MASTER THESIS

PRODUCT SERVICE SYSTEMS FOR BOILERS; TOWARDS A CIRCULAR ECONOMY

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Abstract

Every year around 375.000 boilers are being discarded and end up as waste in the Netherlands. This is not in line with a circular economy. Product Service System Business Models (PSS BM) have great potential to increase the circularity performance in a business, which can reduce the impact on the environment. The heating sector in the Netherlands has potential to become more circular through servitization. This thesis aims to answer the following research question: *"Which PSS BM for boilers could be implemented to enhance the transition towards a circular economy?"*

This thesis uses a case study approach, semi-structured interviews and a Multi-Criteria Analysis (MCA) to answer the main research question. The case study provides in-depth information on the current BM and alternative PSS BM's for boilers. The semi-structured interviews present the needed insights from the perspective of multiple actors relevant in the current BM, whilst the MCA allows for the transformation and comparison of the collected data to alternative scenarios.

The case study is Energiewacht, a company that sells boilers and provides product-related services. The analysis shows that the current BM of Energiewacht focuses on the product while services are an addition. Three alternative PSS BM types are identified. In every alternative, the level of service increased. The analysis shows that an increased level of service results in an increased level of circularity strategies that are present in the BM. The current BM and alternative BM's are compared based on a set of values that are obtained from the interviews. These values indicate what actors perceive as important to be present in a BM. The *product lease* BM and the *functional result* BM scored the highest for these values. Additionally, the circularity performance of each BM is calculated, which shows that the *functional result* BM has the highest circularity potential. Thus, the *functional result* BM can be implemented to enhance the circular economy for boilers.

To increase circularity performance in the heating sector, this thesis recommends trialing the implementation of the *functional result* BM for boilers.

Executive summary

Introduction

The use of natural resources is increasing and results in scarcity, high prices and environmental degradation. Moving towards a circular economy in the business sector is important to reduce the use of natural resources. Product Service Systems (PSS) have a clear potential to enhance the circular economy, by shifting towards a service focused Business Model (BM) that decouples economic success from material use.

The heating sector in the Netherlands has potential to become more circular through servitization. The main product in the heating market is the boiler, which provides heat to 6.6 million households of the 7.7 million households in the Netherlands. Currently, each year around 375.000 boilers are discarded and 50% of the boilers is incinerated (van den Hout, 2017; Snel, 2020), which is not in line with a circular economy. The product characteristics of the boiler (e.g. customers are mainly interested in the result it gives) suit the move towards PSS models. Nonetheless, the current BM's of boilers towards individual customers remain product oriented. However, moving towards PSS BM's is challenging and the changes compared to the current BM of boilers can be quite radical. The successful implementation of a new BM depends on the acceptance of multiple actors and their values.

The main research question and sub questions of this thesis are:

Which PSS BM for boilers could be implemented to enhance the transition towards a circular economy?

1. *What are the features in the current BM for boilers?*
2. *What alternative circular PSS BM's can be designed in line with the actors perception?*
3. *Which values are important as criteria in a BM for the actors?*

Theory

The concept circular economy is concerned with preserving natural resources by minimizing waste, retaking products when their service's life is over and reuse, refurbish or recycle the materials, in order to limit the use of raw materials. Furthermore, in a circular economy economic benefits are considered. Moving towards a circular economy requires changes in production and consumption and thus the business sector. Assessing how circular a business operates helps to understand which improvements can be made. Circularity performance can be assessed by different methods. Most suitable for this thesis is the Material Circularity Indicator (MCI) developed by Ellen MacArthur Foundation (2015).

To change a business model (BM) it is important to understand the features of the current BM. The Business Model Canvas (BMC) is designed by Osterwalder and Pigneur (2010) as framework to identify the most important BM components. To understand the features of the PSS BM's the framework of Tukker (2004) is used. He identifies three main categories of PSS B's: Product-oriented, use-oriented and result-oriented. Product-oriented BM's focus on selling the product and additional product-related services are provided. In use-oriented BM's the product still plays a key role, however, in principal the product is not sold to the customer, but access is provided. This provision of access can be divided in three different types: *product pooling, product sharing* or *product lease*. Result-oriented BM's focus on the delivery of a result, without a pre-determined product, the provider and customer agree upon the delivery of a certain result. To assess how circular a PSS BM is designed, the Circular Innovation Framework designed by Guzzo et al. (2019) is used. This framework identified several circularity strategies that can be assigned to PSS BM's.

To assess the implementation potential, this thesis uses the acceptability of the PSS BM's for multiple actors. Identifying which values are important for multiple actors and understanding to what extent these values are captures by a BM helps to understand the implementation potential.

Method

This thesis uses a case study approach, semi-structured interviews and a Multi-Criteria Analysis (MCA) to answer the main research question. The case study was found with a desk research focusing on the following criteria: (1) the case study is a company sells boilers to private customers. (2) The willingness to participate of the company. (3) The company operates similar to other companies in the heating sector. For the features of the current BM of this company are identified using the Business Model Canvas (BMC).

Semi-structured interviews were held with multiple actors that were identified in the BMC. Through interviews more explanatory data was gathered. Different interview guides were designed for the interviews with companies and for the interviews with customers. This allowed for proper comparison and analysis. Sampling of the interviews started by addressing the customer service of the case company. Through snowball mapping three additional interviews with relevant actors were conducted. The other respondents were addressed via Linked-In or customer service. They were selected based on the list of actors that were derived from the BMC. The interviews with customers were based on my own network. A guarantee of anonymity was given to all participants. After the participants permission was given, the interviews were recorded.

The number of interviews held was based on the saturation technique. With this technique the sufficient number of respondents is based on the previous interview held. Where the first couple of interviews gave the most novel information, after a couple of interviews not much new information was obtained. The interviews were analyzed by transcribing and coding them in NVivo 12 Pro. Bot deductive and inductive coding was used. Deductive coding allowed to analyze the data in line with the theoretical framework and gave a clear structure. Inductive coding helped to stay openminded towards other concepts that are relevant for this specific thesis.

An MCA was used to compare the different scenarios. Values to score the BM's to the criteria were based on relevant information from the interviews and additionally through a desk research using Google Scholar and WorldCat. The MCI was calculated for the different scenarios in line with the formulas as developed by the Ellen MacArthur Foundation (2015).

Results

Sub question 1: What are the features in the current BM for boilers?

The case study chosen for this thesis was Energiewacht: A company that sells boilers and provides additional services in the north-east of the Netherlands. The current BM of Energiewacht shows features of a product-oriented BM. Boiler manufacturers were identified as key partners. Individual customers are an important part of the customer segment.

Sub question 2: What alternative circular PSS BM's can be designed in line with the actors perception?

Alternative PSS BM's that were identified were a *product-oriented* type, a *use-oriented* type and a *result-oriented* type. (1) For the *product oriented* BM an increased level of advice that is given on the use of the product. Although the usage of boilers is quite obvious, giving extra advice could be a useful addition to the BM when other products are implemented that are more difficult in their use. No objections were identified for this BM. Circularity is enforced in this BM through more efficient usage of the product. (2) The *use-oriented* BM focuses on renting boilers to customers instead of selling them. Providers retain ownership of the boilers and cost structure changes to monthly payments. This new financial structure is pleasant for companies due to the stability of a monthly income. However, the high Return on Investment (ROI), that is also a financial consequence of this model, is perceived as less pleasant. Customers are less interested in renting, since they perceive it as more expensive. The additional circularity strategies for this BM occur from(i) an increased re-take of the products, which can lead to a higher recycling rate, (ii) preventive services that can prolong the lifetime of the product and (iii) increased use of second hand components/products. In PSS BM type 3 the provider is responsible for delivering the result, which in this case is the delivery of a comfortable temperature and hot water. Companies have a high level of freedom on how they deliver this, and no pre-determined products are involved. New and increased collaboration is important for PSS BM type 3, and companies are willing to enforce this collaboration. However, customers are reluctant about PSS BM type 3, since they prefer to have a certain level of control over the temperature in their houses, which in this BM is shifted to the provider. Besides the circularity strategies that are also applicable to the previous discussed BM's, the increased collaboration that is a feature of this BM increases the collaboration in the supply chain and this makes it easier to close the material loop. This increases the recycling rate and use of recycled materials as input.

Sub question 3: Which values are important as criteria in a BM for the actors?
Important values for actors to be present in a BM are: customer satisfaction, financial aspects, sustainability, technology, expertise and safety.

Main research question: Which PSS BM for boilers could be implemented to enhance the transition towards a circular economy?
The MCA shows that the current BM has the lowest combined scores of the values. The three alternative PSS BM's have a quite similar score, but the use-oriented BM and result-oriented BM both have the highest score of 17 (score could range between 5-25). That all alternative PSS BM's have a higher score than the current BM implicates that when each of these BM's would be implemented the values are better represented than currently. The circularity potential is assessed through the MCI. For which the highest score is given to the result-oriented BM. Therefore the PSS BM for boilers that is implementable and enhances the circular economy is the result-oriented BM that focuses on the delivery of a comfortable temperature and hot water. The implementation of this BM contributes to circularity, thus reducing the pressure on natural resources and consequently limiting scarcity, high prices and environmental degradation.

Discussion

The perceptions of actors on the alternative PSS BM's differ not that much compared to what is found in other literature. However, the mindset of the companies was perceived as more positive than identified other studies identified. Possibly, this is due to the energy transition that this sector is facing, since it came forward in the interviews that actors were aware of the need for change.

The values used in the MCA table are assumed to have the same relevance for the actors. However, there is a possibility that not all values have an equal weight. This could be included in further research.

The result-oriented BM could be implemented to enhance the circular economy. Future research could focus on analyzing the potential of this BM for the heating sector in terms of contribution to the energy transition.

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Acronyms

ARR = Annual Recurring Revenue

BM = Business Model

BMC = Business Model Canvas

CIF = Circular Innovation Framework

CO_2 = Carbon dioxide

MCA = Multi-Criteria Analysis

MCI = Material Circularity Indicator

PSS = Product Service Systems

ROI = Return on Investment

1. Introduction

Innovating the business sector and the business models (BM) is important in order to make society more sustainable (Alipanah, 2017; Han, Heshmati, & Rashidghalam, 2020). The use of natural resources, such as water, energy and raw materials, is increasing, resulting in high prices and scarcity (Elisha, 2021). Combined with the environmental degradation it causes, there is increasing pressure to change production and consumption behavior (Han et al., 2020). Moving towards a circular economy, where resource inputs, waste and energy leakages are limited, is an important step towards a lower impact on the environment (Geissdoerfer, Morioka, de Carvalho, & Evans, 2018). Servitization is a promising way to innovate the business sector to become more circular (Mendoza, Sharmina, Gallego-Schmid, Heyes, & Azapagic, 2017).

Servitization is a way to add value to a business by offering bundles that combine goods, services, support, self-service and knowledge that are desired by customers (Van der Merwe & Rada, 1988). A particular form of servitization is product service systems (PSS), which allow a focal shift from product to service (Chabot & Gemmel, 2016). The PSS models can take different forms, ranging from more product to more service oriented (Tukker, 2004). PSS models can balance economic, social and environmental benefits by decoupling economic success from material use (Baines et al., 2017; Reim, Parida, & Ortqvist, 2014). Furthermore, the focus on a service in PSS model can lead to the reuse of products, prolong the lifetime of products and increase material efficiency during usage of a product (Bocken, Short, Rana, & Evans, 2014). The strong relationship between PSS models and the main focus of a circular economy (decoupling economic success from material use), make that PSS models have a clear potential to enable a move towards a circular economy (Han et al., 2020; Mendoza et al., 2017).

1.1 PSS in the heating market

Currently, the main product in the heating market is the boiler, which provides heat to 6.6 million houses of the 7.7 million households in the Netherlands (Snel, 2020). Although boilers have quite a long expected lifetime, 10-15 years, there are still around 375.000 boilers discarded every year (Snel, 2020). Since boilers are replaced in its entirety, still well-functioning parts end up as waste (Snel, 2020). Furthermore, it is difficult for companies to re-take the boilers for recycling or reuse. This might be the reason that 50% of the boilers are incinerated (van den Hout, 2017). Therefore, this continuous stream of waste is not handled in line with a circular economy and this can be improved (Snel, 2020).

Although there is often a form of maintenance service included when a boiler is sold, the BM's for individual costumers remain quite traditional and product-oriented: where the focus lies on selling the product, and services are seen as an add-on (Alipanah, 2017). However, the product characteristics of boilers are suitable for a shift towards a service-oriented business because of the following reasons: (1) Buying domestic boilers is a relatively high cost for households, (2) boilers are hardly influenced by fashion trends, (3) there is limited interaction between the product and the customer and (4) the technology in boilers is quite advanced, while customers are only interested in the delivery of the service: a comfortable temperature and hot water (Toxopeus, Haanstra, Van Gerrevink, & Van Der Meide, 2017).

Even though these characteristics are very suitable for PSS BM's, innovating BM's in a sustainable way is still very complex. Moving towards more service-oriented PSS BM's requires radical changes in the current BM of boilers (Toxopeus et al., 2017). For example, in PSS BM's the responsibility for a comfortable temperature and hot water can shift from customer to provider (Reim, Sjödin, & Parida, 2018). This changes the interactions between provider and the private customers and thus it is important to make sure that the BM captures the values of the different actors (Geissdoerfer et al., 2018; Hansson & Lindesson, 2019; Reim et al., 2018). Successful innovation of the BM requires a proper understanding of the perspectives of all involved actors. Furthermore, to design a PSS BM it is important to not only include economic values, but social and environmental values as well (Bocken & Geradts, 2020). So, for innovating PSS BM's it is important to consider multiple values and multiple actors of the BM (Dittrich et al., 2015).

Understanding how to move the current product-oriented BM's for private customers in the heating sector towards more service-oriented BM's offers great potential to make the sector more sustainable, because it gives a higher level of freedom to design the BM in a more sustainable way (Chabot & Gemmel, 2016). The higher degree of freedom for providers to choose how to deliver a comfortable temperature and hot water to the customer might lead to a lower energy and material use (Guzzo, Trevisan, Echeveste, & Costa, 2019). However, the changes might also lead to unwanted environmental trade-offs, for example, because the customers might feel less responsible for using the product efficiently (Doualle, Medini, Boucher, & Laforest, 2015; Reim et al., 2018). This would diminish the potential of a BM to improve its circularity performance. So, to seize this potential it is important to understand what the impact of certain changes in a BM are on the circularity potential.

1.2 Relevance

Many studies and reviews have been conducted about servitization and PSS (Kohtamäki, Henneberg, Martinez, Kimita, & Gebauer, 2019; Raddats, Kowalkowski, Benedettini, Burton, & Gebauer, 2019; Reim et al., 2014; Zhang & Banerji, 2017). However, according to Geissdoerfer et al. (2018) and Reim et al. (2018) there is limited knowledge in the PSS literature on successfully implementing PSS BM's through acceptance of involved actors. Furthermore, there are only a few academic studies conducted on servitization of the heating sector (e.g. Hansson & Lindesson, 2019; Thermafy, 2020). These studies were conducted in Sweden and the United Kingdom. For the Netherlands there are some forms of delivering heat as a service e.g., heat networks and district heating which delivers heat to houses or companies (Schepers & van Valkengoed, 2009). For new buildings this is becoming more common (Schepers & van Valkengoed, 2009). However, the conditions of existing properties (e.g. isolation) that are currently heated by a boiler, are not always suitable to move to new heating systems (van Vlerken, n.d.). This explains why the number of boilers sold is not decreasing. A small scale project focusing on prolonging the lifetime of boilers for the existing properties was done in 2020 called *warmte als een service* (Snel, 2020). This project showed successful results and is therefore promising for further research. However, no further exhaustive academic study has been published on innovating PSS BM's of boilers.

This thesis recognizes the recommendations of Bocken et al. (2018) to identify how BM's can be innovated successfully by considering involved actors and their values. This is done for residential boilers for private customers in the heating sector in the Netherlands, since there is clear potential for circularity in this sector, yet no exhaustive academic study exists. This thesis identifies multiple vales of multiple actors to see if these are aligned in PSS BM's that can replace the current BM of boilers. The circularity performance of this PSS BM will be evaluated to understand the potential of PSS BM's for boilers to enhance a circular economy.

1.3 Problem statement

Moving towards a more circular economy is important to make society more sustainable. The BM of boilers have great potential for becoming more circular through PSS BM's, however implementation is lacking. No exhaustive academic study has been conducted on how a PSS BM can be implemented and to what extent this enhances the circular economy. Therefore, this thesis aims to identify how the current BM of boilers can innovate towards an alternative implementable PSS BM by aligning the different values of multiple actors and enhance the circular economy.

The main research question that this thesis aims to answer is:

Which PSS BM for boilers could be implemented to enhance the transition towards a circular economy?

This main research question has been answered through the following sub-questions.

1. What are the features in the current BM for boilers?
This question describes the features of the current BM, by identifying the important aspects of the current BM, including the actors that are involved in the BM.

2. What alternative circular PSS BM's can be designed in line with the actors perception?
This question shows which alternative PSS BM can be designed for boilers and how the main differences compared to the current BM for boilers are perceived by the actors. Also, the difference in circularity performance is addressed.

3. Which values are important as criteria in a BM for the actors?
This question identifies the values that are important for actors to be considered in a BM. How these values are represented in a certain BM is important to understand how acceptable the BM is for the actors.

2. Theoretical framework

This section introduces and explains the concepts and theories related to the research question and topic. Section 2.1 introduces the concept of circular economy for boilers. Section 2.2 presents two frameworks (1) for Product Service Business Models (PSS BM) and (2) for the circularity potential of PSS BM's. In section 2.3 it is explained how implementation through acceptance is relevant in this thesis. An overview of how the concepts and theories relate to each other and help to structure this thesis is presented in the conceptual framework in section 2.5.

2.1 Circular economy for boilers

The concept circular economy focusses on: preserving resources and economic benefits (Han et al., 2020). For a circular economy it is relevant to conserve the resources used in production and through the functional use for example by repairing products (Han et al., 2020). Furthermore, minimizing waste is important for the circular economy: materials and components should be retaken when the service's life is over in order to reuse, refurbish or recycle the materials (Han et al., 2020; Moraga et al., 2019). Decoupling the use of natural resources from economic growth, allows to reduce the use of natural resources while still creating a maximum value (Han et al., 2020; Moraga et al., 2019). Moving towards a circular economy requires to reconsider production and consumption and therefore the business sector (Han et al., 2020).

Currently, there are around 7.7 million houses in the Netherlands of which 6.6 million are heated by boilers (Snel, 2020). Each year around 375.000 of old boilers are replaced as a whole by new ones, resulting in well-functioning components ending up as waste (Snel, 2020). These materials are not being reused or refurbished and only half of it is being recycled. This is not in line with a circular economy.

To assess the circularity performance different methods are developed, that can be used to assess the circularity performance of BM's, for example: Life Cycle Analysis (LCA), Material Flow Analysis (MFA) and Material Circularity Indicator (MCI) (Lindgreen, Salomone, & Reyes, 2020). In this thesis the MCI, which is developed by Ellen MacArthur Foundation (2015) is used to assess this circularity potential. This method is chosen since it focusses on aspects important for a circular economy: the use of virgin material to make a product, the recycling and re-use rate after the end-of-life, furthermore it considers the use intensity of a product.

2.2 Product Service System Business Model

There are different types of PSS BM's with a different way to deliver the combination of the product and service. Innovating towards PSS BM's changes the current structure of a BM and has large potential for making the BM more sustainable and circular (Bocken et al., 2014). Boilers are very suitable for these PSS BM's (Toxopeus et al., 2017).

2.2.1 Business Model Canvas

For innovating a BM it is important to identify and consider the features of the current BM (Johnson, Christensen, & Kagermann, 2008). Although, there is no accepted definition of a BM in the literature, a description that is often used includes the logic of the company, how the company operates and how value is created for stakeholders (Reim et al., 2014; Zott, Amit, & Massa, 2011). To create this value it is important to know precisely what the customers want to have done or which problem needs solving for the customer (Johnson et al., 2008). When all dimensions of this problem are clear, the company can start designing the solution (Johnson et al., 2008). Furthermore, key resources (assets such as people and technology) and key performances (operational and managerial processes such as training, manufacturing and service) are important aspects of the BM (Johnson et al., 2008).

A general accepted framework to explore a BM is the Business Model Canvas (BMC), developed by Osterwalder and Pigneur (2010). The BMC is used to understand the characteristics of the current BM (Au, Oliveira, José, & Ferreira, 2011; Strategyzer, n.d.). The frameworks include all important BM components and therefore gives a complete overview of the current situation. Figure 2.1 shows the BMC, where the important components of a BM (key partners, key activities, key resources, value proposition, customer relationship, channels, customer segments, cost structures and revenue streams) are structured in a canvas that a company can use to understand their BM.

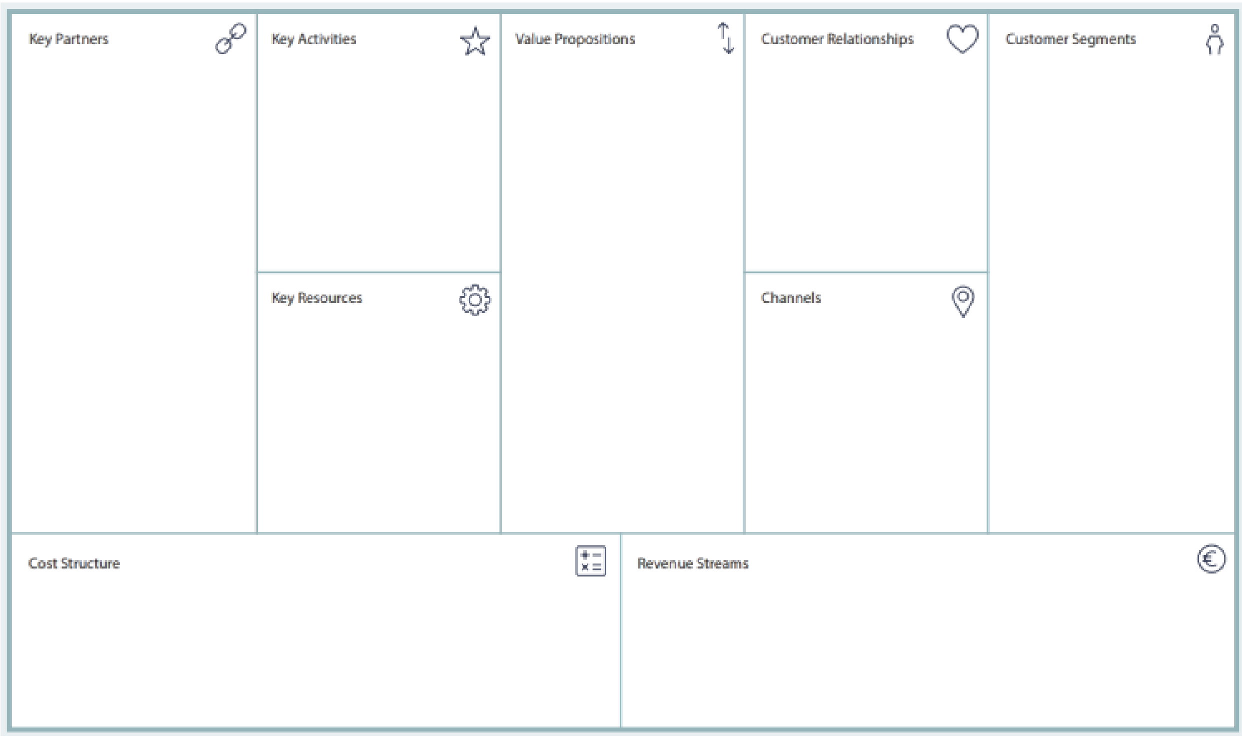


Figure 2.1 Business model canvas (BMC) source: Strategyzer

2.2.2 Product Service System

PSS BM's offer a combination of products and services (Tukker, 2004). Product service systems (PSS) explicitly include environmental impact in its definition: '*a product(s) and service(s) combined in a system to deliver required user functionality in a way that reduces the impact on the environment*' (Baines et al., 2017, p3). Innovating towards PSS BM's is also interesting for companies, because they can generate a steady income for the company, profit margins might be higher and they can increase customer loyalty through an increased relationship with the customer (Mertens, 2012; Tukker, 2004). Tukker (2004) identifies three main categories, product-oriented, use-oriented and result-oriented, for PSS BM's, which can be further specified to a total of eight types of PSS BM's (figure 2.2). The different PSS BM's all have a different structure (Tukker, 2004):

1. Product-oriented BM's have a clear focus on the product. The *product related* BM type offers some product related services, such as maintenance. In the BM for a*dvice and consultancy* information is provided on the use of the product. (Tukker, 2004).

2. In use-oriented BM's the product still has an important role, however the focus is not on selling a product, but providing access for using it. This is provided through *product lease, product sharing* or *product pooling*. In p*roduct lease* BM the provider retains ownership of the product and the customer leases to product. For p*roduct sharing* the provider also retains ownership, but now customers do not have individual and unlimited access, since the product is shared with other customers. *Product pooling* also shares the product with other costumers, but in this case simultaneous use is possible. (Tukker, 2004)
3. In result-oriented BM's a contract is drawn between provider and customer on the result, without a pre-determined product. This category again exists of 3 additional types. *Activity management* focuses on outsourcing the activity to an external company e.g., hiring a catering or cleaning company to execute that task for a company. *Pay per service* unit allows to only pay for the outcome you use, e.g., paying for printing per page. For the *functional result* PSS BM type, an agreement on the performance of a certain product is made e.g., delivering light in a building. In general, the result-oriented BM's have a higher level of freedom on how the result is delivered as long as the agreed upon result is achieved. (Tukker, 2004)

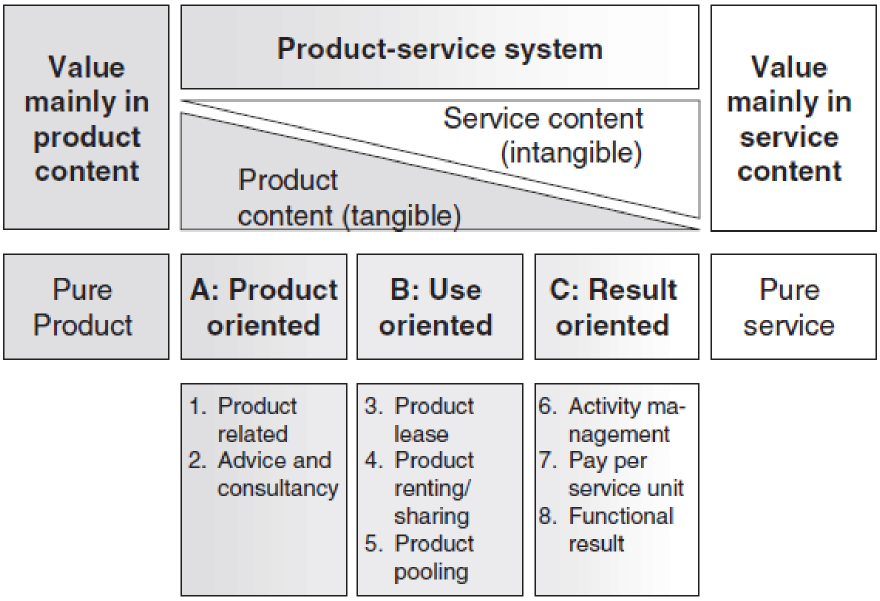


Figure 2.2Categories and additional types of PSS (Tukker, 2004)

The different PSS BM types also have a different sustainability potential. *Functional result* type has the highest sustainability potential as can be seen in figure 2.3. The agreement made between customers and providers in this type focusses on the delivery of a result, there is no predetermined product involved (Tukker, 2004). This gives the provider a high level of freedom how to deliver the result, leading to opportunities for a low-impact design (Tukker, 2004). However, there is a high variety in the sustainability performance for this type of model. Environmental trade-offs might interfere with the sustainability potential when the new BM is not properly designed, for example through opportunistic behavior of customers (Reim et al., 2018). The great variety of sustainability performance implies that implementing such a model does not automatically lead to unlocking this potential and careful consideration of the components of the (BM) is important (Bocken & Geradts, 2020; Johnson et al., 2008).

PSS type	Impacts compared to reference situation (product)				
	Worse	Equal	Incremental reduction (<20%)	Considerable reduction (<50%)	Radical reduction (<90%)
1. Product-related service		←-------	-------→		
2. Advice and consultancy		←-------	-------→		
3. Product lease	←-------	-------	-------→		
4. Product renting and sharing		←-------	-------	-------→	
5. Product pooling		←-------	-------	-------→	
6. Activity management		←-------	-------	→	
7. Pay per unit use		←-------	-------	-------→	
8. Functional result		←-------	-------	-------	-------→

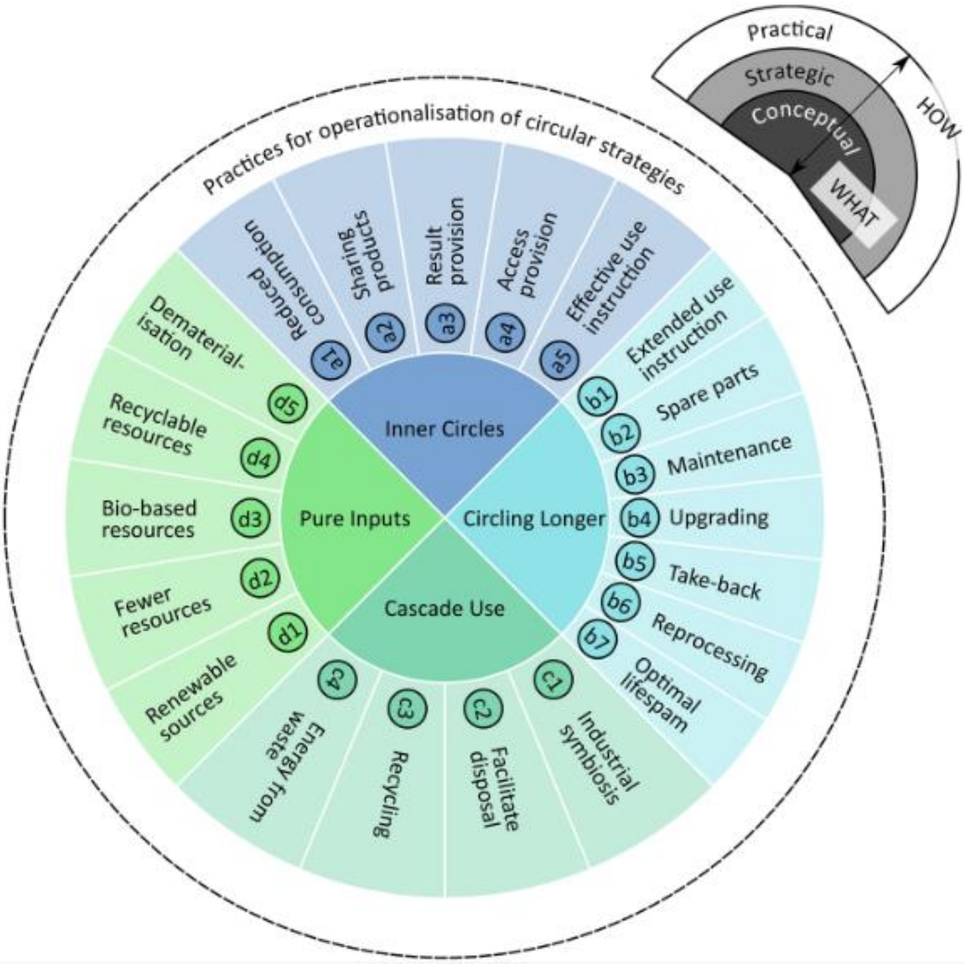
Notes:
- Renting, sharing: radically better if impact related to product production.
- Pooling: additional reductions compared with sharing/renting if impacts related to the use phase.
- Renting, sharing, pooling: even higher if the system leads to no-use behaviour.

Figure 2.3 Characteristics for sustainability for the different PSS types (Tukker, 2004)

2.2.3 Circular Product Service System

Innovating towards PSS BM's is a promising way to make the business sector more circular (Alipanah, 2017; Han et al., 2020). However, this potential is not automatically seized and careful design is needed. Therefore, it is important to design the BM, while considering the aspects of a circular economy. The Circular Innovation Framework (CIF) is developed by Guzzo et al. (2019) to design or assess a PSS BM in a way that enhances the circular economy (figure 2.4). The framework is specifically developed for PSS BM's and thus it allows to link aspects of servitization to these circularity aspects. This makes it a useful framework for this thesis. The framework identifies four areas for PSS BM's in which a link can be found with the circular economy: inner circle, circling longer, cascade use and pure inputs.

The first area, inner circle, is concerned with improving the use and consumption of products, for example to reduce the consumption of the end-user. Circling longer focusses on a longer lifetime of the product for example through replacing parts or upgrading the product. For cascade use it is important to look at the recovery of the discarded materials. Lastly, pure inputs is concerned with strategies that enhance the application of materials and energy, for which it is important to reduce raw material use and increase renewable energy in the manufacturing phase, but also during the functioning of the product. (Guzzo et al., 2019). This framework is in this thesis used to assess the PSS BM's for boilers in line with important aspects of the circular economy.



Circular strategies description

Inner Circles
Strategies for enhanced level of use and consumption of products

- (a1) Encourage reducing end-user consumption
- (a2) Enable shared use or ownership of products among members of a community
- (a3) Provide the functionality or the result of the product use, while retaining ownership
- (a4) Sell access to a product for a specific period or use cycles, while retaining ownership
- (a5) Knowledge-based services to increase the level of use of products

Pure Inputs
Strategies to enhance the application of materials and energy

- (d1) Use of renewable energy for products and components manufacturing and functioning
- (d2) Use of fewer resources for products and components manufacturing and functioning
- (d3) Use of bio-based input material for products or components production
- (d4) Use of fully recyclable input material for products or components production
- (d5) Provide the function of products and services through virtual or disruptive manners

Circling Longer
Strategies for enhanced lifetime of products, parts and components

- (b1) Knowledge-based services to increase the lifetime of products or components
- (b2) Provide spare and consumable parts while keeping longer lifecycle parts
- (b3) Provide or facilitate failure prediction, maintenance or repair services
- (b4) Upgrade system while keeping functional products' subsystems or components
- (b5) Facilitate sales, return or collection of used units of functional products or components
- (b6) Provide reconditioning, refurbishing, or remanufacturing services
- (b7) Manufacture products or components with an optimal lifespan

Cascade Use
Strategies to recover discarded materials and energy

- (c1) Use of a process' by-products as input to another process
- (c2) Facilitate sales, return or collection of discarded material
- (c3) Recover resources out of discarded material through recycling, upcycling, downcycling, or biodegradation
- (c4) Recover energy out of discarded material through heat, electricity or fuel source

Figure 2.4 The circular innovation framework (CIF) including the description of circular strategies (Guzzo et al., 2019)

2.2.4 Circular product service system for boilers

The product characteristics of boilers offer great potential for innovating the BM towards other types of PSS BM's: 1) They are a high cost for households, in general for more expensive products, customers are more open minded toward an increased service level. (2) They are not vulnerable to trends, which means that a longer lifetime of the product or a long-term contract does not interfere with new trends in the product market. (3) There is little interaction between the customer and the product, which gives more freedom to the provider to design a new way of delivering heat (Bastein & Rietveld, 2019; Toxopeus et al., 2017). The current BM of boiler is product-oriented and mainly focused on the selling of the boiler. Value is created by selling the product, and services are seen as add-on (Alipanah, 2017; Toxopeus et al., 2017).

Moving towards PSS BMs for boilers provides opportunities for becoming more circular. Offering a higher level of service makes it easier to properly maintain the product or understand how the product can be used in the most efficient way (Catapult, 2019; Thermafy, 2020). When providing a result, providers no longer need to convince the customer to buy the boiler or other product, but just have to deliver the agreed upon result: a comfortable temperature and hot water. Therefore, providers have more freedom to move to more efficient ways of delivering heat (Thermafy, 2020; Tukker, 2004). Furthermore, for some PSS BM's there will be more control over the take-back of the product and this will help to handle the materials after end-of-life better (Elzinga, Reike, Negro, & Boon, 2020).

2.3 Implementation through acceptance

Implementation of the PSS BM is crucial, otherwise the circularity potential cannot be seized. Several aspects are important for implementing a new BM, for example: legal aspects, technical aspects and acceptance of the BM (Linder & Williander, 2015; Planing, 2014). In 1.2 Relevanceit came forward that acceptance of a new PSS BM for boilers is understudied, therefore this thesis focusses on this aspect of implementation. In a new BM the offering of values changes and therefore the values among actors have to be realigned (Dittrich et al., 2015; Johnson et al., 2008). Identifying what actors find important values is key for aligning their values and making the BM acceptable for all actors. (Dittrich et al., 2015).

Identifying which values are important for private customers to design an acceptable PSS BM is complex. However, it is important, otherwise there is a high chance the system will be misused or not used at all (Planing, 2014). The paper of Antikainen, Paloheimo, Valkokari, Lammi, & Rüppel (2015) identified four categories, amplified with different factors, that influence whether the customers are acceptant towards the new PSS BM: price (perceived costs of lifecycle and costs of product), product/service (quality and reliability of PSS, perceived relative advantage), customer believes (habits, ownership, environmental attitude), relationship with company (reputation, uncertainties, risks, communication). These categories allow to identify thoroughly which values are important for the customer to be present in a PSS BM. To what extent these values are captures in a BM determines how likely customers are to accept the (new) BM (Planing, 2014).

Adrodegari, Saccani, Kowalkowski, & Vilo, (2017) developed a framework to guide companies in innovating their BM towards a PSS BM. This framework is based on the BMC and addresses all relevant components of the BM. This framework helps to identify the attitude of actors towards the different PSS BM's. Additionally for this thesis, it is important to identify a company's attitude towards the circularity performance, therefore this is an extra category for this thesis to understand acceptance. Addressing the attitude of actors within a company towards all these components allows to identify which values are important to be present in a new PSS BM.

2.4 Conceptual framework

Figure 4 provides an overview of how the important concepts of this thesis are connected to structure this thesis. The features of the current BM for boilers for private customers are presented in the BMC. This BMC shows the current interactions and important components of the BM. To design alternative PSS BM's the framework of Tukker (2004), which identifies the product-oriented, use-oriented and result-oriented PSS BM's, provides the needed information. To assess the circularity aspects of the PSS BM's the CIF is used, which identifies circularity strategies for the inner circle, circling longer, cascade use and pure inputs. Implementation is assessed by considering the acceptance level of involved actors for a PSS BM. How a BM captures the multiple values of multiple actors is the key concept for this. Assessing the circularity performance, through an MCI, and presence of multiple values shows which PSS BM for boilers could replace the current BM to enhance the circular economy.

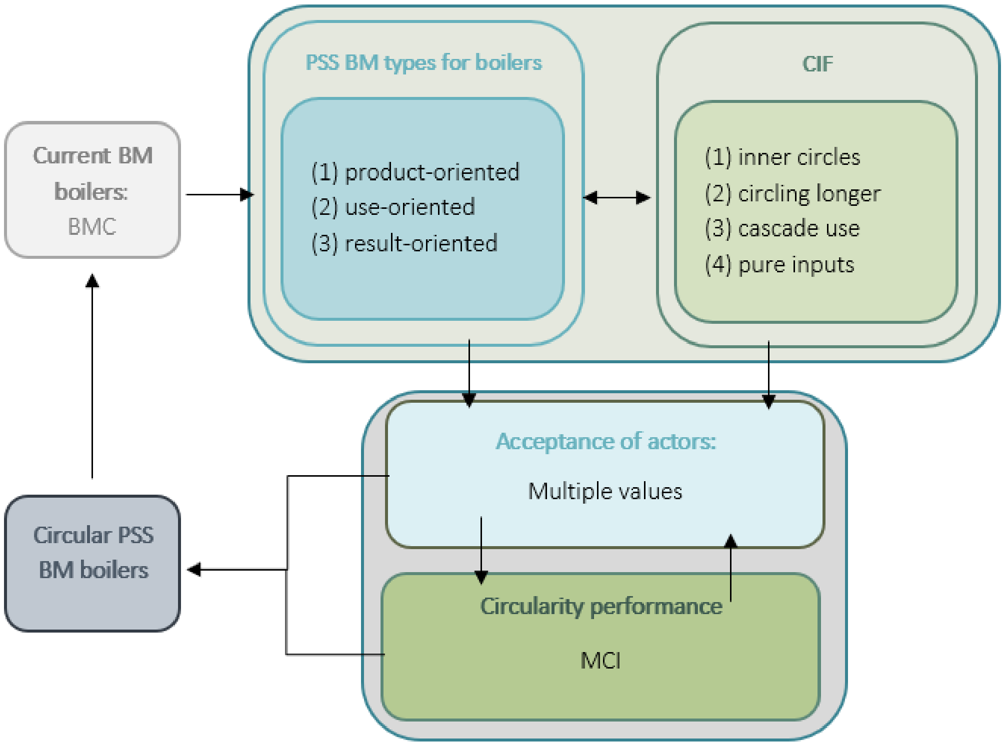


Figure 2.5 Linking concepts and frameworks to study the innovation from the current BM of boilers to an implementable circular PSS BM.

3. Method

The aim of this thesis was to design an implementable PSS BM for boilers to enhance the circular economy. This chapter elaborates on the different methods that have been used to do this. Both quantitative and qualitative data have been gathered and analyzed. Gathering qualitative data was used to identify multiple values of the involved actors. Quantification was used to evaluate the impact of the innovated PSS BM.

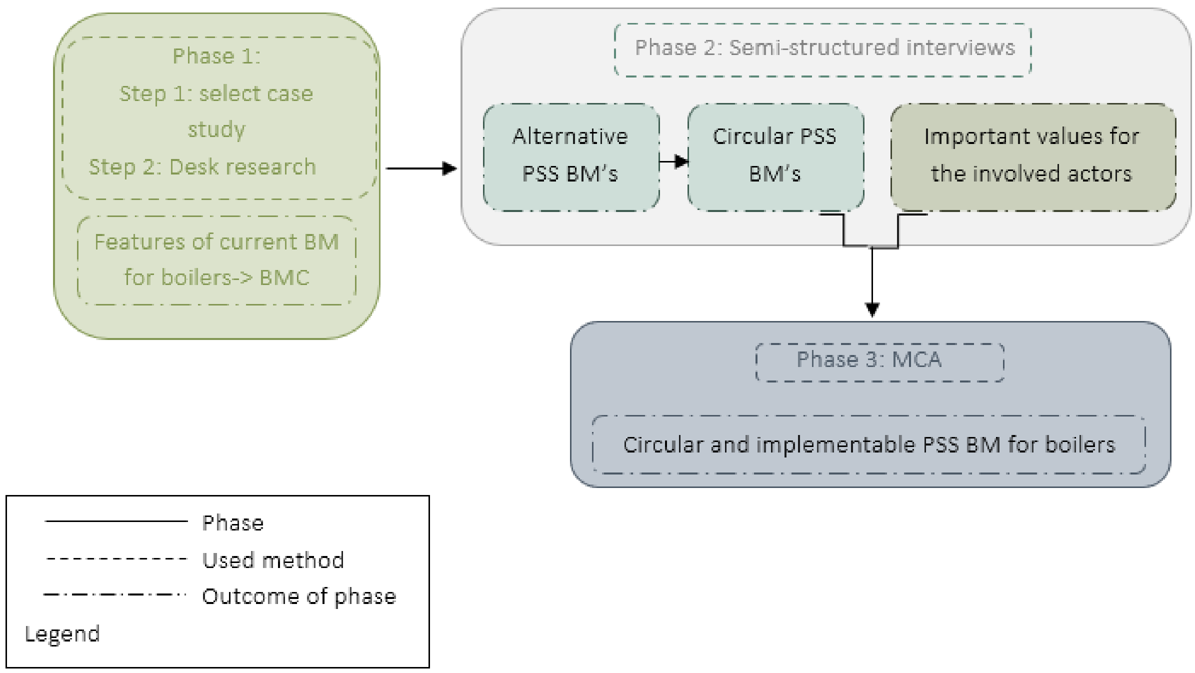


Figure 3. 1 Research framework

The method is depicted in figure 3.1. In phase 1 a case study was chosen and for this case the Business Model Canvas (BMC) was filled in, through a desk research. This information was used as input for phase 2 and 3. In phase 2 semi-structured interviews were held that helped to design alternative PSS BM's and important values for the actors. In phase 3 a Multi Criteria Analysis (MCA) table was developed that allowed to compare the alternative PSS BM's using the identified values as criteria. The MCA helped to identify the PSS BM that has the highest score for circularity and implementation.

3.1 Phase 1: Case study

In step 1 of this phase a case study was chosen. Through a case study, it was possible to gather in depth knowledge on this topic, which helped to answer the research questions (Zainal, 2007). The case study was selected after a desk research using Google and the following criteria were used to find a suitable case study: (1) the case study is a company sells boilers to private customers. (2) The willingness to participate of the company. This was based on earlier involvement of the company in a project about increasing the level of service in the BM, which shows their interest in being involved in such projects. (3) The company operates similar to other companies in the heating sector.

Step 2 in this phase identified the key features for this BM of this case company. The key features were identified by filling in the BMC, as described in section 2.2.1. The data to fill in the BMC was gathered through desk research; Google was used to access websites and annual reports of the company, which provided relevant information about the company.

3.2 Phase 2: Semi-structured interviews

In phase 2 semi-structured interviews were held with multiple actors that were identified in the BMC in phase 1. Through interviews more explanatory data was gathered, which helped to answer this thesis's research questions. With the interview data the designs of alternative PSS BM's were identified and it could be assessed what the circularity potential of these designs was. Furthermore, the interview data showed the values that were important for the multiple actors to be present in a BM.

3.2.1 Interviews

Semi-structured interviews were held with the key actors that were identified in phase 1. The interviews were semi-structured, which allowed to ask follow-up questions. Through semi-structured interviews the thoughts and insights of actors involved in this case could be identified. Semi-structured interviews reduced the chance of misinterpreting the answers, because this method allowed to ask for clarification (Griffee, 2005). Nevertheless, a guide was designed to prepare for the interviews and to better structure and compare the responses. A different guide was made for the customers and the companies. The two guides (Appendix A: Semi-stuctured interview guide were based on the papers of Adrodegari et al., 2017 and Antikainen et al., 2015, discussed in 2.3 Implementation through acceptance. Before the first official interview was conducted, the interview guide was tested on 5 persons, which helped to structure the guide more efficient and to test whether all used concepts were clear.

Sampling of the interviews started by addressing the customer service of the case company. Customer service helped to get in touch with a person that had proper knowledge about the subject and this led to a first interview. Through snowball mapping three additional interviews with actors that were involved with the BM were held. The snowball mapping technique allowed to ask at the end of an interview whether the respondent could help to identify and get in contact with other persons who could be relevant to interview for this thesis. This resulted in three interviews. The other respondents were addressed via Linked-In or customer service. They were selected based on the list of actors that was developed in phase 1. It was not possible to get in touch with customers of the case company. Therefore, the interviews with customers were based on my own network. A relevant group of customers was selected on the criteria's that (1) the house of the customers were heated by boilers and (2) the customers owned the house instead of renting it and thus were in charge of choosing the way of heating their houses. Due to the Covid-19 pandemic, all interviews were held online, using Microsoft Teams. A guarantee of anonymousness was given to all participants. After the participants permission was given, the interviews were recorded. The recordings were used to transcribe the interviews. A short interpretation of the interviews was sent back to the respondents to validate whether the interpretation was correct.

The number of interviews held was based on the saturation technique. With this technique the sufficient number of respondents is based on the previous interview held. Where the first couple of interviews gave the most novel information, after a couple of interviews not much new information was obtained. When it was noticed that almost no new relevant information was obtained from the interviews, the planned interviews were still held, but no new interviewees were searched for. Besides that, to ensure validity, for each actor category at least two respondents were addressed. This resulted in a total of 12 interviews with an average length of 45 minutes per interview. Figure 3.2 gives an overview of the actors that have been interviewed and how the actors relate to each other. Three interviews were conducted with respondents representing the manufacturers. Two interviews were held with employees from Energiewacht to have a good understanding of how the company operates, another service partner, was interviewed that was independent from Energiewacht. This company had a focus on the installation of boilers, which is also a service that is provided to the customers. The customer group was represented by a housing corporation and 5 customers. To guarantee anonymity the respondents were given a code, see table 3.1. The codes for the customers are ranging from 1-5, the first customer interview is coded as C1, customer 2 as C2, etc.

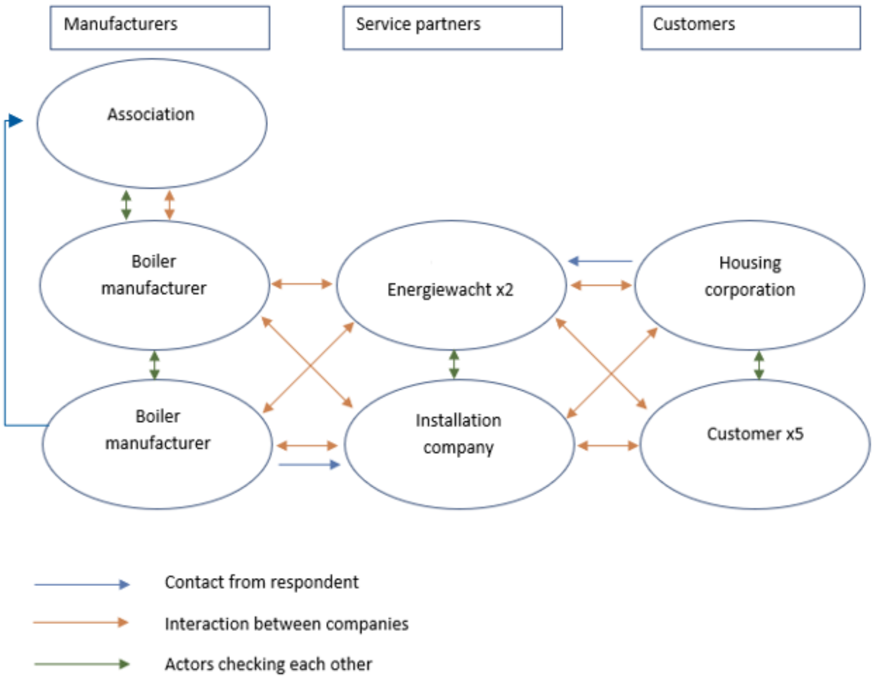


Figure 3.2 Schematic overview of respondents

Table 3.1: Codes for interviewed customers

Companies	Job description	Code
Manufacturer 1	Marketing and communication manager	M1
Manufacturer 2	Board member in charge of sales, product management, service and logistics	M2
Manufacturing corporation	Responsible for knowledge development and technical projects in the organization	M3
Service 1	Accountmanager	S1
Service 2	Marketingteam leader	S2
Installer 3	Director	S3
Housing corporation	Property manager	S4

3.2.2 Data analysis

To analyze the interviews they was first transcribed, which helped to get familiar with the data (Caulfield, 2019). Transcribing furthermore allows to analyze all information given in the interview and no information was left out, which increases the validity. Secondly, these transcribed interviews were coded using NVivo 12 Pro. Both deductive and inductive coding was used. For deductive coding, the concepts identified by Adrodegari et al., 2017 and Antikainen et al., 2015, as discussed in section 2.3, have been used. This allowed to connect information obtained from the interviews to the concepts of BMs and PSS BMs that are identified in these papers. Inductive coding allowed to stay open minded to identify new themes that came forward in the interviews. Therefore it was possible to identify concepts that are specifically relevant for this thesis. The coding process was iterative to make sure that the interviews were coded properly.

The interviews were designed and analyzed in such a way that data was gathered that helped to understand (1) how alternative circular PSS BM's would look like and (2) that showed what were important values for the actors, that can be used as criteria in a BM. To analyze and design the alternative PSS BM's the framework of Tukker (2004) was used, see 2.2.2 Product Service SystemAccording to the framework of Guzzo et al. (2019)2.2.2 Product Service System the circularity aspects of these alternative PSS BM's were assessed, see 2.2.3 Circular Product Service System Using established frameworks for this analysis, creates clarity in how the analysis was performed, and how it can be repeated by other researcher, increasing the external validity. The values that were retrieved from the interview data were sent back to the actors to verify them. Doing this helped to make sure that the proper values were used and increased the validity in this thesis.

3.3 Phase 3: MCA

In phase 3 a MCA was developed to choose a PSS BM that is implementable and circular. A MCA is suitable for this since it helps to make a decision between different scenarios where there is a complex interaction between criteria (Miller & Mattes, 2014). The current BM, alternative PSS BM types and values were used as scenarios and criteria, respectively, in the MCA. Proxies were chosen to turn abstract values into a measurable unit. The choice for proxies was based on the suitability of the proxy for the value in context of this thesis. In some cases, a proxy could directly be taken from the interview data, for example when *sustainability* was explained by a respondent as *CO_2 reduction*, this could be used as proxy for sustainability. When the interviews were not appropriate to identify proxies for certain values additional literature was sought, through a desk research in which search engines as Google Scholar and WorldCat were used. For every value a table was developed which indicates, by using proxies, how a certain score was assigned to the value.

The circularity performance was assessed with the Material Circularity Indicator (MCI). Execution of this method was based on the method developed by the Ellen MacArthur Foundation (2015). To calculate the MCI, data was obtained and combined of the following fields: (1) the mass of virgin raw materials used (V), (2) the mass of unrecoverable waste (W) and (3) intensity and length of the lifetime (X). In Appendix B the multiple equations used for this can be found. This data was gathered, first by asking the company whether they could provide these data. Data that was not available in this way was gathered from literature by using Google Scholar and WorldCat. The choice of articles was based on how similar the data is in the article compared to this case. A table was developed that showed how a certain value of the MCI was translated to a score that could be used in the MCA table.

4. Results

In this section the results are presented. Section 4.1 introduces the case that is chosen for this thesis and identifies the features of the BM of this company. In section 4.2 alternative PSS BM's are designed based and analyzed based on the interview data. For these alternative PSS BM's, it is furthermore analyzed what their circularity features are. The results in section 4.3 also arise from the interview data. In this section the values that the relevant actors find important to be present in a BM are presented. Lastly, a MCA table is presented in section 4.4, using the alternative PSS BM's as scenarios and the identified values as criteria to understand which models have the highest level of acceptance. In the MCA table circularity of the BM's is also assessed.

4.1 Case study: Energiewacht

Energiewacht is a Dutch company operating in the north-east of the Netherlands. Energiewacht is fully owned by Essent, an energy company operating on the energy market in the Netherlands. Essent generates electricity and purchases gas on the energy market to deliver it to its customers. Furthermore, it offers energy related products that are delivered through several service partners operating throughout the Netherlands, one of them being Energiewacht. (Essent, n.d.). Through Essent these service companies have a similar way of operating and together they cover the Netherlands. Energiewacht is therefore assumed to be a quite typical service company for this sector in the Netherlands. Using this company as a case allows to study the way of operating in more detail.

Energiewacht is an energy service specialist and provides several products e.g., boilers, solar panels and heat pumps, furthermore services are provided to maintain these products. The focus of the BM currently lies on the boiler. Figure 4.1 shows a brief overview of the way of operating of Energiewacht, presented in a BMC. Private customers are an important part of the customer segment of Energiewacht. In consult with the customer, they sell boilers that deliver a comfortable temperature and hot water based on the specific

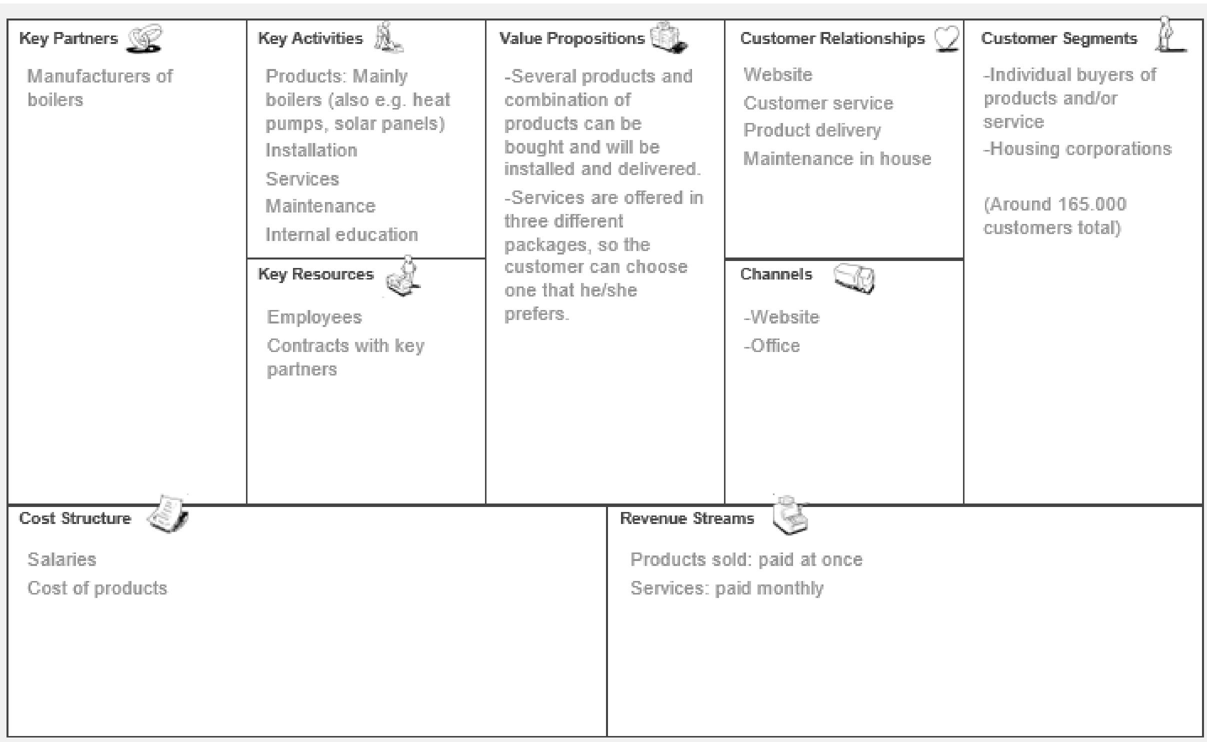


Figure 4.1: Business Model Canvas for Energiewacht based on information *(Energiewacht, n.d.)*

situation and preferences of a customer. Several service contracts differing in duration, inclusiveness of material costs or other costs occurring from maintenance are available. Customers can make use of the services 24/7 in case of malfunctioning of the product. Customers can choose to buy a product with or without service. There is also the possibility to rent a product, but this is not their focus. Energiewacht works with several partners that deliver these products to them, including Atag, Remeha, Nefit and Vaillant. (Energiewacht, n.d.). These manufacturers are identified as key partners and are an important actor for this case. Other actors that are identified are customers and (external) installation technicians. In terms of the identified PSS BM's of Tukker (2004), the features of the current BM are most suitable with the *product-related services* BM. There is a focus on the product, services are offered to support the product during its use phase.

4.2 Results interview: PSS BM's

In this section the interview data is used to identify how the different PSS BM types, as developed by Tukker (2004), apply to this case. For a clear structure, the BMC is used to give an overview of which changes per type of PSS BM compared to the current BM came forward from the interviews. The changes depicted in these BMC's are further analyzed per BM component, based on the interview data. This gives an overview per different type of BM how it is perceived by the actors. Quotes are added to support the analysis. For a better overview the quotes of the companies are presented in a blue text color and customer quotes in a green text color.

4.2.1 Product-oriented BM's

Tukker (2004) distinguishes two types of product-oriented BM's: *product-related services* and *advice and consultancy*. As is described in section 4.1, the features of the current BM fall under the *product-related services*. This leaves only *advice and consultancy* as an alternative BM in the product-oriented category. The *advice and consultancy* BM would besides selling the boiler, inform the customer about its most efficient-use. This type of BM is quite similar to the current BM and therefore the changes that have to be made are relatively small. The main change would occur in the value proposition: the advice and consultancy on product use will increase (see figure 4.2). From this point on this type of BM is referred to as PSS BM type 1.

Figure 4.2: BMC PSS BM type 1, showing the main changes compared to the current BMC.

Value proposition

The interview data showed that whether this value proposition was perceived as useful by the actors depends on the product that is being installed: The usage of the boilers that are currently being installed is not very difficult and no explanation about the use of the boiler is needed. However, new products emerging in the heating sector are becoming more diverse and advanced. This could make it more difficult and less intuitive to use the product in the most efficient way. For these products additional advice is needed for a proper use of the product and it is a useful addition to the BM.

"with new technologies you have to look how to inform people and instruct them that they have to use the product in a different way." -S1

"Hydronic balancing is a new technique that is being used, but this demands a different way of heating your home, it is important to explain to a customer that you have to use the product differently." -S1

This second quote shows that new techniques might also influence how the house is heated. When customers understand how to use the product, they can better regulate the temperature and use it in a way that satisfies their needs in terms of heating. Customer satisfaction is important for companies, see section 4.4, and therefore this gives an incentive to move towards this type of PSS BM. No clear reason against this type of PSS BM could be derived from the interviews. Therefore, this PSS BM type 1 is considered a feasible alternative.

4.2.2 Use-oriented BM's

The use-oriented category contains 3 types of BM's: *product lease, product sharing* and *product pooling*. The latter two BM types are not feasible for this case. In the use-oriented category, the BM's are still centered around the product, boiler, and how this is used by customers (Tukker, 2004). The boiler has a fixed place in a home and is installed with effort. It is not transferable from day to day to share it with other customers. Therefore, *product sharing* is not a feasible PSS BM type for this case. A similar reasoning makes the *product pooling* BM unfeasible: the boiler is placed in the house of a private customer, with the current construction it is not possible to simultaneously use this product in other houses.

This leaves only the *product lease* BM left to discuss for the use-oriented category. The interviews with Energiewacht helped to understand how applying the *product lease* BM would look like for this case: a lease contract would be constructed for a period equal to the expected lifetime of the boiler, approximately 12 years. The responsibility of the boiler would remain at the provider. When the contract period is over, the product is paid off and at that point ownership of the boiler moves to the customer. This form of leasing is called financial lease. However, the regulation for this type of contracts has changed and a permit given by the AFM (Autoriteit Financiële Markten) is needed for this (AFM, n.d.). So, this form of *product lease* is not a feasible for this case.

"We are not a financial institution, so we are not allowed to offer lease contracts." -S2

An alternative way to design a *product lease* BM is through rental contracts. Compared to financial lease, a rental contract is easier to terminate and in a rental contract the ownership of the product remains with the provider at any time (Consumentenbond, n.d.-a). The customers pay a certain amount per month for the use of the product. The main change in this type of BM compared to the current BM is the value proposition. This changes from selling a product to renting it. Consequentially, the cost structure changes from paid at once to monthly income. The responsibility of the boiler stays at the company therefore the interaction between customer and provider increases (Gemser, Kuijken, Wijnberg, & Van Erp, 2012). Figure 4.3 shows for this type of BM the changes compared to the current BM. This type of BM is further referred to as PSS BM type 2.

Figure 4.3: BMC PSS BM type 2

Value proposition

To analyze how the actors perceive PSS BM type 2 the change in value proposition is firstly discussed. Offering a rental contract means a shift in ownership from customers to providers. The insights retrieved from the interview data on this topic are contradictory: some companies perceived it as pleasant, other companies found it more complicated. *S3* foresees discussion between parties when the customer no longer becomes the owner of the product. Whereas *M2* perceives a shift in ownership from customer to provider as a positive change that makes it easier to re-collect the boilers.

"Changing ownership causes discussion among providers [...] who become responsible for what and under what conditions. When you keep the ownership, you have to deal with new problems and I think that the market does not yet have these solutions." -S3

"It is driven by the circular economy, the thought that customer no longer own the product, but that the ownership stays at the company. That that will help us to re-collect more products at the end of their lifetime." -M2

Revenue stream

Analyzing the change in ownership automatically leads to a discussion on the changed revenue streams for this PSS BM type 2. Rental contracts lead to an Annual Recurring Revenue (ARR), which generates a steady income for the companies. This is perceived as an interesting aspect of this BM.

"Rental contracts are really attractive for us, because the constant income is very pleasant." -S2

That a high ARR is pleasant was supported by *M2*, however they noted that this type of BM would also lead to a lower Return On Investment (ROI), which was perceived as less attractive for the actors.

The financial changes also affect the customers: change towards monthly income for companies implies that customers need to shift to monthly payments. In the experience of *S2*, private customers are not particularly interested in this monthly payment structure. Private customers often have enough money to buy the product at once and prefer the uncomplicatedness of this one-time transaction. Furthermore, it appears that customers perceive buying as a much cheaper option than renting.

"They [the customers] say I pay it all at once, because renting is more expensive […] and when you pay 14/1500 euro at once you are done with it." -S2

These statements by Energiewacht were in line with the perception of the customers that were interviewed.

"I believe owning the product is always cheaper than renting it and paying for services." -C1

"I think buying in general is cheaper than renting." -C3

"A factor that also played a role was when we bought the house we also had a certain amount of money to put into it, so you have the money to buy the boiler at once, without this money renting is more interesting" -C2

S2 remarked that when a better insight and more clarity in the benefits of renting is provided to customers, it is very likely that more customers will choose this option. Furthermore, the interview data showed that transparency in how the price of renting is constructed could also help to make renting more attractive.

"You should bake a pie and see what the largest most important slice is for the customer, which factors really matter for the customers and where is the stretch, is it in price, lifetime, or…" -S1

"Yes, then it [rental contract] is always an option to consider, of course." -C3

"Maybe when there would be a better insight in the prices which shows that you do not pay that much more for renting, than it would be interesting, but price difference was the main issue to choose to buy instead of renting." -C2

Customer relationship

The last change for PSS BM type 2 is the increased relationship between customers and providers. This was not perceived as a problem by the actors, as long as the service providers were respectful to the customers.

4.2.3 Result-oriented BM's

Three types of result-oriented BM's are identified by Tukker (2004): *activity management/outsourcing, pay per service unit* and *functional result*. The first two BM's cannot be applied to this case study. The features of these BM's as explained in section 2.2 do not suit the characteristics of the boiler.

This leaves the *functional result* BM as a suitable alternative for this case study. This type of PSS BM has the highest level of service and the value proposition for this BM is the delivery of the result: a comfortable temperature and hot water. The provider is responsible for a proper delivery of the result and has a high degree of freedom in how to deliver this (Tukker, 2004). The customers pay per month for this result, which leads to changes in the revenue stream as compared to the current BM. Furthermore, the relationship with customers and key partners increases for the *functional result* BM. An overview of these changes of this BM, which is named PSS BM type 3, can be seen in figure 4.4.

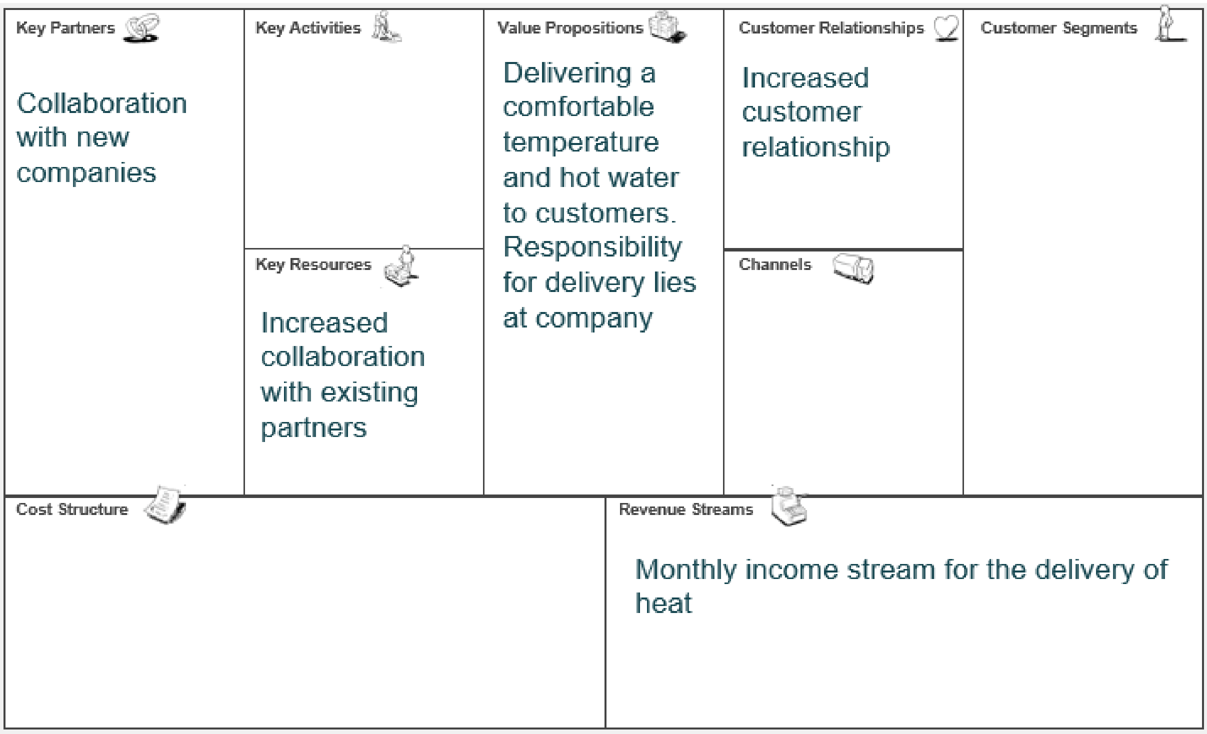


Figure 4.4: BMC PSS BM type 3

Value proposition

Again, first the changed value proposition is discussed. The provider becomes responsible for designing a proper system that delivers the result, a comfortable temperature and hot water, to the customer. It is important to draw up a contract on how this result is delivered. The contract focuses on the result and goes beyond solely delivering a product (Tukker, 2004). A broader package can be offered, for example, isolation can be included or multiple products can be installed. This gives a higher level of freedom to the provider (Tukker, 2004). When the agreement is not met, the provider is responsible to come up with a solution. To deliver a comfortable temperature to a house, smart thermometers play a crucial role. Smart thermometers make it possible for providers to regulate the temperature in houses of the customers. It is possible to adjust the temperatures in the houses of the customers from a distance. This means that the provider can control the temperature in a house and make sure that this is according to the customers preferences.

"When the customer gives permission to use the data, we can adjust the temperature in their homes during a certain period of time in the day." -M1

Revenue stream

In PSS BM type 3 the shift in revenue stream is similar as described in PSS BM type2: compared to the current BM higher stable monthly incomes are generated and there is a lower ROI. The analysis and quotes given in section 4.2.2 are thus also applicable to this section.

Customer relationship

Some obstacles from the new interactions with customers in PSS BM type 3 were derived from the interviews. A contract about the delivery of a comfortable temperature and hot water increases the dependency of customers on the providers. The companies pointed out that in their experience this conflicts with the customers preferences: customers like to be in control over the temperature and be able to adjust it whenever they want. Furthermore, customers are very different in what they perceive as a comfortable temperature. The diversity in preferred temperature makes it difficult to design contracts that deliver heat.

"I think we, as a Dutchman, prefer to keep in check of our own thermostat." -S1

"Comfort for you is not necessarily comfort for me." -S4

"What is a nice temperature for you is not necessarily a nice temperature for me, we could say we give you a comfortable temperature, but what is comfortable for you does not have to be the same as for me." -M1

However, the new customer interaction was also perceived by the companies as a positive change. The delivery of a complete package that delivers heat reduces the time and effort customers have to put into sorting everything out.

"That would be an ideal solution, to offer a complete package for heat and make it the customer as easy as possible to make the heating in their homes more sustainable." -S2

The obstacles and opportunities of this new customer interaction as perceived by the companies came forward in the interviews with customers as well. There is a paradox in liking the fact of having a contract that takes care of all aspects and the loss of control caused by it at the customers side.

"Well, I never know beforehand which temperature I would like to have, when the weather is suddenly colder, like last week, than I like to just turn the heat up, but when I have an agreement about I want to have 20 degrees than I have to wear thick socks or whatever, that's inconvenient." -C4

"A contract about the result, where I can say this is what I would like and the company can provide it, that sounds fine, but then you get more dependent on such a company. If he says, okay than I will deliver that to you, then he can decide that he is going to run 36 cables across my house and you have to accept the humming noise in your backyard. Then I would like to know in advance clearly what exactly the degrees of freedom of this company are and within which lines they are allowed to operate. "-C5

Key partners + key resources

Besides increased interaction with customers, increased collaboration with key partners is important for PSS BM type 3. The provider becomes responsible for the delivery of the result. When this result is not delivered properly due to a problem with the product, the provider is responsible for solving it. Therefore, the risk that a product is not working properly is now with the provider. Compared to the current BM this increases the risk for the provider. A way to reduce this risk, is through an increased relationship with the manufacturers. When manufacturers guarantee a certain performance level of their product, the risk remains at the manufacturer. So, for PSS BM type 3 it is important to increase the relationship with the manufacturers to control the risk.

"You have to have a concrete agreement with the manufacturers about the performance of the product and the availability of components for the coming 18 years, to know that the manufacturer has faith in its product. When that would not be the case, there is a higher risk for us, for example when after 13 years for whatever reason all type of boilers of brand x, construction year x, breakdown, than that would be on my account and I have to replace them. But when proper agreements are made with the manufacturer you can handle this differently and the risk you have to facture in is lower." -S3

"Heat as a service can be seen as an advanced service level, where guarantees are given on the lifetime of the boiler." -S3

The interview data showed the willingness of companies to increase the collaboration with other companies. They saw collaboration as crucial for innovations and implementing this type of PSS BM.

“they [manufacturers] understand really well [...] you cannot do it alone, if you manufacture a specific component in a broader system, you have to work together, therefore we are undertaking pilots and activities to see how we can tackle it together.” -M3

“For delivering Heat as a service collaboration throughout the supply chain is needed.” -S1

“For result-oriented solutions it is important to increase the collaboration and be open and transparent in the collaboration.”-S3

“When we notice that there are good options for new collaboration, then we are definitely up for that.”-S4

The last quote shows that besides enforcing the current collaborations, companies are open towards developing new collaboration with other companies. For this type of BM this extension is important since the provider is in this BM concerned with a broader system. Collaborating with new partners e.g., isolation companies, helps to properly deliver the result for heat that is in the contract. For the delivery of a comfortable temperature and hot water energy is needed. Collaborating with energy companies becomes for this type of BM very useful. Unfortunately, one of the actors that tried to explore this collaboration found out that this is difficult. Energy companies are only allowed to have short-term contracts. Legally, customers should have the freedom to shift between energy providers. For products that provide heat it is not feasible to have short-term contracts. The installation costs for these products are a high share of the total costs of the product and thus the costs for replacing boilers on the short term are too high.

4.2.4 General perspectives on PSS BM’s

From the interviews some general perspective of the companies for innovating towards PSS BM’s are derived. The advanced ICT and monitoring technique and the positive mindset in companies towards change are discussed as factors that make it easier to move to alternative PSS BM’s. Market uncertainties and the lack of human capital, however, are discussed as limiting factors to move towards PSS BM’s. The aspects discussed in this section are relevant for all three alternative PSS BM’s, PSS BM type 1, 2 and 3.

ICT and monitoring

Strengthening the use of ICT and monitoring is valuable for every PSS BM to deliver services more efficiently. Smart meters, for example, provide information about the state of the boiler or certain components. Information is available about how intensively the product is used, which influences the lifetime of the boiler and components. The information obtained from the smart meters can help to understand when an error might occur and the problem can be solved in advance. Preventive service can be delivered.

“We can monitor the product and provide all needed maintenance based on this information, which will lead to less movement and knowing beforehand when a component might break or what component is not working right.” -M1

With these techniques errors can be solved from a distance. When an error occurs the provider can see what the problem is and, in some cases, it is possible to reset the system and solve the problem. This decreases the number of times a technician must drive to a house to solve the problem where the boiler is situated. Next to that, the extra information that is available on the components can help to make the onsite service delivery more efficient. The technician already knows what the state of the components is and can prepare his visit better.

“This could mean we have to drive less often and see beforehand if a component might break.” -M1

“When there is an error message, this data can help to understand what the cause might be and what we do we need to do to fix the problem.” -M2

The companies recognize that the information that can be gathered by smart meters and monitoring can be very useful for service delivery. However, this data is currently not used and not part of their BM.

"The possibilities for preventive service delivery are there, however that is currently not broadly exploited." -M2

"There is a lot of data that is currently not used, it is not our business yet." -M1

Positive mindset

The interviews showed that in general most companies had a positive attitude towards PSS BM's. This is beneficial for implementing more servitized BM types (Alghisi & Saccani, 2015). Companies are aware of the changing environment and increasing awareness for sustainability and are willing to incorporate these changes in their businesses.

"Heat as a service is interesting and we would like to take part in this concept." -M2

"There is a lot going on, there is a movement from traditional company towards a service-oriented company" -M1

"Awareness for sustainability results in movement throughout the supply chain: this is a positive change." -S1

Although the attitudes and mindset of the interviewed actors themselves were optimistic and positive towards change, some of them stressed that they perceived the sector as conservative. They said the sector remains traditional and that the employees are mainly conservative.

Market uncertainties

The interview data showed that there are many developments in the heating market, new products and techniques are designed and introduced. Part of these products will stay but the others will disappear again, which creates uncertainty in the market. It is difficult to anticipate what the future will bring.

"How the market is developing is unclear, so you have to work with what is reached to you." -M2

"The market is in transition and it is noticeable that nobody has a clear idea of what the future will bring." -M2

Furthermore, not every company agreed that natural gas would disappear in the future, arguing that the vision around natural gas is changing again and that the outcome is not yet clear.

"We are not convinced that the role of natural gas is over." -M1

The uncertainty in the market makes it very hard for companies to know what they are up to and can cause some negative effects. For example, installed products cannot be maintained for a long period when the product is taken out of the market, since this means that the components required to fix the boiler are than not being produced anymore. Another example, if new and more difficult products are implemented, the chance that customers do not know how to properly use the product increases. PSS BM's can help to prevent these negative effects. Section 4.2.1 already showed that extra service can be given that properly explains how to use the new products. This reduces the chance for misuse by customers. Furthermore, since the company is in these BM's also responsible for the service delivery, they have an incentive to choose a product that is maintainable for a long-term. This ensures customers that their product can be properly maintained.

The uncertainty in the market might make PSS BM's more attractive. PSS BM's create flexibility which can be an opportunity in an uncertain market (Shimomura & Kimita, 2013). This happens through the lower dependency on a certain product in PSS BM's. The company owns the product and is not only responsible for choosing a sufficient product, but it also has an influence on when to replace the product. This creates freedom to offer new products that suit a certain situation better (houses with high insulation). The old products, that belong to the company, can replace older products in houses that are not yet suitable for the newest developments. This creates a more dynamic environment in which the company can offer new techniques to the proper customers and stay competitive.

Human capital

Another aspect that is an issue for the whole sector is the availability of human capital. The companies clearly indicated there is great shortage of technicians and installers in this sector. For increasing the service level, in general more human capital is needed (Adrodegari et al., 2017). Therefore, the lack of human capital makes it harder to move to PSS BM types.

4.3 Circular PSS BM

In this section the perspectives of the actors on circularity are analyzed. This section uses the circularity strategies from the Circularity Innovation Framework (CIF), see section 2.2.3. These circularity strategies of the CIF are in this section linked to the different BM's; the current BM and PSS BM type 1, 2 and 3, identified in section 4.2.1, 4.2.2 and 4.2.3. For every circularity strategy of the CIF there is a specific code, a1-d5, to indicate where a circularity strategy applies the codes are added in brackets.

4.3.1 Current BM

The current BM has several circularity strategies that helps to extend the lifetime and components of the product. The first two strategies are delivered through the service that is offered. The service exists of replacing broken components to extend the lifetime of the remaining, and still well-functioning, components (b2). The boiler is cleaned and maintained once in the 18 months, this helps to keep the components well-functioning and extends the lifetime of the product and components (b1).

"It is important to maintain the product and remove the dirt once in a while, because that extends the lifetime of the product and ensures efficiency in use." -S2

Extending lifetime also occurs in the manufacturing process. Manufacturers try to design a product with an optimal lifespan and efficiency in use (b7).

"From the beginning of our business we have tried to make the lifetime as long as possible, to let the boiler work as long as possible and as efficient as possible." -M1

"The material we use are specifically chosen. We do not use plastic materials, but stainless steel, which extends the lifetime of the product and increase the energy efficiency. That's a characteristic of stainless steel, it does not easily get rusty and it does not get dirty, assuring a high efficiency, whether it is day 1 or day 395 of year 18." -M1

Furthermore, the components of the boiler are made from pure materials: apart from exceptions here and there, no composite materials are used. This increases the recyclability of the boiler (d4).

"Considering the quantity of composite materials used is important, it is needed to use as little composite materials as possible." -M2

"In principle our building blocks are designed as such that no components are blend together, and are inseparable, so, basically everything is designed to be detachable and recyclable." -M1

4.3.2 PSS BM type 1

In PSS BM type 1 advice and consultancy on how the product should be used is given. The discussed circular strategies in 4.3.1 still apply for this BM. Additionally, giving advice on how to use the product brings knowledge to customers on how to reduce their heat consumption. This reduction can occur from a more efficient use of the product and through less heat needed, for example, closing windows when the boiler is turned on (a1+a5).

"Proper explanation and guidance of the product and its use is definitely important and can help to create more awareness on how to use the product more efficient." -S3

"It is a challenge to clearly instruct the customers who are ambiguous about the installation of the product, there is a risk that they do not use the product well, having the heating on and windows open, just to give an example, that could even increase the use of energy instead of reduce. So, you have to carefully consider these aspects and instruct customers when you place certain technologies." -S1

Although giving advice on the use of the products brings opportunities for more efficient use of the product, this does not guarantee that customers will take this advice to heart.

"I understand you explain to the customers what the consequences of their behavior are, but it is up to them what they do with this information. When you have informed them and they say: "I understand, but I am not going act accordingly". That's up to them, that's fine, that's their choice." -S3

4.3.3 PSS BM type 2

For PSS BM type 2 some additional circularity strategies are identified. The shift in ownership in this BM, discussed in section 4.2.2, is also a circularity strategy aimed at enhancing the level of use of the product (a4). In the current BM secondhand boilers or components are rarely/not used. Customers prefer to have a new product when they have the option. Secondhand boilers are currently not requested or considered and are not part of the current BM.

"It is astonishing that I have never considered the use of secondhand boilers, because I never had a question about this, never." -S2

When ownership remains at the company, it is easier to reallocate the boilers when a customer ends the contract. In rental contracts the provider is responsible for a proper working product, there is more freedom on how this is delivered, therefore the company does not have to justify the use of second handed materials (c2).

"If a boiler is 4 or 5 years old, we can still relocate it […] we replace it and make sure it works, but we do not necessarily inform the customer that it is a secondhand product. With rental contracts this is easier since we are responsible for delivering an all-inclusive concept and we are responsible for installing it and make sure it works." -S2

"Customers rather have a new product but delivering it as a service will give the opportunity to move away from that discussion." -M3

Furthermore, it is easier for providers to collect the boilers back at the end of their lifetime when they still own the product (b5). This makes it easier to properly handle this 'waste'. At this moment it is not clear what happens to the boilers at the end of their lifetime, where and how they are being recycled.

"We are almost certain that the boilers are being recycled, but we cannot determine or prove where." -M2

There is even an obligation from the European Union to collect a certain percentage of these products, the WEEE (Waste form Electrical and Electronical Equipment). The WEEE is a directive stating that at minimum a certain percentage of the electrical and electronical equipment in every European country has to be re-collected and recycled (WEEE Nederland, 2015). For boilers to be registered under this WEEE directive the boilers must be brought to a WEEE-certificated recycling station. Although, boilers are being recycled, only 5% is recycled at these certificated recycling stations. For the other boilers no information is available.

"The registered collection of boilers is rare. In principle the WEEE obliges the sector to re-collect at minimum 65% of the boilers […] at this moment, the last number I have heard, this collection is only 5%. These boilers are probably being recycled, just not at certified stations. The reason for this is probably that you get paid more when you hand in the boiler at a non-certificated station than at a certificated station." -M3

A different aspect of PSS BM type 2 is the possibilities for further increasing the service delivery. The provider has the responsibility for a well-functioning boiler and can monitor the boiler. This provides information that can help to better understand the problem and provide more specific service for the precise problem. Furthermore, this information can be used to deliver preventive services (b3), see section 2.2.4. This is beneficial for circularity since proper maintenance can prolong the lifetime of a product and increase its use efficiency.

4.3.3 PSS BM type 3

In PSS BM type 3 a result is deliver, giving a higher responsibility to the provider and freedom to operate more circular. Providers can choose to install boilers that are designed in a circular way (b4); e.g. designed for recycling (Toxopeus et al., 2017). Currently how circular the design of a product is, is not a criterion for installing a product or not.

"The recyclability or circularity of components is currently not part of our procurement and supply policies." -S3

Price is often a limiting factor for further enhancing the implementation of more circular products. A boiler that is designed to be more circular might be more expensive. It is often not clearly communicated to customers what explains the price differences between boilers. Without this communication customers are less willingly to pay a higher price.

"The willingness to pay a higher price for customers increases when they are aware of what the difference is in a product, if it is better recyclable or demountable than other products. Or when the price is similar another trade-off between efficiency and circularity of components." -S3

4.3.5 Uncertainty

Prolonging the lifetime of a product is a circularity strategy and section 4.3.1, 4.3.2 and 4.3.3 showed that this was applicable to various PSS BM types. However, in the interview data it was argued whether this was always the most sustainable option for boilers. Compared to the production phase of boilers, much CO_2 is emitted during its use phase. Through the R&D departments of the manufacturers the efficiency of boilers (or other heating products) is still being improved. Although efficiency in use of gas has reached a peak, significant efficiency improvements are still made in the electricity use of boilers. This makes it arguable that replacing old boilers for more efficient boilers is better than prolonging the boilers lifetime as long as possible, even though this is contradictory for a circular economy. Different statements were made in the interviews on this topic:

"The boilers now, compared to 10 years ago, are more efficient. Mainly in electricity use and a couple of percent in gas."-M2

"Most boilers are in a house for about 15 years [...] but it would be better to replace them after 7 or 8 years, because that would give a lower total emission. That is contradictory to the circular economy, for which it is important to extent the products lifetime, but technological developments cause that an old boiler is not always state-of-the-art anymore." -M2

"Boiler, especially HE-boilers, are very efficient, so although new boilers are a bit more efficient calculations show that it is not always obvious that it would be unbeneficial to extent the boilers lifetime in terms of total emissions compared to a new boiler." M3

Therefore, prolonging the lifetime is not necessarily unsustainable, but it is important to get a proper understanding of the situation to make a decision of whether to replace the product or prolong the lifetime. E.g.; whether the new boiler is replacing a HE-boiler or one that has a lower efficiency; or how long the house is connected to the current boiler system. This last example is relevant since the heating market is changing and new innovations might lead to replacement of boilers by other products. Replacing a boiler when it is known that in 2-3 years the house is shifting towards other products that deliver heat is more unsustainable than prolonging the lifetime of that boiler for those years.

4.4 Interview results: Values

This section presents the values that are important for the interviewed actors. A short explanation per value is given and supported with quotes from the interviews. These quotes are presented in tables where quotes from companies are marked green and from customers blue.

Customer satisfaction came forward to be an important value. The customer segment differs per company, for the manufacturers of boilers the main group of customers are the installation and service companies, however the contact with the end-customer seems to be increasing. For service and installation companies and housing corporations the customers segment focusses on end-customers. In the heating sector customer satisfaction is reached when customers have a comfortable temperature in their homes and delivered according to the preferences of the customer. Given that the customers have quite diverse preferences it is important to give personal advice. Delivering this heat happens by installing a boiler or other product in the houses of customers, meaning that the installers come in the customers' personal sphere. Therefore, it is important that these installers are well manured and respectful to increase the customer satisfaction. The same goes for service delivery, which also happens in the personal spheres of customers. Customers must be home when service is provided, this might be inconvenient for them, therefore it is better to limit those visits.

"End customers are increasingly important, since they can find us more easily."-M1
"We search for solutions that suit the customers preferences best." -S3
"It is important that the installers have social skills, work neat and deliver a good result." -S2
"It is nice when the installers are friendly and do a proper job." -C2
"A second visit is less pleasant for a customer." -S1
"When someone comes to look at the boiler you have to move stuff to give them space." -C5

Financial aspects are also an important value for customers and companies. For companies it is important to be profitable. Whereas customers are interested in finding a solution for their problem at an acceptable price. However, both groups also indicated that a higher price/lower profit, is fine when there is a clear and good reason for this, for example: a lower environmental impact.

"Price has to seem fair, but I am not choosing the cheapest boiler." -C1
"When an option has a slightly higher price, but is more sustainable than that could be a decisive factor, but not when it is way more expansive." -C2
"Making profit is important, of course, you have to stay competitive, if you do not make a profit your company is doomed, that is not feasible." -S1

To a certain extent all actors agree that there is a responsibility to operate *sustainably*. Some actors clearly identify it as a main value in their BM, others perceive it more as a side value. Different actors perceive sustainability in a different way. Moving towards a CO_2 neutral environment was by most actors mentioned as important for sustainability.

"Sustainability in the sense of CO_2 emission has some awareness in our company, however it is not strongly present in our main vision." -S2
"Since last year we operate CO_2 neutral, that was a decision of our board in Germany, the CEO has been concerned with this subject for quite some time and he said 2030 is too late, we will be CO_2 neutral in 2020, well that are pleasant and important values." -M2
"We perceive extending the lifetime also as sustainable" -M1
"We have the ambition for the future to move to a CO_2 neutral society and we have to do that together." -S4
"An option that is better for the environment and helps to become CO_2 neutral or something like that, I would like to have that option." -C5
"I find it important that the boiler uses the least amount of gas for the highest warmth output, so that is a sustainability aspect." -C2

Technology is a value that mainly concerns the manufacturing companies and the installation companies. Technology distinguishes them from their competitors, customers want a trustworthy and efficient product. The same goes for installation and maintenance it is important to have a proper knowledge on the new technology and know how the product works.

"Of origin, our company is very interested in technology, technology is very important for the development of our products and customers with an affinity for technology often choose for our products" -M1

"We are a technical installation company, we do not want to shift towards a marketing business, we want to know how the product works and be a technical service provider." -S3

The value *expertise* for this case should be interpreted as giving honest and independent advice, based on knowledge. Companies can provide this expertise by retaining a certain level of independency from their suppliers, so they are not obliged to promote a certain brand. Furthermore, the service they deliver focusses on giving honest advice and not a commercial agenda. Customers value to experience this honesty and knowledge.

"We want to stay independent to give unbiased advice, so we can give advice based on what is the best solution for the customer." -S2
"We are carefully trying not to commercialize our technicians, that would affect our credibility and our expertise and we do not want that, because those technicians are a great thing, their expertise, they are responsible for judging the situation and what needs to be done and we do not want to make that unreliable in any way." -S2
"When an installer has proper knowledge and gives honest advice, I trust him better." -C1

A boiler can be a dangerous product due to the combination of electricity, fire and water. This explains why *safety* is another important value in this case.

"Safety is without discussion the most important aspect." -S1
"With service delivery it is important that is done properly, because when something goes wrong with the boiler, in terms of gas or whatever, you have a big problem in your home." -C2

4.5 Multi-criteria analysis: implementation and circularity

This section combines the (alternative) PSS BMs and the values derived in the previous sections to create a Multi-Criteria Analysis (MCA) table. Section 4.5.1 explains how the values (obtained in section 4.4) are operationalized to become measurable. Furthermore, this section assigns scores to the different BM types. In section 4.5.2 the circularity performance is calculated through the MCI. Section 4.5.2 presents and discusses the MCA table.

4.5.1 Scoring values as criteria

The in the previous sections (4.1 Case study: Energiewacht, 4.2.1 Product-oriented BM's-4.2.3 Result-oriented BM's) identified PSS BM's are used as scenarios in this section. Which leads to 4 scenarios: current BM, PSS BM type 1, PSS BM type 2 and PSS BM type 3. To compare the values in a MCA table, the values identified in 4.4 Interview results: Valuesare used as the criteria. To determine how good a certain BMs captures the value, a score per value is assigned for every BM. Determining these scores is based on the interview data (mainly the perceptions from actors as discussed in the sections 4.2.1-2-3 and 4.4) and additional literature. Empirical data is limited because, besides the current BM, the other PSS BM types are not implemented in the heating sector. Comparison on characteristics and categories is most reliable, when empirical data is lacking (Kim et al., 2016).

The assessment of *customers satisfaction* was based on several characteristics of the product/service that are important for customers. These factors were derived from the interviews: (1) delivery of a comfortable temperature, (2) price of the product/service, (3) control and freedom over use of the product/service, (4) efficiency of the boiler and (5) efficiency of the service delivery. The score for customer satisfaction is based on the number of factors present in a BM (see table 4.1). These factors can be explained in more detail to clarify how they were assigned to a BM: (1) A comfortable temperature is different for every customer, due to individual preferences. However, every BM is designed in such a way that the customer can have their preferred temperature. (2) Customers would prefer to have to pay a low price. What is low is relative to other options. Therefore, factor 2 is assigned to the two BM's with the lowest price customers have to pay. The price the customers have to pay for the product/service is based on the interview data and the Consumentenbond (n.d.), a Dutch website comparing products and different contracts. (3) Factor 3 focusses on the choice for products and the control customers have over the delivered temperature. Assigning this score is based on the interview data. (4) Factor 4 is about how efficient a boiler operates in terms of energy; customers prefer this since it is more sustainable and saves energy costs. Interview data is used to assign this score. (5) When the service is efficiently delivered this increases customer satisfaction since it is inconvenient for customers to receive mechanics or other employees (4.4 Interview results: Values).

Table 4.1: Scores for customer satisfaction

Customer satisfaction	Factors present	Score
Very low customer satisfaction	1	1
Low customer satisfaction	2	2
Medium customer satisfaction	3	3
High customer satisfaction	4	4
Very high customer satisfaction	5	5

Factor 1 is appointed to every BM. Factor 2 is assigned to the two BM's with the lowest price for customers. Consumentenbond (n.d.) showed that for customers buying is cheaper than renting. Therefore, the current BM and PSS BM type 1 have a lower price than PSS BM type 2 and 3. So, factor 2 is appointed to the current BM and PSS BM type 1. Factor 3 cannot be appointed to PSS BM type 4, because it was clearly stated in the interviews that this PSS BM type would affect the level of control and freedom of customers over the use of the product. This factor can be added to all other BM's. Factor 4 is added to the result-oriented BM's where the providers have the freedom to choose which products they install, which leads to the installation of more efficient products (Thermafy, 2020). The last factor is assigned to PSS BM type 2 and 3, when ownership lies at the provider, service can be delivered more efficiently, see 4.2.4

For *financial values* two factors are used as proxy: (1) Return on Investment (ROI) and (2) Annual Recurring Revenues (ARR). The level of the ROI and ARR differ between the PSS BM's. Furthermore, the ROI and ARR are mentioned in the interviews as important financial values for the companies. ARR are perceived as pleasant, as is discussed in section 4.2.2. The ROI is also important for a company: *'the ROI is important; it is one of the KPI's of the company'-S2.* ROI is the ratio between the profit and the investment. A high ROI is preferred over a low ROI. ARR is the monthly income a company has, which provides a stable income. Therefore, a high ARR is preferred over a low ARR. Table 4.2 and 4.3 show how based on the height of the ROI and the ARR scores are assigned.

Whether a BM has a high ROI is based on where the ownership of the boiler lies. When ownership remains at the provider, the company has to finance the whole project and low ROI come from monthly payments for the product and services (Mertens, 2012). When customers own the product, no investment of providers is needed and the ROI is high. The ARR is considered to be low, when it is below 10 euro per month per customer. Between 10 and 20 euros it is considered medium and an ARR above 20 Euro is considered a high ARR. Product-oriented BM's have a high ROI, because the customers own the product. The ARR of the current BM is 7 euro (Consumentenbond, n.d.-a). It is therefore considered to be low. PSS BM type 1 has both a high ROI and medium ARR, 12.5 per month (Consumentenbond, n.d.-a). PSS BM type 2 and 3 have a low ROI, because in these BM's companies own the boilers. However, ARR is high since it is above 25 euro in these cases (Consumentenbond, n.d.-a).

Table 4.2: Scores for financial value for ROI

Financial	ROI	Score
Unpleasant financial aspect	Low	0
Pleasent financial aspect	High	2

Table 4.3: Scores for financial value for ARR

Financial	ARR	Score
Very unpleasant financial aspect	No ARR	0
Unpleasant financial aspect	Low ARR	1
Medium pleasant financial aspect	Medium ARR	2
Pleasant financial aspect	High ARR	3

The value *sustainability* was by most actors understood as reducing the emission of CO_2. It is obtained from the interview data that reducing CO_2 emissions in these PSS BM's can happen through more efficient material use and reducing the use of gas and electricity in the boiler during the use phase. Implementing HE-boilers are a way to make the boiler more efficient. However, moving away from using fossil fuels for heating towards renewable energy will eliminate the CO_2 emitted in the use phase. Assessing the sustainability of every BM's happens through flexibility. Flexibility is the ability of the BM to incorporate more sustainable products and flexibility helps to make a BM more sustainable in terms of reducing CO_2 emissions (Shukla, Deshmukh, & Kanda, 2010).

The result-oriented BM's have the highest level of flexibility (Weking, Brosig, Böhm, Hein, & Krcmar, 2018). Changes in the market can easily be implemented in these BM's as long as the result is being properly delivered. PSS BM type 3 falls under this result-oriented BM type, and is therefore assigned with the very high flexibility. In the current BM and PSS BM type 1, the providers have little influence on the placed products and this leads to the lowest flexibility score (Weking et al., 2018). PSS BM type 2 has medium flexibility since in this BM providers keep ownership of the boiler, which makes it easier to replace them. However, the focus is still on the product and not on the result, making it more difficult to implement new innovations.

Table 4.4: Scores for sustainability

Sustainability	Flexibility	Score
Very low sustainability	Very low	1
Low sustainability	Low	2
Medium sustainability	Medium	3
High sustainability	High	4
Very high sustainability	Very high	5

Expertise is operationalized according to the knowledge, skills and the experience of the organization's human capital (Germain & Tejeda, 2012). In this thesis, the PSS BM's are all designed for the same company, Energiewacht, therefore the human capital is the same in all the BM's. Knowledge, however, can be increased through training and education and by sharing knowledge with key partners, creating cooperative knowledge (Germain & Tejeda, 2012; Herling, 2000). A main difference between the PSS BM types and current BM is the increased level of service. For a higher level of service it is important to train employees to deliver this service properly (Ployhart, Van Iddekinge, & Mackenzie, 2011). The interview data showed that companies are willing to put effort in training their employees. Therefore, it is assumed that when the level of service increases through a BM, more training will be given to the employees and the level of expertise will increase. This means that in PSS BM type 1, 2 and 3 extra training is given to employees. Furthermore, knowledge can be increased by sharing knowledge with key partners (Herling, 2000). Based on this, the following assumption is made: the higher the level of corporation between companies, the higher the level of knowledge. 2.2 Product Service System Business Modelshowed that for PSS BM type 3 corporation with key partners increases. Therefore, this BM's is expected to have a high level of knowledge due to corporation.

Table 4.5: Scores for expertise

Expertise	Knowledge	Score
-	-	1
Low expertise	No extra training nor cooperation	2
Medium expertise	Extra training or increased cooperation	3
High expertise	Extra training and cooperation	4
-	-	5

A proper *technology* in terms of a good functioning boiler with advanced features, is important for the interviewed actors. To measure technology of boilers, reliability of the product can be used (Weber, Gebhardt, & Fahl, 2002). To understand whether a technology is reliable warranties can be given on the product/installation. When a warranty is given over a long period it is assured that the boiler operates properly during that period. Therefore, the longer the warranty period is, the better the technology is assumed to be. A warranty of 10-15 years is considered to suit a very reliable technology, since 10-15 years is the expected lifetime of a boiler (Snel, 2020). When a boiler is sold, which is the case for the current BM and PSS BM type 1, the warranty period is 2-5 years (Consumentenbond, n.d.-b). When the boiler remains at the provider, they are responsible for a working product, and a warrantee is given over the lifetime of a boiler, 10-15 years. PSS BM type 2 is therefore assumed to have a very reliable technology. A higher warranty can be given in PSS BM type 3 since the provider is responsible, however in this PSS BM a shift to other products can be made, for which there is more uncertainty of how long they can be maintained or operate, see 4.2.4 Therefore it is assumed a warranty of 5-10 years can be given in this BM.

Table 4.6: Scores for technology

Technology	Warranty	Score
-	-	1
Higher uncertainty technology	0-5 years	2
Reliable technology	5-10 years	3
Very reliable technology	10-15 years	4
-	-	5

Safety is an important value as is explained in 4.4 Interview results: Values. Safety has to be present to the same degree in all BM's to prevent dangerous problems. Therefore, this is not a criteria that differs between the BM's and is left out of the MCA table.

4.5.2 Circularity performance

Circularity is discussed in this separate section, since this was not among the identified values, but a separate main criterion for this thesis. To assess the *circularity performance* of every BM the Material Circularity Indicator (MCI) is calculated for every BM. The formulas used to calculate the MCI can be seen in Appendix B. Table 4.7 shows how based on the MCI a score could be assigned for circularity. Data to calculate the MCI is based on the interviews (mainly the perceptions discussed in section 4.3) and additional literature.

$$MCI = 1 - \frac{V + W}{2M + \frac{WF - WC}{2}} * F(X)$$

Table 4.7: Scores for circularity

Circularity	MCI	Score
Very low circularity performance	0-0.20	1
Low circularity performance	0.20-0.40	2
Medium circularity performance	0.40-0.60	3
High circularity performance	0.60-0.80	4
Very high circularity performance	0.80-1	5

Current BM

In the current BM the manufacturing of boilers no reused sources are used in the manufacturing of a new boiler. The interviewed manufacturing companies said that a part of the material used for this new boiler is based on scrap material, however none of these companies could specify this percentage. This data could also not be found in other literature. With this lack of data, the use of recycled resources as input is put to 0. This brings the value in the MCI of used virgin materials to 1.

The next step of the MCI is to determine the amount of waste generated in this BM. The collection for recycling of boilers in the current BM is 50%, the other 50% is incinerated (van den Hout, 2017). From the interviews it was retrieved which materials were mainly used in boilers: plastics (PPA, PA6, PC/ABS) and metals (Aluminum, (stainless) steel, cupper, brass). From the different types of metal used, steel and aluminum have the largest share. Together with plastics they form the three main groups of materials. Since recycling is not 100% efficient, extra waste is generated in the recycling process (Ellen MacArthur Foundation, 2015). The efficiency for dismantling, shredding and sorting of the materials is retrieved from De Meester, Nachtergaele, Debaveye, Vos, & Dewulf (2019) which identified these efficiencies per material. The average efficiency of the three main materials (aluminum, steel and plastic) are taken to use for the MCI. This gives an efficiency of 77%. To calculate the MCI the efficiency for producing new feedstock from the recycled materials is also needed. Again, to calculate this, the average of the efficiency rate of the three main materials was chosen based on the data provided in (De Meester et al., 2019). Resulting in an efficiency of 92%.

The last factor in the MCI is the utility of a product. This factor depends on two ratios: (1) the ratio between the lifetime and the average lifetime and (2) the ratio between use intensity and average use intensity of the product. For the use intensity of the boiler, it is assumed that this is not dependent on the type of BM. This assumption is based on the facts that, (1) it did not came forward in the interview data. (2) The boiler delivers a comfortable temperature and hot water and provides this whenever a customer requires it. Factors that play a role in the use intensity are whether there is a cold winter or cold climate, these factors cannot be influenced by a certain BM type. The lifetime is for this BM also assumed to be equal to the average lifetime. Since in this BM a service is offered that focuses on the product, providing maintenance to the product that provides the product from breaking down to early. The utility factor of 1 is therefore used to calculate the MCI.

$$MCI = 0.28 = 1 - \frac{1 + 0.558}{2 + \frac{0 - 0.115}{2}} * 0.9$$

PSS BM type 1

In terms of circularity as discussed in section 4.3, the main difference between this BM type and the current BM is only derived from more considered use of the product during its lifetime. However, this factor is mainly influencing the use of energy in the use phase of the boiler and does not affect use of virgin material, waste collected or utility factor as identified in the MCI. Therefore, PSS BM type is assumed to have the same MCI as the current BM: 0.23.

PSS BM type 2

The main difference of this BM compared to the current BM is the increased level of recycling. Data on the exact recycling rate for boilers after implementation of this BM is not available. The data from a case similar to this case was therefore used. The study of Ellen MacArthur Foundation (2013) assessed for washing machines what the increased recycling rate for washing machines would be when the BM would innovate towards renting the washing machines. Washing machines and boilers share a product characteristic that is important for servitization, namely that customers are mainly interested in the result delivered by the product. Therefore, the percentage (65%) of recycling after implementation of the renting BM for washing machines is used in this thesis to calculate the MCI. This BM furthermore has better control over where the boilers are being recycled, resulting in a recycling at certificated plants. Recycling plants with such a certificate have an recycling efficiency of 95% for boilers (CV-ketelrecycling, n.d.). Lastly, in this BM there is a higher percentage of re-use. Secondhand boilers are used again, which prolongs their lifetime. Furthermore, preventive services are given, which can further help to extend the lifetime of a product, as discussed in section 4.3. In this BM boilers therefore have a higher lifetime than average. Giving the average lifetime of boilers is 12 years and the maximum lifetime is 15 years, we assume that the lifetime of boilers is in between these numbers, which is 13.5 year. All other values remain similar to the current BM.

$$MCI = 0.45 = 1 - \frac{1 + 0.367}{2 + \frac{0 - 0.033}{2}} * 0.8$$

PSS BM type 3

For this BM it is also assumed that the high level of collaboration increases the collection rate and therefore the number of boilers that is being recycled. This becomes 95%, based on the washing machine scenario of Ellen MacArthur Foundation (2013) which is applicable to this case study as is explained in the previous paragraph. Furthermore, data is retrieved from the study of Toxopeus et al. (2017), they identified that it is possible to use the recycled materials as material input to produce new boilers. They claim that closing the material loop is technically feasible when there is a high level of collaboration in the supply chain. This increased collaboration is present in this type of BM. Furthermore, in this type of BM it is easier to install boilers that are easier to recycle, which increases the possibilities for recycling (Toxopeus et al., 2017). A limitation described by Toxopeus et al. (2017) is that the difference in the design of products over the years limit the use of recycled materials as only input. Therefore, the use of recycled materials as input is assumed to be 50%. The other values remain similar to PSS BM type 2.

$$MCI = 0.75 = 1 - \frac{0.5 + 0.141}{2 + \frac{0.043 - 0.048}{2}} * 0.8$$

4.5.3 MCA table

In table 4.6 the MCA table is presented. The table shows how scores are assigned to the different BM's, the current BM and the three alternative PSS BM's. Section 4.5.1 explained how the values are given a score. The combined score of the values tells something about how acceptant the actors are towards the BM (Dittrich, 2015). To put the total scores per BM in perspective, it should be noted that the maximum score that was obtainable was 25 and the lowest score 5. Moving towards an alternative PSS BM type seems for all three cases a suitable option, since all alternatives have a higher total score than the current BM. This means that when the alternative BM's are implemented a higher total value would be captured for the actors than in the current BM. For this thesis the implementation potential of a BM is conceptualized as acceptance of actors based on the presence of multiple values (Dittrich, 2015). This means that PSS BM type 2 and 3 are most suitable for implementation.

Table 4.6 also shows how the BM's are assessed in terms of circularity, which happens by calculating the MCI, which was done in section 4.5.2. Circularity is purposely put in the table as a separate value since it is a main concept of this thesis and is throughout the thesis analyzed as a separate aspect to consider. Adding it to the total scores of the values would eliminate the meaning that it has in this thesis. However, putting it in the MCA helps to see in one look that PSS BM type 3 comes out as best choice. Although, PSS BM type 2 is also assessed with a higher circularity performance than the current BM, in terms of enhancing the transition towards a circular economy PSS BM type 3 is most suitable.

The PSS BM for boilers that is thus most suitable for implementation and enhancing the circular economy is PSS BM type 3. The features of this BM are that it delivers a result: a comfortable temperature and hot water. The provider is responsible for this delivery to the customer and cooperation with key partners is important.

Table 4.6: MCA table, showing the current BM and alternative PSS BM types, and the scores for values and circularity

	Current BM	PSS BM type 1	PSS BM type 2	PSS BM type 3
Customer satisfaction	3	3	4	2
Financial	3	5	3	3
Sustainability	1	1	3	5
Expertise	2	3	3	4
Technology	2	2	4	3
Total	13	16	17	17
Circularity	2	2	3	4

5. Discussion

Section 5.1 identifies the theoretical implications. In section 5.2 limitations of the thesis are discussed, leading to suggestions on how this thesis could be improved. Furthermore, based on the insights retrieved in this thesis, section 5.3 suggests new research topics that further enhance the theory in this field.

5.1 Theoretical implications

To identify the alternative PSS BM's for boilers the framework of Tukker (2004) is used. Tukker (2004) identifies 8 different types of PSS BM's. The results of this thesis showed that not all 8 types are applicable for the boiler. First, the current BM is identified to suit the *product-related services* BM: the BM with the lowest level of service. The alternative suitable PSS BM's are: *advice and consultancy, product lease,* and *functional result.* The focus on service increases respectively for the discussed BM's.

These PSS BM types all differ in a way from the current BM. For *advice and consultancy* the change remains limited, *product lease* and *functional result* required more radical changes. In other literature these changes are also discussed e.g., Mont, 2004; Vezzoli, Ceschin, Diehl, & Kohtala, 2012. Especially the shift in ownership and subsequent changed revenue stream are acknowledged as implications in the *product lease* BM by both this thesis and literature. These changes are not necessarily seen as negative by the actors in this thesis. Mainly, it showed that insights and openness in the costs for renting is important to implement this BM. For *functional result* the main difficulty, as identified in this thesis, is in customer acceptance. The loss of control over the heating installation is not in line with the customers preferences. In other literature this is found as well (Mont, 2004; Vezzoli et al., 2012). Often mentioned in literature as barrier is the mindset in a company (Baines et al., 2017; Kaddoura, Kambanou, Tillman, & Sakao, 2019; Mont, 2004). However, this did not come forward in this thesis as a barrier for the companies. This difference with other studies could be explained by the awareness that change is necessary in this sector, from the interviews it became clear that the sector is really changing due to the energy transition. Although, this is a different focus than the circular economy, it requires a mindset open for change.

The Circular Innovation Framework (CIF) developed by Guzzo et al. (2019) is used to see how circular these PSS BM types are for boilers. As was expected, the greater the level of service in the BM, the higher the number of circularity strategies could be assigned to the BM. A point for discussion is whether prolonging the lifetime of a boiler is a good thing or a bad thing. It is stated as a circularity strategy, however due to efficiency improvements of newer boilers it is argued that this is not always the option that emits the least CO_2. The discussion what is the best option: prolonging or replacing, is more often stated in literature (Iraldo, Facheris, & Nucci, 2016). Iraldo et al. (2016) identify that it depends on several factors, such as how large the efficiency improvement is for newer products, and how the products are being produced. Their conclusion that it is important to get a proper understanding of the specific situation, is therefore similar to the findings of this thesis.

To see which PSS BM could be implemented they are compared in a MCA table. The criteria that are used are the values that actors find important to be present in a BM. The values are retrieved from the interviews and were validated by sending them back to the respondents, allowing them to make adjustments. Two PSS BM's came forward as most suitable: the *product lease* BM and the *functional-result* BM. This might seem surprising since some disadvantages of these PSS BM types are identified by the actors, see section 4.2. This difference can be explained by the more complete overview is given in the MCA table compared to the overview in section 4.2 were only some aspects, in terms of changes in BM compared to the current BM, are discussed. Another remarkable result is that the current BM has the lowest combined score. An explanation could be that some of the values that are identified are quite novel and where not yet important when the current BM was designed and implemented. Especially the low score in the current BM for sustainability could be a to the fact that sustainability awareness has been increasing lately and is a novel value for the actors.

The second part of the MCA focused on the circularity performance. The performance is calculated by using the MCI as designed by Ellen MacArthur Foundation (2015). This showed that the higher the level of service in a PSS BM, the higher the circularity performance. The functional result BM has the highest potential to enhance the circular economy. The MCI used extending lifetime as a factor that enhances the circular economy. This was for the CIF framework already discussed to be a conflicting point for boilers. It is logical that this point comes forward in calculating the MCI again, since both are indicators for a circular economy and prolonging lifetime is a clear circularity strategy. However, that in this case prolonging lifetime is not always the best option does not change the results of the circularity performance. The *functional result* scores the highest, not only due to prolonging lifetime, but mainly due to increase recycling, more efficient recycling and use of recycled materials as virgin material. Therefore, regardless of lifetime, the *functional result* BM has the highest circularity potential. This shows that more service oriented BM's have a higher circularity potential. Which is in line with how in general PSS BM's are acknowledged in literature (Baines et al., 2017; Mendoza et al., 2017; Reim et al., 2014).

The main result in this thesis is that for Energiewacht moving towards a *functional result* BM is recommendable, because it is well implementable and has a good circularity potential. To compare this outcome to a similar study to this thesis the study performed by Hansson & Lindesson (2019), focusing on servitization of the Heat Pump in Sweden, is chosen. In their study they identified the potential for a *functional result* BM (as they identify it: *Climate as a service*) in terms of circularity through reverse logistics. Reverse logistic also played an important role for the circularity potential of the *functional result* BM in this thesis. For implementing such a BM Hansson & Lindesson (2019) identified some barriers, mainly derived from the radical shifts that have to be made: reorganize internal processes, better act upon customer data, change mindset of companies and customers. Some of these aspects came forward in this thesis and to what extent they are present in this thesis is discussed in this section as well. However, this thesis uses acceptance of actors as criteria for implementation and acceptance is reached when multiple values are captured in the new BM. This different view on implementation can explain why the study of Hansson & Lindesson (2019) concluded with more barriers for implementation.

5.2 Limitations

A case study is used in this thesis, because it is a useful method when in-depth information has to be gathered (Zainal, 2007). Besides some predetermined criteria, see section 3.1, this case study (the company Energiewacht) was chosen because of their prior involvement in a small scale project about delivering heat as a service. Choosing a company that is interested in servitization helped to find respondents that are willing to cooperate. However, the positive attitude of the companies towards PSS BM's influences the results. More optimistic outcomes can be generated when the companies that are more reluctant towards PSS BM's are less represented. Nonetheless, the familiarity of the interviewed companies allowed for interesting and in-depth insights, since they had more knowledge on this topic.

Qualitative data were gathered through semi-structured interviews. In section 3.2 some ways in which validity was increased was discussed. This section elaborates and discusses this validity further: The interviews are kept in the native language, Dutch, of the person who conducted and analyzed the data, which helps to limit misinterpretation. The interviews are transcribed to make sure no data is left out. Furthermore an interview guide is developed, helping to better compare and analyze the data in a structured way. To further limit subjective interpretation a summary of the interviews are sent back to the respondents for them to check. Further validation of the interview data is obtained by conducting at least two interviews per group of actors. The actors (customers and boiler manufacturers) are chosen based on the BMC of Energiewacht, the case study in this thesis. A limitation of the data gathering is the amount of private customers interviewed, which is a very small number compared to the total population. To be able to draw conclusions from solely customer insights it is suggested to either conduct more interviews with customers or use a survey. For this thesis, the insights from the interviews with private customers, nonetheless are useful to verify statements made by companies about the customers.

An additional limitation of the data gathered through interviews could be attributed to the use of the current BMC of Energiewacht to find relevant actors to interview, see section 4.1. Focusing on the current BMC gives clear insights on the current situation, however it also means that other companies, not directly mentioned in the BMC were not addressed. Therefore e.g., no interviews were conducted with recycling companies, which could have given interesting insights in what happens with the boilers at the end of their life. Taking a broader perspective on identifying relevant actors is therefore recommended. However, this does not mean that this information could not be gathered for this thesis. The respondents of this interviews could provide knowledge on the topics of interest, including recycling aspects, and additional literature could be consulted.

This thesis uses the framework of Tukker (2004) which provides a complete overview of PSS BM types ranging from product-focused to service-focused. The study of Tukker (2004) is cited over 2.500 times, indicating that it is a well-accepted framework. A large body of literature that also uses the PSS BM types of Tukker (2004) is thus available. Therefore, useful literature was available to develop the MCA in this thesis. A limitation of using the framework of Tukker (2004) is that it assumes that a company can only have one BM at the time. This is not always in line with reality since in companies often multiple BM's are used at the same time to be more competitive (Yang, Smart, Kumar, Jolly, & Evans, 2018). However, using this framework and excluding hybrid BM's allows for a clearer comparison of BM's, which fit the aim of this thesis.

The values used in the MCA table are assumed to have the same relevance for the actors. However, there is a possibility that not all values have an equal weight. In this thesis it was tried to identify these preferences, by sending an email to the respondents and ask them to rank the values. Unfortunately, due to the vacation period there was a lack of response and therefore the values could not be weighted. However, this is a limitation of this thesis and should be considered when interpreting the results.

The data used to fill in the MCA table was based on the interviews and additional literature. Two limitations are identified for the data that is used in this table. First, due to the fact that the alternative PSS BM's are not implemented, no empirical data of these BM's is available. To be able to compare the scenarios, other literature is used to give meaning to these values. The dependency on other literature makes it harder to find fitting and specific data for this case. Thus, although it is useful to find this literature and still be able to do an analysis, it should be noted that the MCA table could become more reliable when more case specific data is available. Secondly, this thesis uses proxy variables to operationalize abstract values. Although, the proxies used are supported with literature, the fact remains that a proxy cannot fully cover the original value. For example, using warranties covers the most important aspects of reliability, but not the full value. However, through using proxy variables it was possible to include abstract values in the comparison.

The Material Circularity Indicator (MCI) is calculated in this thesis based on interview data and literature. Due to the limited amount of data that was available to calculate the MCI, the following assumptions are made: (1) The input of virgin material for the current BM and BM type 1 and 2 was put to 1. (2) The three main materials used for boilers are assumed to have an equal share in the boiler. Based on this efficiency rates are calculated. (3) The study of Ellen MacArthur Foundation (2013) on washing machines is assumed to be comparable to the boilers in this thesis. The combination of these factors lead to a more general understanding of the differences in circularity performance between the BM's. However, the data used is selected with care and the large difference between the outcome of the MCI between the different BM's indicates that the conclusions are robust.

5.3 Future research

This thesis shows the potential of PSS BM's for boilers for the case of Energiewacht, to enhance a circular economy and it is found that the *functional result* BM is the PSS BM type with the highest potential. The *functional result* BM focuses on the delivery of a comfortable temperature and hot water, without a predetermined product involved. This offers the opportunities to move towards other products e.g., heat pumps, solar boilers, H2-boilers. The move towards other products to provide a comfortable temperature and hot water is important in the heating sector to be in line with the energy transition. In this thesis this aspect was briefly touched upon for the identification of the sustainability of this BM, section 4.5.1. However, it was beyond the scope of this thesis to further identify the possibilities of the *functional result* BM. The potential of the *functional result* BM that is shown in this thesis thus allows for future research e.g., exploring the potential of the *functional result* BM in the heating sector to implement heating products to enhance the energy transition.

This thesis explores that the *functional result* BM could be implemented to enhance the circular economy. In this thesis there was a focus on private customers through the case of Energiewacht. Exploring if there is a similar potential for this type of PSS BM for companies a different customer segment e.g., delivering heat to offices or industries, might lead to further insights on how to enhance towards a circular economy.

6. Conclusion

Moving towards a circular economy is important to reduce the impact on the environment. Product service system Business Models (PSS BM) have been acknowledged to have great potential in increasing the circularity performance in a business. However, less is known about aligning the values of multiple actors in order to successfully innovate toward PSS BM's. The heating sector has great potential to perform more circular through implementing PSS BM's. The main product in this sector is the boiler, of which around 375.000 are replaced every year resulting in a large waste stream. This thesis aimed to answer the following research question: "*Which PSS BM for boilers could be implemented to enhance the transition towards a circular economy?"* Three phases were designed to answer this research question. Phase 1 identified a case study and features of the current BM of boilers. In phase 2 semi-structured interviews were conducted with relevant actors that were identified in phase 1. The interviews were used to identify suitable alternative PSS BM's and the circularity implications of these PSS BM's. Furthermore, important values were derived from the interview data. In phase 3 this data was combined in a MCA table. This allowed to compare the BM's in terms of how the values and assess the circularity performance of the different BM's.

1. What are the features in the current BM for boilers?

The case study chosen in phase 1 was Energiewacht: A company operating in the north-east of the Netherlands. The current BM of Energiewacht shows features of a product-oriented BM. Meaning that there is a clear focus on selling the product, and some services are provided as add-on to the product. Boiler manufacturers were identified as key partners. Furthermore, the customer segment of Energiewacht existed of housing corporations and private customers.

2. What alternative circular PSS BM's can be designed in line with the actors perception?

Three alternative PSS BM's are designed in this thesis: PSS BM type 1 (*advice and consultancy*), PSS BM type 2, (*product lease*) and PSS BM type 3 (*functional result*). PSS BM type 1, is still product-oriented, but with an increased level of advice on how the product should be used. No clear objectives are identified for this BM. PSS BM type 2 is use-oriented, meaning that boilers are being rented to customers instead of being sold. Providers retain ownership of the boilers and cost structure changes to monthly payments. Monthly payments provide a steady income for the company which is perceived as pleasant. The higher return on investments in this BM, however, are less pleasant for companies. Customers are also less interested in renting, since they perceive it as more expensive. PSS BM type 3 is a result-oriented BM, meaning that companies become responsible for providing a result, a comfortable temperature and hot water in this case. There is a high level of freedom for companies on how they deliver this. New and increased collaboration is important for this type of PSS BM, and companies are willing to enforce this collaboration. In this type of PSS BM a large part of this control moves to the provider. This might interfere with the preferences of customers, who prefer to have a certain level of control over the delivery of a comfortable temperature and hot water.

The design of the current BM and the three alternative BM's, imply different circularity performance. The shift in ownership in PSS BM type 2 and 3 allow companies to better re-collect the boilers at the end of their life. This leads to the possibility to re-use the boilers and the recycling rate can be increased when more boilers are collected. The increased collaboration in the functional result BM could even further enhance the circular economy, since collaboration in the supply chain makes it easier to close the material loops.

3. Which values are important as criteria in a BM for the actors?

The values that are identified are: customer satisfaction, financial aspects, sustainability, technology, expertise and safety. These values are important criteria for the actors to be present in a BM.

This thesis shows that all alternative BM's have a higher total score for the identified values. Meaning that these BM's are acceptable for the actors and could be implemented. Furthermore, PSS BM type 2 and 3 have a higher circularity potential than the current BM. In particular PSS BM type 3 scores best on both circularity and the value criteria. Thus, PSS BM type 3 for boilers is implementable and enhances the circular economy.

Implementing alternative PSS BM's can improve circularity in the heating sector. Focusing on the delivery of a result, which is the main feature of PSS BM type 3, can increase reverse logistics, recycling rate and increase the re-use of components and products. These factors enhance the circular economy, while still matching the values that are important for the different actors. The implementation of this BM contributes to circularity, thus reducing the pressure on natural resources and consequently limiting scarcity, high prices and environmental degradation.

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Appendix A: Semi-stuctured interview guide

Companies

Introduction

Thank you for your time for this interview. I will briefly introduce myself and the research. I am currently graduating at the Utrecht University and combined with an internship at TNO I am writing my master thesis.
The research I am doing is about identifying different options for the delivery of heat and see if different forms could make this sector more circular. I am researching if companies and customers are willing to further enhance the service of heat and decoupling it from the product. This concept is called servitization and would result in changes in the BM. In this interview I am interested in your view on this.

For this interview I have prepared a set of questions. I will transcribe this interview and analyze it. The information will be combined with other interviews and these results will be presented in my thesis. The interviews remain anonymous. Would it be okay if I record this interview and use the outcome in the way I described?

Background

-Could you briefly introduce yourself and the company?

Current BM

-How is the company currently operating?

- Which products are offered?
- Which services are offered?
- Which values are present in the company?
- Who are the customers of your company?
- Which are important partners for your company?

Circularity

-What do you know about the impact on the environment your company currently has?

- How circular are the products and what could be improved?

Servitzation

-What do you think about offering increased services?

- What would need to change for this?
- How do you perceive these changes?
- Are there particular challenges for your company?
- Are there particular chances for you company?

End

-Do you have any questions?
-Do you know other relevant people that would be open to do an interview with me on this topic? -> or ask for other relevant papers that were mentioned during the interview.
Thank you for the interview.

Customers

Introduction

Thank you for your time for this interview. I will briefly introduce myself and the research. I am currently graduating at the Utrecht University and combined with an internship at TNO I am writing my master thesis.
The research I am doing is about identifying different options for the delivery of heat and see if different forms could make this sector more circular. I am researching if companies and customers are willing to further enhance the service of heat and decoupling it from the product. This concept is called servitization and would result in changes in the BM. In this interview I am interested in your view on this.

For this interview I have prepared a set of questions. I will transcribe this interview and analyze it. The information will be combined with other interviews and these results will be presented in my thesis. The interviews remain anonymous. Would it be okay if I record this interview and use the outcome in the way I described?

Background

-Could you briefly introduce yourself?

Current situation

- How do you currently use the boiler?
-What do you like about the product?
-What do you not like about the product?
-Which services do you have and why?
-How is your experience with these services?
-Which risks do you perceive in changing the current boiler system?
-What do you value in how your heat your house or the products?

Servitzation

-Why did you not choose to rent a boiler? (or why did you?)
-What would convince you to rent a boiler instead of buying?
-Would you be acceptant towards a contract that delivers heat by the provider instead of placing a boiler? (E.g. when servitization is not clear for customer, give further explanation).
-How would you feel about having a closer relation with the provider?
-What is your position towards sharing knowledge with the provider? Which kind of information would you be okay with to share?
-Which degree of freedom would you want to give to the provider? (Could he install solar panels, different types of products, isolation?)
-Could your behavior change when the provider retains ownership of the product?
-What information would convince you to move towards a servitization contract?

End

-Do you have any questions?
Thank you for the interview.

Appendix B: Equations for Material Circularity Indicator

These equations are derived based on the methods design developed by the Ellen MacArthur Foundation (2015), the equations are slightly adjusted to fit the thesis e.g., biomass was left out, since that is not relevant for this thesis. Beneath the equations, a table showing the meaning of every symbol, for clarity.

The total mass from virgin feedstock (V) can be obtained with equation 1: Contracting the amount of feedstock from recycled sources (F_R) and reused sources (F_U) from the total mass of the finished product (M).

Eq. 1 $V = M(1 - F_R - F_U)$

The total mass of unrecoverable waste can be obtained with equation 2.1: Contracting the amount of waste collected for recycling (Cr) and for reuse (Cu), from the total mass of waste generated.

Eq. 2.1 $W_0 = M(1 - C_R - C_U)$

Since the recycling efficiency (Ec) is not 100%, additional waste is generated in this process (Wc), equation 2.2.

Eq. 2.2 $W_c = M(1 - E_c)C_R$

Additionally, the production of feedstock from recycled sources (F_R) was generated with a certain efficiency (E_F), and therefore waste was generated from producing feedstock (W_F) as well.

Eq.2.3 $W_F = M\,((1 - E_F)F_R)\,/E_F$

When the recycled feedstock does not come from the waste that is being recycled for the product, there might be a difference in efficiency for these values. To account for this an additional equation is constructed which equally emphasizes both waste streams, without double counting.

Eq. 2.5 $(W_F + W_C)/2$

Which leads to the final equation for the overall amount of unrecoverable waste generated.

Eq. 2.6 $W = W_0 + (W_F + W_C)/2$

To calculate the utility of the product the lifetime (L) will be divided by the average lifetime (L_{av}) in the sector. This will be multiplied with the intensity use (U) of the product divided by the average intensity use (U_{av}) in the sector.

Eq. 3 $X = (L/Lav) * (U/Uav)$

Eq. 4 $F(X) = 0.9/X$

The final equation for the MCI will combine the groups of equations. The outcome will be a number somewhere between 0 and 1, where 1 would be a fully circular model.

Eq. 5 $MCI = 1 - \frac{V+W}{2M+\frac{WF-WC}{2}} * F(X)$

Table A1: overview of symbols used in the equations with explanation source: Ellen MacArthur Foundation (2015)

M	Mass of product
F_R	Fraction of mass of a product’s feedstock from recycled sources
F_U	Fraction of mass of a product’s feedstock from reused sources
V	Material that is not from reuse or recycling
C_R	Fraction of mass of a product being collected to go into a recycling process
C_U	Fraction of mass of a product going into component reuse
E_C	Efficiency of the recycling process used for the portion of a product collected for recycling
E_F	Efficiency of the recycling process used to produce recycled feedstock for a product
W	Mass of unrecoverable waste associated with a product
W_0	Mass of unrecoverable waste through a product’s material going into landfill, waste to energy and any other type of process where the materials are no longer recoverable
W_C	Mass of unrecoverable waste generated in the process of recycling parts of a product
W_F	Mass of unrecoverable waste generated when producing recycled feedstock for a product
$F(X)$	Utility factor built as a function of the utility X of a product
X	Utility of a product
L	Lifetime of a product
L_{av}	Average lifetime
U	Actual average number of functional units achieved during the use phase of a product
U_{av}	Average number of functional units achieved during the use phase of an industry average product of the same type
MCI	Material Circularity Indicator