accessible databases or reduced costs by avoiding intermediaries? While this notion is likely the ground for much research, many papers seem to remain conceptual. All of the 51 designs found through the systemic literature review were conceptual. There is likely some bias here since the literature review protocol searched specifically for designs. Designs tend to be more conceptual by definition. The results of the systemic literature review on blockchain and CE and blockchain and PSS literature conveyed the same limitation. The majority of the papers were conceptual. The abundance of conceptual papers is a limitation of this thesis' research question. Addressing the potential of blockchain in specific fields might be exciting but, at the moment, does not move the implementation of blockchain technology forward. Overall, more research is necessary in this regard.

The literature review into blockchain technology, PSS, and CE revealed some additional challenges and promises. Blockchain can provide real-time data that can help service providers monitor each product. While the CiSe platform aims to reduce costs, a key manager comes with additional costs and can become problematic. How much are these costs? Do they outweigh the benefits of reduced administration costs? If so, this is problematic. Other problems are that the sensitivity of blockchain systems move to the sensors. The autonomous and automated processes and blockchain's immutability can result in the wrongful execution of transactions that can not be reversed. Also, a lot of redundant data of use and on transactions can clutter and slow down the whole system. More research is necessary for how these challenges are overcome.

6.3 Business Analysis

To address the issue of implementing blockchain applications, desk research was done on different companies. It resulted in 32 different companies, of which a significant portion mentioned a sustainable motive. There is likely some bias here. Finding companies was limited by using Google and general keywords such as "blockchain", "company", and "start-up" and was based on some tips from this thesis' committee as well. Another problem is that, unlike the literature designs, these companies are not transparent about their designs. Most companies had minimalistic websites with minimal information. Most websites functioned only as contact pages. It made it hard to assess the companies on their use-case, compare them with the CiSe platform, and assess the implementability of blockchain technology. Only 6 out of the 32 companies was live. This result is likely skewed in favor of companies that are live. More successful companies are likely to show up more frequently through Google. Still, there is an overall abundance of companies that are not yet live after five or more years. It is an indication that the technology has many implementation challenges. Overall, there is a need for more qualitative and quantitative data on these companies.

6.4 Explorative Case Study

While SFL provided contacts at Bundles, it was not possible to get in touch with employees at Bundles, Miele, and Vonk en CO. This limited the case study in getting sufficient quantitative data. Precise numbers on the avoided administration costs, avoided costs for added value, and how the initial investments spread in different PSS are crucial in determining the potential effectiveness of the CiSe platform. PSS business models, where these costs are high, are likely best suited for the CiSe platform. This case study was also limited to two other stakeholders. Miele and Vonk en Co have a profound contribution to the washing machine PSS. However, research into secondary stakeholders, such as the detergent provider, could provide exciting results. This case study is also limited to one business model.

Nevertheless, the case study provided valuable insights into benefits and problems of CS and the SFL had not yet mentioned. The most profound conclusion is that a CS business model is unlikely to happen between Bundles, Miele, and Vonk en Co. One of the reasons a collectively serviced Bundles washing machine was hindered was because Bundles did not provide any additional value to the washing machine. Miele is also a huge company compared to Bundles. In a broader context, this tells us that this is likely the case in other value chains. More equal value chains, where every stakeholder adds unique value, might be better suited for CS. It further emphasizes the need for the SFL to research the need and intricacies of CS. If there is no need for CS, then CiSe is irrelevant. The CiSe platform has to address the right problems for it to be adopted.

Chapter 7 **Conclusion**

In this chapter I will first briefly describe the overall approach of this research. Following, I will answer all the sub-questions and finally the main-research question.

This research used a threefold structure in order to answer the main research question of identifying the effectiveness of the CiSe platform to help overcome CS barriers. The literature study provided background information on the CE and PSS. It provided insights into the problems and need for CS. The study also consisted of a systemic literature review that provided an overview of blockchain designs amongst the literature and an overview of the state of combined blockchain and CE and blockchain and PSS literature. The purpose was to find information that could help explain the technical and social viability of the CiSe concept. Due to a predominance of conceptual papers, business analysis was done. Through desk research, different blockchain companies were identified and compared with the CiSe platform. Finally, since there was insufficient evidence regarding the CS in the literature, an exploratory single-case study was done. It helped to identify additional problems and benefits of CS within a specific context.

Sub-question 1: *"How are the Sustainable Finance Lab's defined circularity requirements and collective servitization problems described amongst the product-service system and circular economy literature?"*

First of all, the definition of CS is not supported in the literature. Nevertheless, there is some support in PSS and CE literature that CS can significantly improve circularity. Scholars regard PSS as promising in stimulating companies to behave more circularly (confirming requirement 1: *Products are serviced instead of sold*). By compensating multiple stakeholders for as long as the product is working, each becomes incentivized to increase resource-efficiency and product longevity. There is also support for the second circularity requirement of the SFL: *The entire life-cycle of products must be considered*. With CS, multiple stakeholders will likely work more closely and adapt and integrate business processes. Furthermore, the benefit of spreading initial capital investments amongst multiple members and barriers of high administration costs seem both relevant. There is also some mild support in favor of the share innovation costs. Generally, transparency and sharing resources will improve the overall PSS.

The literature does not mention an increasing complexity of ownership and the need for micro-transactions or the need to handle micro-transactions directly.

Sub-question 2: *"How do the Circular Service platform's solutions compare to blockchain designs in literature?*

First of all, it is striking that there is no direct comparison to the CiSe platform. None of the designs mention PSS or anything similar. However, multiple designs can be categorized in the same use-case category. These mention reduced transaction costs and increasing transparency of data as a reason to use blockchain technology.

Papers mention additional problems. Blockchain systems are limited in their scalability and are less flexible. Private key management is also difficult and can become costly when handeled by an intermediary.

However, the literature designs are all conceptual and demonstrative. This raises questions if these solutions and ideas can be applied at a larger scale and within the current infrastructure.

Sub-question 3: *"How are the Circular Service platform's solutions described amongst blockchain and circular economy- and blockchain and product-service systems-oriented literature?"*

There is support for the idea that blockchain can be used to reduce transaction costs and stimulate transparent collaboration. Combined blockchain and PSS literature mention an additional benefit that payments for a service can be increasingly responsive with blockchian technology. Data of use can be tracked real-time.

The literature also mentioned three additional problems that can happen when servicing products through blockchain technology. Firstly, smart contracts are irreversible. This means that a transaction for use cannot be canceled. Similarly, blockchain's immutable properties prevent the correction of wrong data entries. Finally, all the information about product use can result in a lot of redundant data that has to be synchronized across all nodes. This can slow transaction processes.

Sub-question 4: *"How do companies' blockchain designs compare to that of the Circular Service platform?"*

There is no direct comparison to the CiSe platform. None of the designs mention PSS or anything similar. Nevertheless, Tradelens is a company that is live and it mentions improved and more efficient administration processes and secure sharing of information.

Most companies are not yet live.This suggests that there are a lot of challenges related to implementing blockchain technology. It is likely that the CiSe platform will take quite some time before going live.

Sub-question 5: *"How do the Circular Service platform and collective servitization affect the Bundles' washing machine service?"*

There is some promise that the transactional relationship disappears between Bundles, Miele, and Vonk en Co. By avoiding these costs and using the CiSe platform to handle the revenue distribution efficiently, the CS washing machine business model could see significant economic benefits. Further promising, the overall initial investments reduce and are spread amongst the collective members. However, likely, a CS Bundles proposition will not happen. Bundles will lose their role as risk-taker, and Bundles does not provide any additional value. It makes them not necessary in the CS business model with Miele and Vonk en Co. Furthermore, Miele has the resources available to do the washing machine service themselves. Moreover, Miele and Vonk en Co currently have a profitable collaboration with Bundles without long-term risks.

Main research question: *"How effective could the Circular Service platform implement collectively serviced Bundles washing machines?"*

Thus, the results of this study are not straightforward and mainly raise questions for additional research. There are promises and problems on all three IE perspectives when implementing a CS Bundles washing machine using the CiSe platform.

There is some economic potential as the transactional relationship, the cost for added value, and the administration cost for revenue disappear. Spreading the initial investments amongst multiple stakeholders can lower the barrier for entry. Blockchain technology also allows for real-time data collection. This means that Bundles, Miele, and Vonk en Co have a better insight into what washing machines are performing well and which ones are not.

While the CiSe platform highly regards disintermediation to reduce costs, The SFL then mentions a need for a "costly" third-party key manager. A CS proposition will likely happen on the merit of income versus risks. If such an intermediary becomes costly, it might make a CS proposition significantly less likely to happen.

Another observation is that It is improbable that a collectively serviced Bundles washing machine will happen. It is because Bundles will lose their role as risk-taker, and Bundles does not provide any additional value. Furthermore, Miele has the resources available to do the washing machine service themselves. Moreover, Miele and Vonk en Co currently have a profitable collaboration with Bundles without long-term risks.

Furthermore, there is also a problem with flexibility. Once live, blockchain systems and their smart contracts can not be altered. It can become problematic with a business model that is intended to be long-term. Especially where these agreements of revenue distribution are stored in smart contracts. It might be that down the road things change. For instance, if Miele or Vonk en Co innovate a lot, they migh request a more massive cut in the revenue distribution. For this to happen, the smart contracts have to be altered. If such agreements can not be changed it could become very risky to start a CS business models through the CiSe platform. Moreover, the vulnerability of the system moves to the sensors. Due to the autonomous and automatic nature of the CiSe platform, a faulty or hacked sensor can wrongfully activate transactions. Due to the immutable nature of blockchain, these can not be reversed.

Blockchain systems can generally handle only low transaction volumes. Quorum is the blockchain software that the CiSe platform currently uses. It can handle up to 150 transactions per second. It pales in comparison with the 65000 transaction VISA can handle per second. Additionally, blockchain systems can become cluttered with redundant data on product use and transactions. It can affect the scalability of the system over time. These limits in scale raise questions regarding how many washing machines can be serviced through the platform.

Chapter 8
Recommendations

In this chapter I will describe the recommendations.

The main limitation of this study is in its conceptual and explorative nature. This is due to four reasons. Firstly, there is no support of the definition of CS in literature. Secondly, no direct comparison could be found of the CiSe platform concept either. Moreover, the results from the two systemic literature reviews were mainly conceptual papers. Finally, the case study is explorative. All in all, this means that these results are not final. They are indicative and more research is necessary to determine the effectiveness of the CiSe platform in overcomming CS barriers.

To move the development of the CiSe platform forward it is essential that the need for- and problems of CS are research more thoroughly. The case study revealed that CS is not for every value chain. If there is no need for CS, then the CiSe platform is irrelevant. If the CiSe platform does not address the right barriers of CS the same fate awaits. It is advised to prioritize research into CS before developing the CiSe platform further. Especially, qualitative data can help assess the significance of economic reductions in different PSS value chains and help assess which markets are best suited CS. Following, more case studies can reveal and confirm more problems and opportunities. The CiSe platform can be designed accordingly.

Following it is advised to research blockchain challenges that might hinder implementation of the CiSe platform. First of all, a concern is that regarding the scalability of the CiSe platform. The CiSe platform's scale is dependent on the amount of products and the types of products that are going to be serviced. To address this issue, more research is necessary into the different types of PSS and product markets. Furthermore, the inflexibility of blockchain technology can become problematic for the CiSe platform. Especially since the smart contracts, that contain the agreements for revenue distribution, are intended to be long-term. If smart contracts cannot be change would be very risky for companies to start a CS business model on the CiSe platform. Moreover, the use of a key manager comes with additional costs. The reason to start a CS business model on the CiSe platform will likely be on the merit of economics. Thus, it is important to understand the costs associated with such practices. Finally, data of product use and on transactions can clutter teh system over timee. This affects scalability of the system. To address these challenges, more in-depth research into blockchain companies can help. While this thesis' business analysis was limited to desk research. Other methods such as qualitative interviews and field research can provide better insights.

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Appendix

Appendix A
Blockchain Step-by-Step

A.a. A Brief History of Blockchain

Blockchain started in the year 2008, in the midst of the financial crisis. A white paper was published under a pseudonym named Satoshi Nakamoto of which the identity (or identities) is still a mystery. In this paper, Nakamoto introduced the first blockchain technology named Bitcoin, a peer-to-peer electronic cash system that worked without the need for a trusted intermediary, like a bank.

Over the years, Bitcoin slowly started to gain popularity. Different cryptocurrencies started to rise up as well. In May 2010, Bitcoin was worth less than $0.01. In 2017, Bitcoin's market value rose from $20 to $200 billion. Eventually, it reached a peak value of $19,126 per Bitcoin before crashing down, losing 40% of its value in just six days. Since the crash, Bitcoin reached a low of $3,247 per Bitcoin. The volatile history of Bitcoin leaves many to believe that cryptocurrencies and the technology behind it, blockchain, is a hype and that the bubble has burst.

Similarly to revolutionizing technologies, such as the internet, blockchain follows the familiar path of the hype cycle by Gartner. The bursting of the bubble and the widespread skepticism of the technology means that it has passed the peak of inflated expectations. The hype has subsided and has been replaced by more realistic expectations, kicking in the trough of disillusionment phase. This is the phase where blockchain currently stands (see figure A.a). Most blockchain projects are stuck in the experimentation phase (Gartner, 2019). If producers of the technology manage to overcome the challenges the slope of enlightenment begins. In this phase, useful implementations of the technology start to crystallize within companies and start-ups. Gartner (2019) estimates that the market will climb out of the trough of disillusionment phase by 2021, whilst full technical scalability and operationality is expected until at least 2028. The technology is thought to see the feasibility of scale somewhere in 2021 to 2023 according to Mckinsey (Carson et al., 2018).

A.a.a The Term Blockchain

The term blockchain can mean a number of things. For instance, it can refer to the specific data structure of chained blocks. It can also be used holistically as a term that describes the overall technology which consists of peer-to-peer systems, distributed ledger technologies, hash functions, asymmetric cryptography,

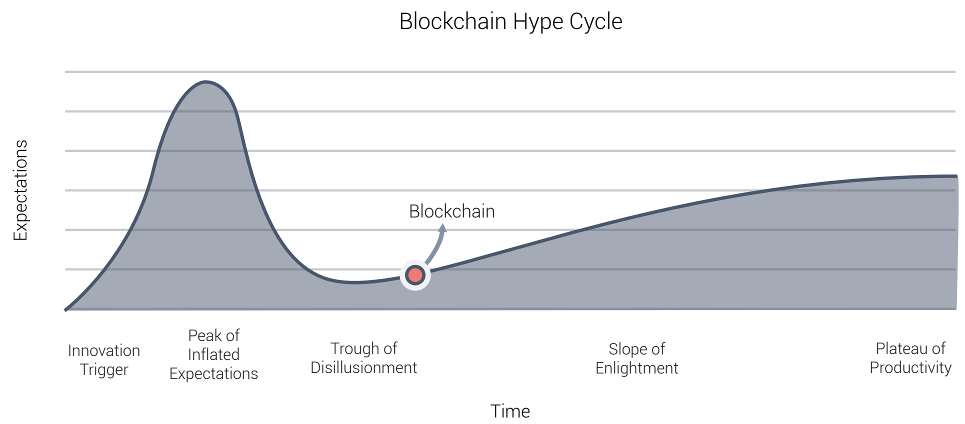

Figure A.a: Blockchain hype cycle, *source: Gartner (2019)* consensus mechanisms, the data structure of chained blocks, and more. The latter holistic definition is used in this report.

Before delving into each of the blockchain components a good grasp of the general idea of blockchain can come in handy. With blockchain, a distributed set of computers run the same software that helps them connect to each other, helps them listen for transaction requests and lets them produce new blocks of information on the ledger, find consensus about the correct sequence of blocks, and maintain a full copy of the transaction history.

A.b. Blockchain Components

A.b.a Distributed Systems

Blockchain is a distributed system at its core (Bashir, 2017). Distributed systems are computing systems whereby a minimum of two nodes work with each other in order to achieve a common outcome. A node is a device that can receive and transmit information. It requires memory storage and a processor to do so. The benefit of a distributed system over a non-distributed system, a single supercomputer, is that they are generally;

- More resilient
- More powerful and faster
- Have reduced costs
- Can grow naturally

As multiple nodes work together, with each their own processing power, they are more likely to outperform a single computer in power and speed. If the processor in a single computer system fails or breaks, the whole system is down as well. With distributed systems, if one node fails or breaks there are many nodes left that can still perform the computational work. The cost of maintaining and operating a supercomputer is high, more than that of many smaller computers. The computational power of a distributed system is modular and can easily be increased by adding additional computers within the system. Centralized systems will have a stagnant performance until the supercomputer is replaced.

There are some downsides to a distributed system. They can be hard to coordinate as there are many components/nodes. A node can malfunction due to a number of reasons. The node can have physical damage, a software error, broken sensors or it can be hacked. Data transfer between nodes can be slowed or broken as well. A node can also be outside the communication reach of other nodes or the link can be broken. The information can become blocked or the wrong information is sent to other nodes. Some nodes within the system might have malicious intent.

Distributed and centralized systems are two extremes. Hybrid systems exist as well, each variation comes with its own benefits and limitations. This will be further explained in chapter A.d.

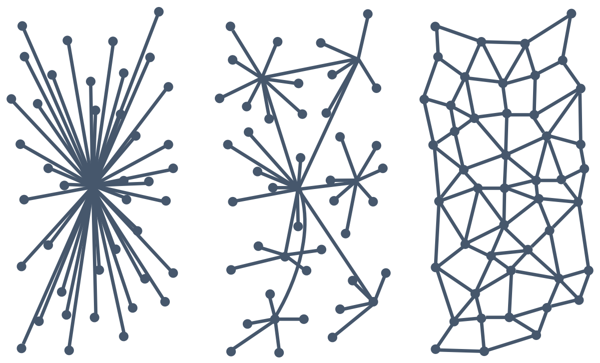

Figure A.b: Centralized vs decentralized vs distributed, *source: Bashir (2017)*

A.b.b Peer-to-peer Systems

Peer-to-peer systems are distributed software systems that have nodes that each share their computational resources (Drescher, 2017). With peer-to-peer systems, direct interaction happens between nodes. No middleman or central coordination is necessary and this eliminates fee costs and reduces processing time. This can have groundbreaking results for many industries. Any industry that acts as a middleman between producers and consumers is under threat of being replaced by peer-to-peer systems. The most obvious example is that of the finance sector. A huge part of it consists of intermediation. A peer-to-peer system could eliminate the need for banks. However, peer-to-peer systems can have trust and security issues as it is prone to malicious users or technical failures. For the system to work it is important that users trust each other and that they use it as expected. This can be achieved by confirming the trustworthiness of each node. The more nodes that are confirmed credible, the more trust. Peer-to-peer systems are generally not able to reliably confirm trustworthiness and the number of nodes. Blockchain promises to solve these securities and trust issues. Even in conditions where the amount of nodes and their trustworthiness is unknown. Blockchain solves the Byzantine generals problem (Lamport et al., 1982). Enabling disintermediation in an untrustful environment is one of the key reasons for the excitement in blockchain.

A.b.c Distributed Ledger Technology

Blockchain is not just a distributed system, but more specifically, blockchain is a distributed ledger technology (DLT). DLTs (and thus blockchains as well) are a set of distributed nodes that each store a copy of the same ledger. Essentially, they are a database but distributed. What is noticeable is that DLT has been used to describe blockchain and this is not entirely accurate (Bashir, 2017). Rauchs (2018) makes the distinction that blockchain is a specific subset of DLT with a particular data structure of hash linked blocks (explained in-depth in chapter A.b.e and A.b.f). Aste (2017) described DLT as a larger family of blockchain and as a technology for all methods of decentralized data sharing where digital data is replicated and synchronized across multiple nodes. This paper uses the definition of Rauchs et al. (2018).

"DLT is a peer-to-peer system of nodes that have a shared dataset, where new additions to the dataset are added based on a consensus process and where data is cryptographically secure"

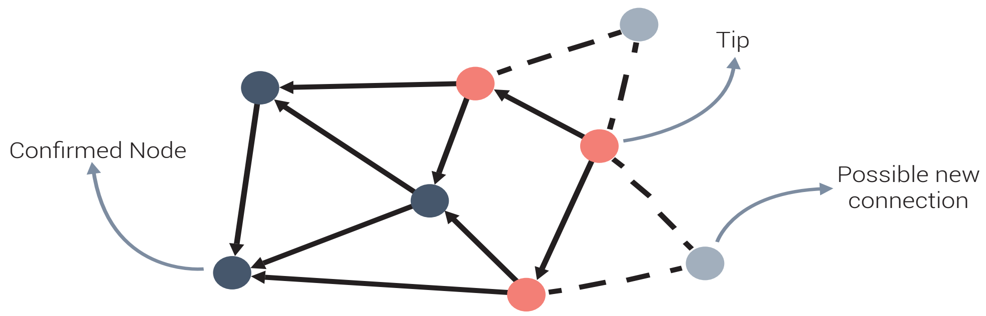

Figure A.c: The Tangle from IOTA, *source: Popov (2018)*

Examples of DLTs that use blockchain technology are Bitcoin and Ethereum. R3 Corda and IOTA are examples of DLTs that do not operate through blocks. Instead of securing transactions and information in the chain of blocks, IOTA operates through the Tangle (Popov, 2018). All DLTs share the property where non-trusting participants can introduce new information which is then agreed upon using a consensus mechanism.

A.b.d Concensus Mechanism

Consensus is the process where nodes that do not necessarily trust each other agree on a final state of data (Bashir, 2017). With a consensus mechanism, a set of steps are taken by all or most nodes in order to agree upon a proposed data state. Once information is agreed upon it is added to the overall database. No central authority or central cloud system is necessary.

There are many types of consensus mechanisms, Proof-of-Work (PoW) is the consensus mechanism of Bitcoin. Here, nodes have to solve computational heavy puzzles before being allowed to validate a transaction or set of information. Other consensus mechanisms, such as Proof-of-State (PoS), are less energy resourceful. Each has its benefits and limitations. These will be explained further in chapter A.d.

A.b.e The Chain of Blocks

Blockchain is a specific type of DLT that stores information in so-called "blocks". A block is simply a bundle of transactions or information. Blocks can be of varying sizes. With Bitcoin, blocks have a size limit of 1MB. Over time, when transactions happen, more blocks form. Each block references the previous block with a hash value. Hash values are a fixed length of numbers that uniquely represent some data (see chapter A.b.f). With these hashes, blocks are essentially chained together, each to the previous block of information. Doing so, a record of all the transactions that have happened is recorded all the way to the genesis block. The genesis block is the start of the chain and is hardcoded into the system. The whole history of transactions is stored in sequential order in each ledger. From it, each node can reconstruct ownership. Regulating ownership is arguably the most prominent use case of the blockchain (Drescher, 2017). The blocks have some additional attributes. The design and structure of these blocks can change, depending on the type of blockchain, and can be divided into the block header and block body.

Block header:
- The block software version
- Timestamp: Marks the time for each of the transactions in the block. It proves when what has happened and helps connect the blocks in chronological order
- The hash value of the previous block: a 256-bit hash that points to the most recent block in the chain
- Merkle tree root hash: A hash value of all transactions in the block body
- Nonce (PoW only): A nonce is a number that is only used once. The nonce is random and is key to the cryptographic puzzle with PoW
- Difficulty target (PoW only): This number regulates how difficult it is for miners to add new blocks to the blockchain

Block body
- Transaction or information
- Transaction counter

A.b.f Hashing

Hash functions transform any kind of data into a number of fixed length, regardless of the size of the input data. This reduces the need to compare large sets of data. Instead, the smaller hash values can be compared. Specifically, cryptographic hash functions can function as digital fingerprints for any kind of data. Cryptographic hash functions have some important properties. They are consistent as they provide the same hash value for the same input data. However, they are also unpredictable. Minor changes to the input data result in different and unpredictable changes to the hash value. Cryptographic hash values are one-way functions, meaning that input data can not be recovered based on the hash value. Cryptographic hashes also rarely produce the same hash value for different input data.

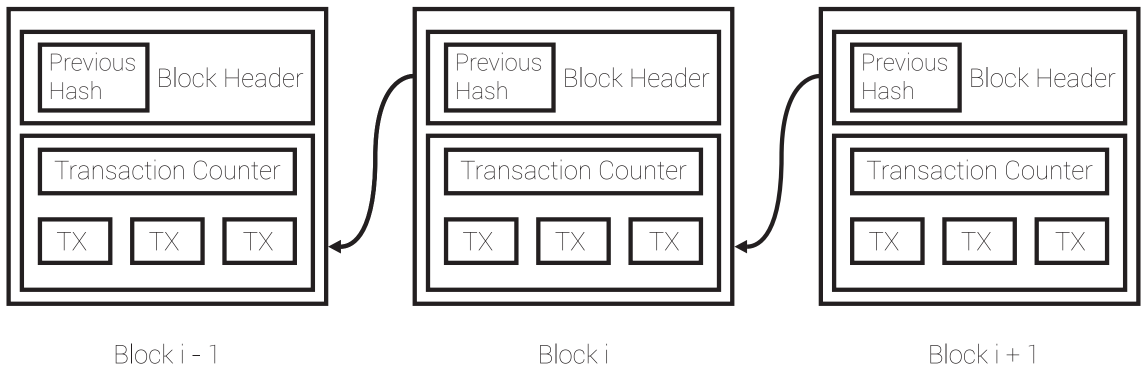

Figure A.d: A sequence of blocks, *source: Zheng et al. (2017)*

A.b.g Merkle Tree Root Hash

The Merkle Tree is a multitude of hierarchical hashes. The Merkle Tree is named after computer scientist Merkle and its tree-like structure. The Merkle tree root hash is the single hash that references all transactions or information. Different datasets create different hash values. Following, hash values are combined to create a new hash value. Effectively, creating a new hash value from multiple hash value inputs. An example can be seen in figure A.e. A transaction Ta and Tb can each be summarized to a hash value, Ha and Hb. Both hash values are combined to create a new hash value. Similarly, transactions Tc and Td follow a similar route, and so a tree-like structure is created, eventually resulting in one "top" hash value at the root of the tree, rightfully called the Merkle Tree Root Hash.

The Merkle Tree Root Hash combines a whole block of information into one small hash value. Any change of information within the Merkle Tree will result in a different Merkle Tree Root Hash. Validators will only have to check upon the root hash to know if a transaction has taken place. This eases the validation process

A.b.h Assymetric Cryptography

Blockchain uses asymmetric cryptography to secure transaction processes. Each user owns a private and public key. The private key is used to sign transactions and has to be kept secret from other users. When a user wants to start a transaction, he or she signs it using their personal private key. The transaction gets encrypted in such a way that it can only be done by the user of that private key, ensuring that he or she is the one activating this transaction process. To verify the transaction the recipient can use the public key, which can only be used to decrypt transactions. This way of asymmetric cryptography secures that unauthorized people are unable to access data.

A.b.i Cryptocurrencies

Cryptocurrencies are digital assets that work as a medium of exchange. Cryptocurrencies are stored in digital ledgers and use cryptography to secure transactions and the creation of new coins. Cryptocurrencies have existed before the invention of blockchain. In 1983, the American cryptographer David Chaum conceived ecash, an anonymous cryptographic electronic cash system. Later, in 1995, it turned into Digicash and was used as a micropayment system by a US bank until 1998. However, with Bitcoin, the first decentralized cryptocurrency was born. In contrast with centralized banking, governments control the supply of the currency and can produce additional fiat money. In the case of decentralized cryptocurrency, the supply of currency can not be increased so easily. The rate and rules of how cryptocurrencies are produced are publicly known. For instance, with Bitcoin, Bitcoins are only created and earned through mining,

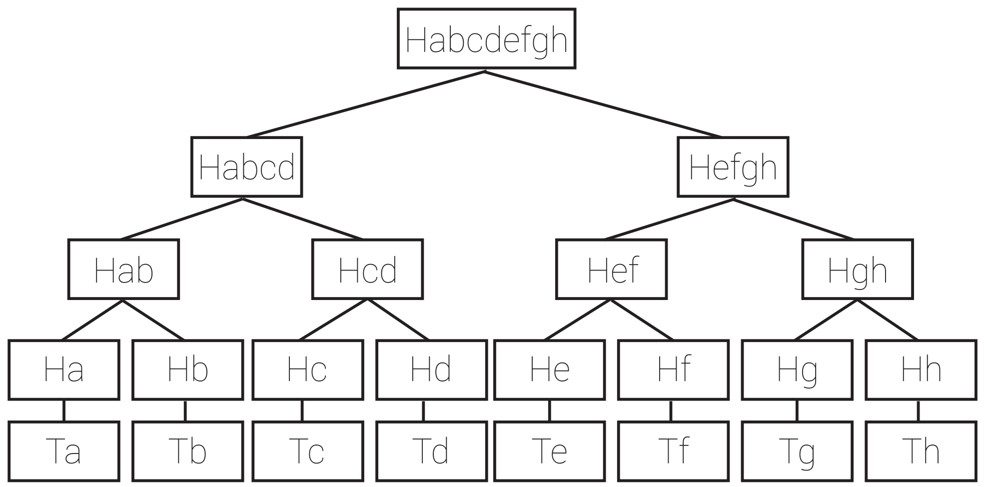

Figure A.e: The Merkle Tree

the process where transactions are validated and added to the distributed ledgers. The miner, the one validating the transaction, receives some amount of Bitcoin for his work.

A.b.i Smart Contracts

Smart contracts are automated and autonomous programs that have rules and algorithms for the exchange of information and are executed when certain conditions are met (Bashir, 2017). Smart contracts can be built on top of certain blockchains, like Ethereum. With a smart contract financial settlement can be done without the need for a third-party, like banks, which reduces the turnaround time and transaction costs significantly (Zheng, 2020). Due to the immutability of the blockchain, smart contracts cannot be altered once they are issued on the blockchain, and transactions that come from it are traceable, this reduces risk, and skipping the mediator reduces administration and service costs and improves efficiency (Zheng, 2020).

Smart contracts are not that smart. They consist of simple If this then that logic (IFTTT). This logic is programmed onto the blockchain and run by all the blockchain nodes, which automatically updates the transparent ledger that anyone sees. A blockchain-based smart contract is visible to all users of said blockchain. However, this leads to a situation where bugs, including security holes, are visible to all yet may not be quickly fixed. In June 2016, a hacker found a loophole in one of the smart contracts stored on the Ethereum blockchain and managed to steal $50 million dollars worth of Ether, the cryptocurrency of Ethereum (DuPont, 2017). Due to a time delay in the smart contract, the Ethereum software was fortunately hard forked in time before the hackers could retrieve their funds.

Appendix B
Literature Blockchain Designs

(Healthcare)

BlocHIE (2019): Blockchain-based healthcare information exchange with On-chain, proof of existence, storage, and off-chain storage of healthcare data.

B4Health (2019): Blockchain-based platform that provides a unified view of health records scattered across various health organizations.

Clinicappchain (2019): Blockchain-based platform that unifies access in healthcare data where patients decide what to share, with who, with minimal costs.

CUREX (2019): Secure blockchain-based healthcare storage that is save from cybersecurity threats.

MedBloc (2019): Blockchain-based platform which allows the sharing of healthcare data, where patients and healthcare providers are able to access and share health records.

MedChain (2019): Blockchain-based healthcare sharing platform without the need to trust a third-party cloud service

TrialChain (2018): A blockchain-based platform that is used to validate data integrity from biomedical studies in order to help generate accurate results.

(Academic publishing/scientific publishing)

Eureka (2019): A blockchain-based scientific publishing platform, developed to address the imbalance of supply and demand in publishing academic work and providing fair reward distribution for all contributors and ownership rights to authors.

(Crowdsourcing)

ABCrowd (2020): Blockchain-based crowdsourcing platform that allows trusted execution of auctions for tasks.

CrowdBC (2019): Blockchain-based crowdsourcing framework where a requester's task can be solved by workers without the need of a trusted intermediary.

Fluid (2019): Blockchain-based crowdsourcing framework that includes an incentive mechanism for workers.

Vizsafe (2019): A blockchain-based platform that is designed to mobilize the crowd in providing information.

zkCrowd (2019): A blockchain-based crowdsourcing platform that verifies transactions and that secures communication.

(Crowdsensing)

CrowdBLPS (2019): Blockchain-based crowdsensing system that is decentralized and where information is tamper-resistant.

Dmap (2019): A blockchain-based platform where users can share data anonymously with service providers for online mapping.

SenseChain (2019): A blockchain-based system that captures the reputation of sensors.

SPIR (2019): Blockchain-based platform that uses an incentive mechanism to recruit vehicle users to send data for real-time map updates.

(Data)
ADvoCATE (2019): Blockchain-platform for the management of consent regarding access to personal data.
BCSolid (2019): Blockchain-based decentralized data storage and authentication scheme for Solid.
HyperProv (2019): A blockchain-based framework for data provenance and data lineage of information in research
PrivySharing (2020): Blockchain-based framework for data integrity in a smart city environment. Users get rewarded PrivyCoins for sharing their data.
Searchain (2020): A blockchain-based keyword search system that enables search in a decentralized storage setting.

(Social media)
Ambient (2019): Blockchain-based social media platform that builds on trust and aims to discredit fake news.
Tawki (2019): A blockchain-based social communication platform where users remain in control of their personal data.

(Smart homes)
HomeChain (2019): Authentication system for smart homes based on blockchain.

(Job application)
JobChain (2020): A blockchain-based platform that manages job recruitment.

(Resource management)
BCEdge (2019): A resource management scheme for mobile edge computing that is based on blockchain
CollabChain (2019): Blockchain-based volunteer computing platform that functions as a market place to buy and sell computing power and where volunteers are incentivized to share computer resources.
Nebula (2019): A decentralized blockchain-based platform for sharing computing resources.

(Energy management)
BIJLI (2019): A blockchain-based application where renewable energy consumers can buy renewable energy and producers can sell renewable energy.
Transax (2019): A blockchain-based energy exchange for microgrids.

(Licensing)
LicenseChain (2019): Blockchain-based trading platform for licenses of intellectual property

(Vehicle registration)
BVD (2019): A blockchain-based database of vehicle registration and tracking or traffic violators.

(Document verification)
SPROOF (2019): Blockchain-based platform for the management, issuing, and verifications of digital documents, such as educational certificates.

(Genomic data)
Genesy (2019): A blockchain-based platform that aims to incentivize people to share their genomic data.

(Voting)
GenVote (2019): A blockchain-based voting system that achieves a transparent and cost-effective voting process.
LaT-Voting (2019): Blockchain-based voting scheme that ensures the security against tampering, such as malicious voters voting twice.
Votereum (2019): A blockchain-based e-voting system that is open, fair, and universally verifiable.

(Video streaming)
Aurum (2019): A blockchain-based media-streaming platform where content creators returns get maximized by skipping intermediaries.
Red5 (2019): A blockchain-based live video streaming platform where users are incentivized to share computer resources.

(Art)
Artchain (2019): A blockchain-based trading system for art that provides a transparent and tamper-proof transaction history for one of the largest unregulated markets in the world.

(Car renting)
Cryptober (2019): Blockchain-based platform for car rental services that is cost-optimal, since there is no intermediary.

(EV charging)
EVChain (2019): Blockchain-based platform where charging credits can be shared in the EV charging market.

(Farming)
Legacy Fish Farm (2020): A blockchain-based platform that provides security, and transparency for fish farmers' smart agriculture data.
VegIoT Garden (2019): Blockchain-based platform aiming at the enhancing management of vegetable gardens through the collection, monitoring, and analysis of sensor data and where blockchain is used for supply chain traceability.

(Augmented reality)
WARP (2019): Blockchain-based platform where users can share tracking data for the contribution of a sensor network for a worldwide augmented reality platform

(Flood protection)
Smart Dam (2020): Blockchain-based platform for the fair transaction of water rights that is combined with an upstream sensing method in order to

(Supply chain)
BRUSCHETTA (2019): A blockchain-based application for the traceability of the certification of Extra Virgin Olive Oil supply chain.
HIDALS (2019): A blockchain-based platform where handover conditions are recorded between organizations using smart sensors within parcels that measure violations of SLAs
PartChain (2019): Blockchain-based application where physical parts of a supply chain network are monitored.

(Plastic reuse)
PlasticCoin (2019): PlasticCoin is a cryptocurrency that aims to encourage plastic recycling. People are incentivized to reduce their plastic waste by rewarding them with the PlasticCoin token.

Appendix C
Blockchain Companies

(Supply chain)

Circularise: Knowing what a product is made out of is key for allocating it through one of the circular economy loops: repair, refurbishment, recycling, etc. Circularise is a tool that aims to solve this problem by providing transparency and traceability in supply chains, using blockchain technology.

Provenance: Provenance aims to provide an open and secure record of products in order to communicate the origin and impact of products to consumers.

CERA: CERA aims to establish a standard for the certification of mineral resources. Using blockchain, CERA wants to track the origin of those minerals and if they are certified or not.

Monochain: A blockchain platform that aims to combat counterfeiting

TraceMet: With the global sustainability goals comes to an increased awareness of materials and their climate impact. TraceMet aims to give knowledge on the origin of metals

TradeLens: A digital shipping platform that uses blockchain in order to provide transparency and efficiency in global supply chains. It provides control and management of shipping data.

GrainChain: A platform where blockchain is used to issue payments between suppliers and farmers and where fraud and corruption of goods are combated through certification and accountability.

Vinsent: A blockchain-based platform where consumers can directly buy wine from wineries which allows for direct connections with customers and lower prices.

(Land governance)

Medici Land Governance: A blockchain-based platform that aims to support land governance, titling, and administration with a secure public record of land ownership.

(Voting)

Voatz: A blockchain-based mobile voting platform. Users can vote with their smartphones and verify that their vote was counted correctly.

Votem: A mobile voting platform that uses blockchain.

(Social Media)

Minds: A blockchain-based social media platform that improves there freedom and revenue for content creators. Creators get paid in cryptocurrency for their contributions.

(Document verification)

Factom: A blockchain-based platform that lets you secure physical documents on the blockchain for authentication and document proof.

Vital Chain: Blockchain-based birth and death certificate management.

(Data)

Evernym: A platform that uses blockchain to move and prove data in an efficient way.

PeerNova: A blockchain-based platform that aims to improve the data integrity of business flows.

Appendix D
Bundles Service Blueprint