coolblue

October 2020

TU Delft

Universiteit Leiden

IMPROVING THE ENVIRONMENTAL IMPACT OF THE WASHING MACHINE PRODUCT-SERVICE SYSTEM OFFERED BY COOLBLUE.

Master thesis Industrial Ecology

THESIS.

Drum roll please.

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Master Thesis
MSc. Industrial Ecology
Joined program at Delft University of Technology
and Universiteit Leiden
University Course Code: 4413TRP30Y

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ACKNOWLEDGEMENTS.

"If you want to be a true professional, do something outside yourself." – Ruth Bader Ginsberg

This thesis marks the end of my master's degree in Industrial Ecology. At the same time it marked the beginning of the Covid-19 period in the Netherlands. At times this made communication and personal contact for everyone more challenging. I can say that writing this thesis was the greatest learning process. Not just theoretically but also personally (patience, prioritizing, perseverance and work ethics). Therefore I am extra grateful for the help and support I received.

First I would like to pay thanks to my supervisors Jaco Quist, Arjan de Koning and Ruud Balkenende. These challenging times also resulted in a lot of changes in your work. I am grateful for the time you have taken to read through all my drafts and provided me with feedback. Thank you Ruud Balkenende for your sharp feedback on my work. It helped me to be more critical and thereby improve its quality. Thank you Arjan de Koning for your constructive criticism and positive words when I sometimes was not that sure about my work. Lastly I would like to thank Jaco Quist for your guidance throughout the entire process. I appreciate your enthusiasm and the times you checked in on me.

Furthermore I would like to thank Coolblue for the opportunity in carrying out this case study for their company. Your inspiring working environment made my experience all the more enjoyable. I want to thank my Coolblue supervisor Sietse for guiding me through the world of PaaS and including me in his team. I would also like to thank Wouter for his time and the insightful discussions that we had on sustainability, meditation or homemade tooth paste. I would further like to express my gratitude to all the other Coolblue'ers who have helped me throughout this research.

This research would not have been possible without the input of the companies BlueMovement, Homie and Bundles. Thank you for taking the time to meet with me and discuss your business models.

Lastly I would like to express my gratitude to my friends and family. Thank you Lukas for your patience and input throughout this period. Thank you to my sisters Rosie, Milou and Zoë for your enthusiasm and uplifting words. A special thanks to my parents Frank and Therese for their continuous support throughout my years of study.

EXECUTIVE SUMMARY.

In 2019 over 670000 new washing machines (WMs) were purchased in the Netherlands (Statista, 2020). With a WM ownership rate of 98%, the Dutch people have one of the highest WM ownership percentages in the world (Laitala *et al.*, 2018). In the traditional business model (BM) these WMs will be used, discarded and recycled. In order to increase sales some WMs are even designed with a planned obsolescence. This 'take-make-dispose' economy is reaching its limits and caused significant resource losses (EMF, 2013). The Circular Economy (CE) suggests that the economic growth can be decoupled from the use of natural resources.

A product-service system (PSS) is perceived as a pioneering business model (BM) shifting the traditional ownership-based model towards a CE (Spring and Arauja, 2017; de Pádua Pieroni *et al.*, 2018; Yang *et al.*, 2018). In this BM the provider remains the owner of the product in return for access to the product and additional services (Tukker, 2004). This offers the possibility to decrease resource and material consumption, improve energy efficiency during usage and extend the products lifespan (Bocken *et al.*, 2014; Mont, 2008). Some concerns have been expressed on the pitfalls of a PSS. For example, high investments for the provider and carelessness by the customer. A PSS does not automatically lead to a reduced environmental impact. There are three PSS archetypes: product-oriented, user-oriented and result-oriented (Tukker, 2004). Each archetype creates a different environmental potential.
The literature shows that in a linear BM the user phase has the largest environmental impact in the life cycle of a WM. It is unknown if this also applies to a product lease PSS BM. It is assumed that in a product lease BM more logistic steps are performed to realise the PSS.

Coolblue is an online webshop that operates in consumer electronics and appliances. Since 2018 they offer a product-lease subscription where a WM can be leased against a fixed fee. Coolblue is curious to know what the environmental impact of their product lease BM is in comparison to the traditional linear BM and how they can improve upon this impact. Therefore this thesis aims to answer the following research question: How can Coolblue improve the environmental impact of their current and future washing machine product-service system?

This thesis is structured in four parts. First a literature review is carried out in order to assess the current state of product-service systems in the washing machine industry. Second, a conceptual framework is developed which consists of the following six elements: Value proposition, Customer, Key activities, Key resources, Adoption factors and Life cycle impact assessment. The outcome of the framework analysis will form the basis for assessing the environmental impact of the two Coolblue BMs (i.e. traditional selling and product lease business model). The environmental impact is measured in CO_2 emissions with the help of a screening Life Cycle Assessment (LCA). The CO_2 emissions between the two Coolblue models are compared with each other and a hotspot analysis on the five phases (i.e. production, distribution, use, life extension and End-of-Life) in a WM life cycle of the PaaS BM is performed. A phase is considered a hotspot if it contributes more then 10% of the total share of emissions.
Third, three alternative companies in the washing machine industry were interviewed to evaluate how they improve the environmental impact of their PSS BM. Lastly, three new design concepts are established that can reduce the CO_2 emissions in the WM lifecycle of the PaaS BM. These design concepts are established with the help of the methodological chart method. The concepts to decrease the environmental impact of the Coolblue PSS BM combine different solutions that came up from the literature review, the interviews and brainstorming. Data is collected through a literature

review, desk research, field visits and semi structured interviews with representatives of the two Coolblue BMs and three alternative companies in the PSS WM industry.

In the traditional selling BM of Coolblue the WM has a lifespan of twelve years, an A+++-10% energy label with a mid-ranged built quality. In the product lease PSS BM by Coolblue (also describes as the PaaS BM) the WM has a nine year lifespan, an A+++-30% energy label with a basic built quality. The comparative LCA shows that the CO_2 emitted during the life cycle of the WM in the PaaS BM is 35% less than in the traditional BM. The greatest difference is expressed by the user phase (42%). This difference in kilogram CO_2 emitted is mainly due to the lifespan and improved energy label in the PaaS BM. When comparing the kilogram CO_2 emitted per year, the difference between the two BMs is 10% in favour of the PaaS BM.
The hotspot analysis on the PaaS BM itself showed that the user phase has the largest influence (71%) in the overall CO_2 emitted in the WM life cycle. The second largest contributor is the production phase with 39%. 5% remains for the distribution and life extension phase. The last hotspot is the End-of-Life (EoL) phase with a recycling credit of 15% in kilograms CO_2 emitted..

From the interviews with the other companies in the washing industry 21 possible solutions (means) for the improvement of the PaaS BM were identified. These means were tested on their suitability and effectiveness to reduce the CO_2 emissions from the PaaS BM. After evaluating all means three new design concepts were constructed: The Friendly Reminder, Planned Maintenance and Pay-per-wash. The three concepts can be regarded as step stones towards more circularity by implementing small to more radical changes. The concepts respectively show a CO_2 reduction of 17%, 19% and 29% compared to the current PaaS BM.

In conclusion, based on this research the user phase in a life cycle of a WM shows to have the greatest impact in CO_2 emissions, both in a linear and product lease BM. Ways to decrease this impact should focus on educating the user and stimulate sustainable washing behaviour.
A pay-per-wash model with tiered prices can influence the washing behaviour significantly. It stimulates the customer to wash less using a more environmental friendly program. The model would require a built in device which would also make predictive maintenance possible.
PSS providers can also influence the emissions of the WM lifecycle by using a high-end WM with a high energy label.
Furthermore, the production phase is the second greatest contributor to the overall CO_2 emitted in the WM lifecycle of a product lease BM. WM manufacturers can play a major role in designing new washing machines that are more suitable to a PSS BM. When WMs are modular built disassembly is easier and refurbishing and upgrading more efficient. This could decrease the need for new raw materials.

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List of abbreviations

A.I.S.E.	Association for Soaps, Detergents and Maintenance Products
BM	Business Model
BMC	Business Model Canvas
CBM	Circular Business Model
CE	Circular economy
C2G	Customer to Grave
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
EMF	Ellen MacArthur Foundation
EoL	End-of-Life
ER	Environmental return
kg	Kilogram
km	Kilometers
LCA	Life Cycle Assessment
LE	Linear Economy
NPS	Net Promoter Score
PaaS	Product-as-a-Service (department at Coolblue)
PSS	Product-service system
rpm	Rotations Per Minute
RQ	Research question
SG	Satisfaction guarantee
SQ	Sub question
SBM	Sustainable Business Model
QG	Quality guarantee
WH	Warehouse
WM	Washing machine

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01.

INTRODUCTION

1.1 Research background and context

With the Industrial Revolution came the era of mass production. The consumption of goods increased through the vast development in technology and globalisation. Together with a growing world population the demand for raw materials increased and energy consumption per capita soared (Ritchie and Roser, 2019; Roser et al., 2019; WU Vienna, 2019). Economies bloomed at the cost of natural resources. In the predominant Linear Economy (LE) production is based mostly on a cradle-to grave concept (C2G) where products usually end up as landfill waste. This 'take-make-dispose' economy is reaching its limits and causes significant resource losses (EMF, 2013). In order to decouple the economic growth from the use of natural resources, institutions and policy makers were pushed to explore other economic models. The Circular Economy (CE) suggests that such a link can be decoupled (EMF, 2013; Sauvé et al., 2016) by maximising the value of products and materials whilst at the same time decreasing the depletion of natural resources and its environmental impact (Bocken et al., 2018; Kraaijenhagen et al., 2016). However a lack of assessment methods to evaluate the impact of the CE is hindering its implementation (Bocken et al., 2016b; Bresanelli et al., 2019).

Product-Service System (PSS) is a concept that has gained a lot of popularity in the field of the Circular Economy (Bocken et al., 2018; Tukker, 2015: Reim, 2015). In the last few years it is perceived as a pioneering business model shifting manufacturing and consumption (i.e. the traditional ownership-based model) towards a performance-based payment model (Spring and Arauja, 2017; de Pádua Pieroni et al., 2018; Yang et al, 2018). PSSs consist of "*tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customers' needs*" (Tukker, 2004: 246). PSSs can be divided into three categories: product-oriented, use-oriented and result-oriented (Tukker, 2004). Each category has a different focal point. Product-oriented systems focus on the sales of a product while offering some extra services (e.g. maintenance contract). In the use-oriented system the traditional form of ownership is shifted towards the provider who allows the product to be used by multiple owners (e.g OV fiets*)*. In the result-oriented system the focus is not on the product but on the result that is agreed upon between the provider and the customer (e.g. printed copies). This last category allows for the partial decoupling of environmental impact and economic growth since the BM stimulates the service provider to make the most of the production assets whilst providing the consumer with a service (Bocken *et al.,* 2018; Tukker, 2015).

Many researchers say that PSS has the potential to improve the environmental impact of a company (Goedkoop et al., 1999; Tukker, 2015). This business model (BM) has the possibility to separate profit from production volumes. It can decrease resource and material consumption, motivate the inclusion of through-life (e.g. upgrading) and end-of-life issues, improve energy efficiency during usage and extend the products lifespan (Bocken et al., 2014; Mont, 2008).
Some concerns however have been expressed over the pitfalls of PSSs. For example a PSS BM demands high investments from the provider (Annarelli *et al*., 2016) and quality degradation of the returned product can occur because the consumer may feel less responsible without ownership (Sumter *et al.*, 2018; Tukker, 2015).

Therefore a PSS by definition does not necessarily lead to a reduced environmental impact and it should not be seen as the "*sustainability panacea*", according to Tukker (2015: 88). In order for a PSS to reduce the environmental impact, it should be intentionally designed to do so (Michelini *et al.,* 2017).

1.2 Problem definition

Inspired by Swapfiets Coolblue looked at the possibilities of product-service systems. Coolblue is an online webshop specialised in consumer electronics and appliances in the Netherlands and Belgium. Since October 2018 Coolblue offers subscriptions to lease (i.e. use-oriented) white goods. This is run by the Product-as-a-Service (PaaS) department. In the current portfolio of PaaS washing machines, dryers, washer dryer sets, washer dryer combinations, dishwashers, refrigerators and freezers can be rented for a fixed monthly fee. Its best running lease at the moment is the washing machine (WM). In the Netherlands there is still a washing machine ownership rate of 98% (Laitala *et al.*, 2018). In 2019 around 670000 WMs were sold in the Netherlands (Statista, 2020). This shows that there is a market for a PSS BM. Coolblue is curious to know what the environmental impact of their WM product lease is and how they can diminish this impact (Boven, 2020; Van Der Meer, 2020). More information on Coolblue's history, its core values, how company successes are measured and the Go Green department can be found in Appendix A.

From the literature research it becomes clear that there is not one unanimous view on which activities in a WM life cycle have a considerable effect on the environment. The user phase in particular shows many variables. Some scholars state that washing behaviour such as the frequency of washing, the selected temperature, the load size or detergent quantity have a critical effect on the environment (A.I.S.E., 2015; Amasawa *et al*., 2018; Bocken *et al*., 2018; Laitala *et al*., 2018). Others state that the materials used in the production phase also have a high environmental impact on the overall life cycle (Amasawa *et al.*, 2018; Rüdenaur *et al*., 2005).
A PSS BM is particularly interesting since additional services can be offered as opposed to the traditional linear BM. It is expected that differences in the environmental impact will occur between the traditional and PSS BM due to extra transport and the services offered. The environmental impact of a WM life cycle in a product lease PSS BM is yet unknown. Coolblue has expressed that this knowledge gap is also relevant to them.

Therefore this thesis aims to develop knowledge about the major environmental contributors (hotspots) in a WM life cycle in a product lease BM. The effect of PSS services on the environment of the WM lease will be analyzed through a screening LCA based on information gained through literature research and interviews. Life Cycle Assessment (LCA) is a way to analyse the environmental impact of a product or service over its full life cycle (Guinée, 2002). Furthermore, other companies with a PSS BM in the washing machine industry will be researched. The outcome of that research will inspire new design concepts that Coolblue could use in order to diminish the environmental impact of their current and future WM PSS business model.

1.3 Research questions

The objective of this research is to investigate the environmental impact of a product lease WM BM so that the PaaS department of Coolblue can become more environmentally friendly both now and in the future. The research a multiple case study wherein the environmental impact of the traditional Coolblue BM and product lease PSS BM is estimated. In order to analyse the impact a qualitative and quantitative approach is with semi-structured in depth interviews. Furthermore, alternative PSS BM cases in the current washing machine industry are examined and used as an inspiration for new PSS design concepts. These concepts might decrease the environmental impact of the PaaS department of Coolblue without compromising their high service standards. To achieve the above-mentioned objective the main research question is formulated as follows:

"How can Coolblue improve the environmental impact of their current and future washing machine product-service system?"

In order to answer the main research there are four sub-questions:

1. What is the current state of product-service systems within the washing machine industry and their environmental impact?
2. What is the environmental impact of Coolblues washing machine business models and how can they be analysed?
3. How do alternative product-service systems in the washing machine industry decrease their environmental impact?
4. What alternative washing machine designs can be developed in order to improve the environmental impact of the Coolblue washing machine lease?

1.4 Report outline

This report is divided into six chapters. See figure 1.1 for a detailed view on the structure of the study. The first chapter consists of the introduction in which the problem statement, objective and corresponding research questions are formulated. In the second chapter the results of current literature concerning PSSs and the washing machine industry is presented. The third chapter describes which methodologies are used in this study. Chapter four describes the results of the five case studies in the washing machine industry. With the help of desk research and interviews the traditional selling business model and PaaS Bm of Coolblue will be analysed on their BM and environmental impact. Furthermore, three other inspirational cases in the washing machine industry are examined. This examination will be the input for new design concepts that can possibly improve the environmental impact of current and future Coolblue PaaS BM. The fifth chapter consists of the limitations that were experienced throughout the research. In chapter six a final conclusion will be drawn and recommendations are given. Given its explorative character, the results of this study cannot be used for a comparative assertion disclosed to the public.

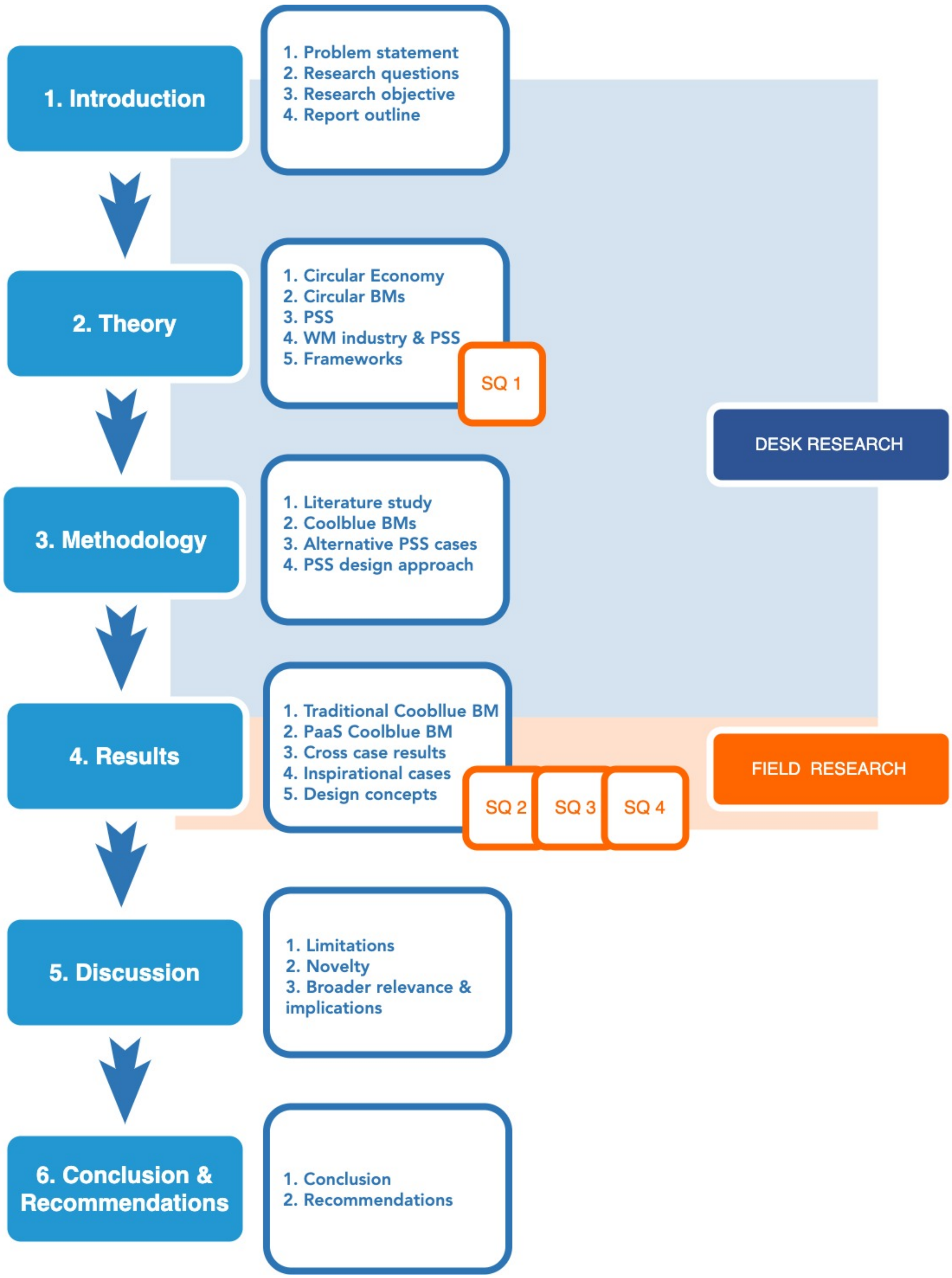


Figure 1.1 Report structure (Source: Author)

02.

THEORY

This chapter is made up of six parts. First the Circular Economy and its business models are explained. In the second paragraph, product-service systems and the three categories are defined. Third, all barriers, drivers and strategies of PSSs are mentioned. The fourth part focuses on PSS in combination with the washing machine industry. In the fifth part, possible frameworks are discussed. At the end of this chapter the literature review is summarised with the corresponding scientific knowledge gap. The selection criteria for the literature study are explained in chapter 3.1.

Figure 2.1 Theory outline (Source: Author)

2.1 Circular Economy

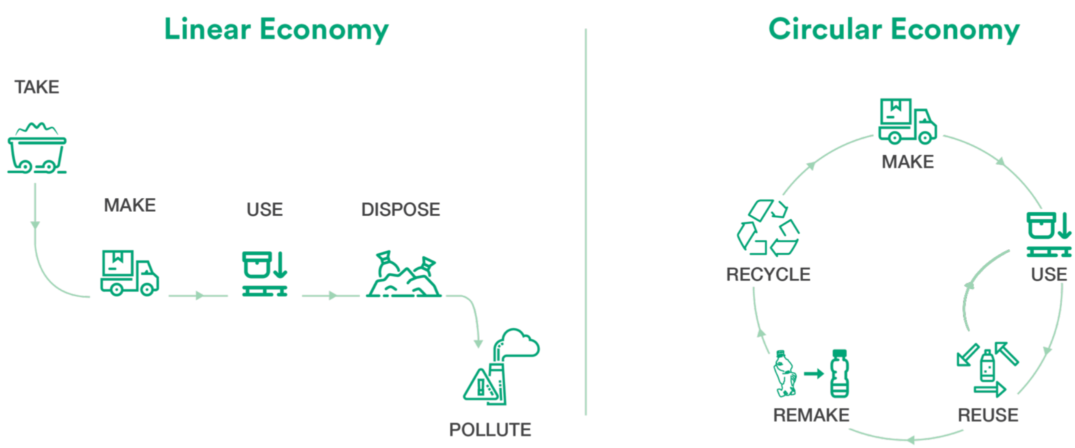


Figure 2.2 Linear Economy and the Circular Economy (Source: Adapted from RTS, 2019)

According to popular literature concerning the predominant Linear Economy (LE), production is mostly based on a cradle-to grave concept (C2G) where products mostly end up as landfill waste. Consequently, material and energy flows are interrelated to the economic prosperity in the LE (EMF, 2013). With a growing population and increasing energy consumption per capita, a shift away from the LE is needed (OECD, 2019; Roser *et al.*, 2019; Ritchie and Roser, 2019). The Circular Economy (CE) suggests that such a link can be decoupled by maximising the value of products and materials, decreasing the depletion of natural resources and decreasing the environmental impact (Bocken *et al.*, 2018; EMF, 2013; Kraaijenhagen *et al.*, 2016; Sauvé *et al.*, 2016) (see figure 2.2). It must be noted however that this does not mean that a CE is always better than the current more LE.

2.1.1 Defining the Circular Economy

After analysing 114 definitions Kirchherr *et al.* (2017: 229) proposed to define the CE as *"an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes*".

The Ellen MacArthur Foundation (EMF) is a foundation with the mission to accelerate the transition towards CE. The so-called Butterfly diagram, shown in figure 2.3, was created by the EMF (2013) in order to depict the CE with its closed material loops and principles. The right side shows the technical cycle, where there are two key takeaways. The role of the consumer shifts from owner to user in some business models and consumer goods. In the second take away the represented circles show a form of hierarchy. The tighter the circle, the more material, labour, energy and capital is saved, whilst still maintaining product functionality and performance. A longer circle could also be beneficial because the product, component or material is longer in use of the CE (EMF, 2013). The cycles for technical materials, based on the work by Stahel and Reday-Mulvey (1981), are described in Appendix B (Bakker *et al*, 2014; EMF, 2013b; Lansink, 1979; Mentink, 2014 and Planing, 2018) and these definitions of the cycles will be used throughout this study. Whenever possible a hierarchy amongst the cycles is preferred (Park and Chertow, 2014).

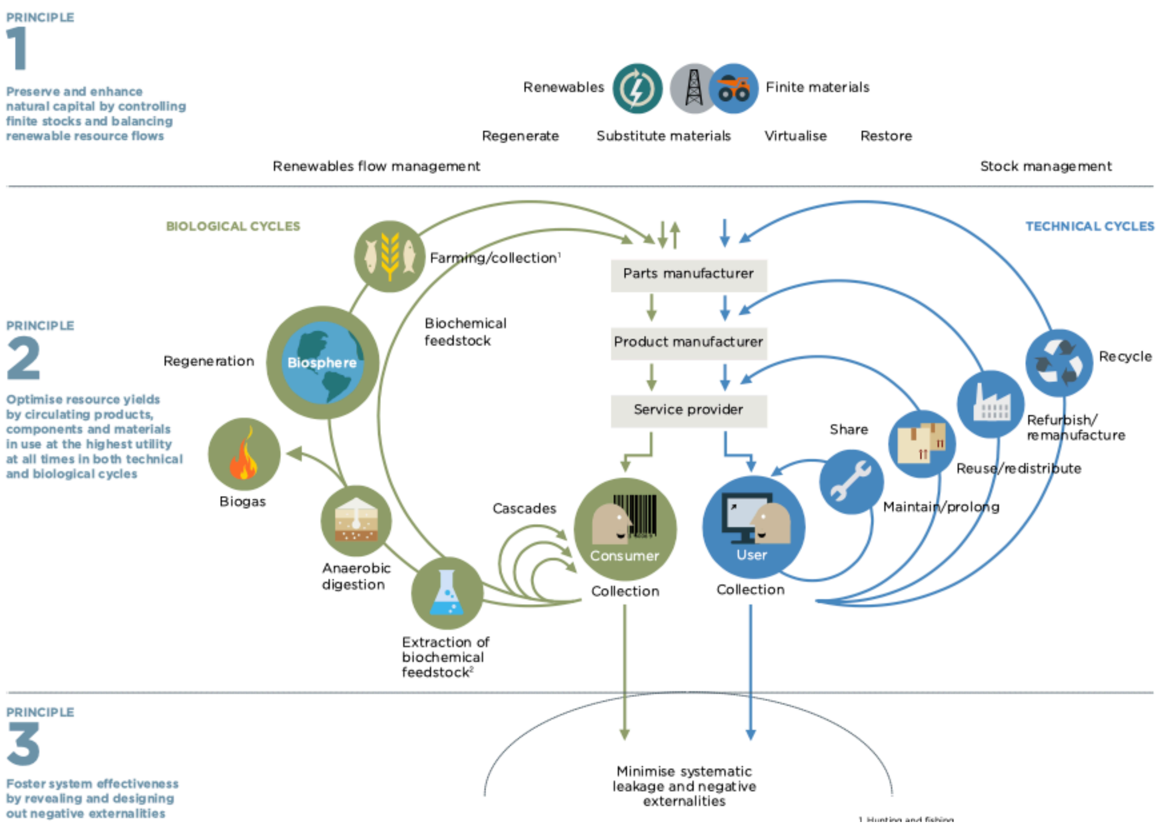


Figure 2.3 The butterfly diagram including the 3 principles by the EMF (EMF, 2013)

2.1.2 Transitioning towards a Circular Economy

A circular economy can bring many benefits. According to the EMF (2013), a strong advocate for the CE, market prices will become less volatile due to the use of circular products, because this will decrease the demand for upstream products. Economies will become more resilient and job opportunities will arise. Companies will also experience benefits by the creation of new profit pools such as the reverse logistic chain. Consequently CE benefits can tackle strategic challenges that companies face today like decreased product life cycles and declined customer loyalty. Consumers could encounter benefits from the CE in the form of higher customer comfort and lower prices against more product choices.

Although the momentum for a transition towards the CE is growing, the path is still long (Ellen MacArthur Foundation, 2013; Elia *et al.*, 2017). There are factors that drive or block the transition for business. These factors are categorized within seven areas: environmental, economic, social, institutional, technological & informational, organizational and supply chain factors. Appendix C explains four macro building blocks that should be built upon towards the CE.

Environmental

Resources are becoming more and more scarce. This drives the willingness to adopt a circular economy (Tura *et al*., 2019) as the CE offers ways to minimise resource input (Geis, 2018A). The CE also offers the possibility to prevent the negative impact caused by current actions on the environment (Linder and Williander, 2015; Tura *et al*., 2019).

A lack of assessment methods for evaluating the CE impacts is hindering the implementation of CE (Bocken *et al.*, 2016b; Bresanelli *et al.,* 2019*)*.

Economic

Resource scarcity has serious financial implications for companies. The CE can be financially interesting for companies as it puts a focus on performance and value retention of products, while minimising the resource input (Geis 2018A; Ghisellini *et al.,* 2016). The CE can also realise cost savings by decreasing waste and energy costs. Financial crises, such as COVID-19, drive companies to become creative in saving costs (Leising, 2015). CE also offers the potential for new business development (Kok *et al*., 2013; Tura *et al.*, 2019) and synergy opportunities (Tura *et al.*, 2019). However, currently there are still many financial barriers. Large upfront investments, high uncertainties (Tura *et al.*, 2019) high prices recycled materials, the fact that externalities (i.e. indirect environmental costs) are not incorporated and shareholders of companies are more focused on short term goals (EMF, 2012; Kok *et al*., 2013; Leising, 2015), are considered to be reasons for ineffective development for CE.

Social

The increased awareness of sustainability is considered to be a social drive for CE (Tura *et al.*, 2019). According to the EMF (2014) more and more consumers are willing to shift away from ownership and choose for access to services, because of economic recession and extensive youth unemployment. This trend is especially important under young consumers as they are the generation who can shift the economic model towards a CE (EMF, 2014). The CE also has the potential to create more jobs and vital workplaces (Tura *et al.*, 2019).

Social barriers include the lack of public awareness and hesitant approach from the government (Leising, 2015; Tura *et al.*, 2019). Consumers demand references on success cases, the lack of it is considered as a barrier. Furthermore, the lack of market mechanisms for recovery also makes the transition towards CE more difficult (Tura *et al.*, 2019).

Institutional

Some governments have stimulated the transition towards a CE by introducing positive incentives for circular business models like increasing taxes on linear business models (e.g. increasing landfill costs) (Leising, 2015; McDowall *et al.*, 2017), free take back schemes, increasing awareness (Adams *et al.*, 2017) mandatory recycling rates (Jang *et al.*, 2020; McDowall *et al.*, 2017), standardised labeling and funding research for new innovations (McDowall *et al.*, 2017). Also global standards (e.g. ISO standards) drive the development of CE (Tura *et al.*, 2019)
Institutional barriers are also present in the form of highly taxed labour and recycling policies are ineffective in securing high-quality waste. Some policies obstruct cooperation amongst corporations. This makes it all the more difficult and unlevels the business playing field between the LE and CE (EMF, 2012; Kok *et al*., 2013).

Technological & informational

A technical driver for the CE are the new technologies that keep on arising. Also information sharing is increasing due to information management technologies (e.g. platforms) (EMF, 2014; Tura *et al.*, 2019). These advances make it possible to track material flows, improve logistic set ups and increase renewable energy usage (EMF, 2014).
Innovations could make separation and recycling of components even more difficult and use more scarce resources. Recycling products does not necessarily mean upcycling as the quality is often downgraded and some products and materials have a limited time of reusing or recycling. Furthermore, closing the material loop fully is fundamentally impossible as it would require that the separation and recycling of products should be absolute up to the smallest particles. The CE would require the use of renewable energy sources as they are supposed to be more circular. Manufacturing devices that obtain renewable energy or store the energy, require a high amount of critical materials (Kleijn, 2012; Kok *et al*., 2013; Leising, 2015; Mentink, 2014).

Organisational

The CE can enable companies to differentiate themselves in the market and strengthen their brand (Linder and Willinder, 2015). The growing understanding of sustainability requirements and integration of sustainability in company strategies are driving the transition towards CE (Tura *et al.*, 2019).
The lack of CE knowledge, skills to implement and management support still inhibits the transition towards CE (Tura *et al.*, 2019). A silo mentality between departments, risk aversion and strong organisational hierarchy delay the CE transition (Liu and Bai, 2014).

Supply chain

In a good functioning CE BM the dependence on supply is decreased (Ghisellini *et al*., 2016) and thus avoiding price volatility. Currently, more than 55% of the world's population lives in urban

areas (Worldometers, 2020). The United Nations (2019) have projected that by 2050 this number will be increased to 68%. Furthermore, more pick-up and drop off points, higher acceptance and scale for service providers and simpler logistics arise. Due to the increase of urbanisation and centralisation, reverse logistics will become more efficient which could lead to lower costs (Leising, 2015).
Supply chain challenges rise from the strong industrial focal point on linear models. The lack of network support makes a transition more difficult, as CE business often requires the involvement of multiple stakeholders (Tura *et al*., 2019). The CE also requires an efficient information exchange system which might be difficult to establish due to privacy issues (Damen, 2012; EMF, 2012; Leising, 2015; Planning, 2018).

2.1.3 Defining Business Models

Business models are widely accepted to be the key tool to support the realisation of environmental and societal needs, whilst still generating economic benefits (Bocken *et al*., 2013; Geissdoerfer *et al*., 2018a; Pieroni *et al*., 2019; Planing, 2018). When a BM is not well-developed, it is said that innovators will not capture the total value from their innovations (Planing, 2018; Teece, 2010). One of the most well-known frameworks for the conceptualisation of BMs is the Business Model Canvas framework (BMC) by Osterwalder and Pigneur (2010). The framework is made up of nine elements (figure 2.4). The BMC is easy-to-use, allows the analyst to be intuitive and it covers all the crucial components of a successful BM (Adrodegari, 2016; Song *et al*., 2014; Wallin *et al*., 2013).

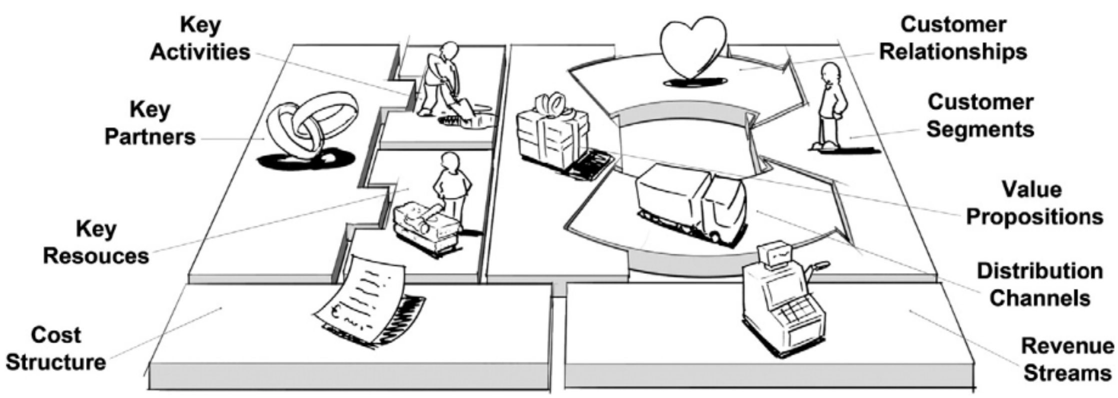


Figure 2.4 Business Model Canvas (Osterwalder and Pigneur, 2010)

2.1.4 Sustainable and Circular Business Models

According to Valkokari *et al*. (2018) there are Sustainable Business Models (SBMs) and a subset of SBMs, namely Circular Business Models (CBMs). Figure 2.5 gives a visual representation of the relations between traditional BMs, SBMs and CBMs.
To fully make use of the strengths of a BM and integrate sustainability considerations into the organisational level, three strategies can be pursued: sustainable value creation, pro-active management of the stakeholders and a long-term perspective (Geissdoerfer *et al*., 2018a). A Sustainable Business Model (SBM) is defined as "*innovations that create significant positive and/or*

significantly reduce negative impacts for the environment and/or society, through changes in the way the organisation and its value-network create, deliver value and capture value (i.e. create economic value or change their value proposition)" (Bocken *et al*., 2013: 44). The CE however requests designers to think differently, as was indicated in the four CE building blocks. Designers will have to adopt a more system-thinking perspective around the product. They should also look into ways to generate new value while maintaining that value over a longer period of time (Bocken *et al*., 2018; Bresanelli *et al.*, 2019). Adopting circularity into the BM, leads to a Circular Business Model (CBM) which can be defined as "*as a business model in which the conceptual logic for value creation is based on utilising economic value retained in products after use in the production of new offerings"* (Linder and Williander, 2015: 2).
In order to transit towards a CE a total of five strategies can be applied (figure 2.5). Closing, narrowing and slowing down resource loops are three commonly mentioned strategies (Bocken *et al*., 2016b; Pieroni *et al*., 2019). Geissendoerfer *et al*. (2018a) mentions two other circular strategies, namely intensifying and dematerialising resource loops. It is important to note that a CBM should be seen as a part of a system of BMs and thus it does not have to close the material loop by itself to achieve circularity (Mentink, 2014). In other words the waste of one company could be used as the input of another in order to achieve circularity together. In reality absolute circular BMs do not occur because of practical and physical restrictions.

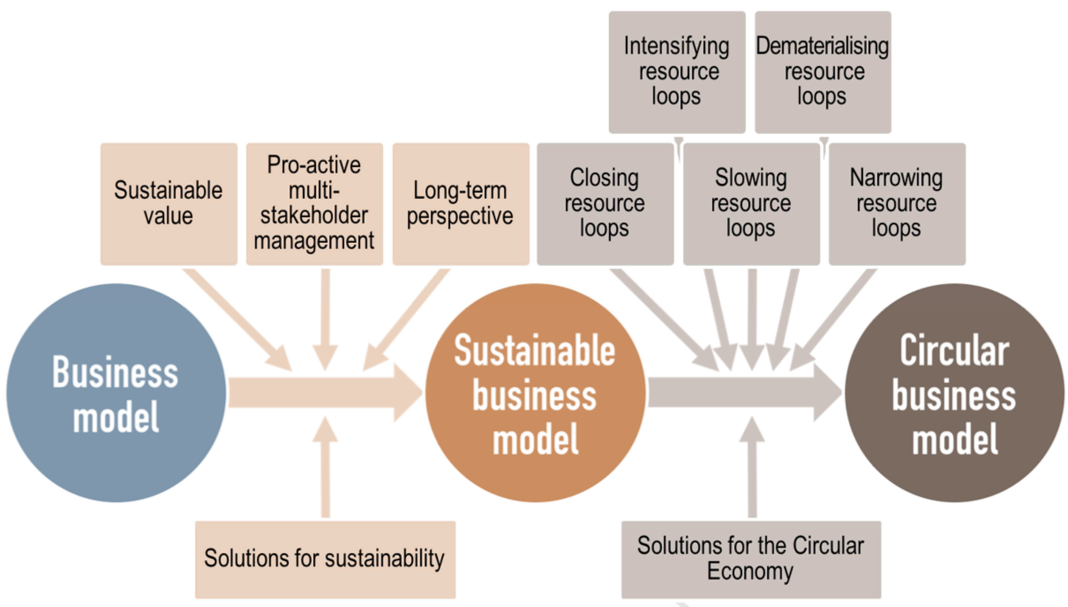


Figure 2.5 Comparison of traditional, sustainable and circular business models (Geissdoerfer *et al.,* 2018a)

2.2 Product-service systems

The product-service system is a concept that has obtained a lot of popularity in the field of Circular Economy (Bocken *et al.*, 2018; Tukker, 2015: Reim, 2015). Many say that in the last few years, these are seen as the pioneering business model for consumer goods to shift manufacturing and consumption away from the linear model towards circular economy and improve the circularity of a business (Bocken *et al.*, 2016a; Spring and Arauja, 2017; Urbinati *et al.*, 2017; Yang *et al,* 2018). Not all scholars however are convinced and state that PSS should not be recognised as the sustainability panacea (Tukker, 2015). Some critics say that PSS does not automatically lead to a reduction in resources (Kjaer *et al.* 2016; Tukker 2004; Tukker and Tischner 2006) and that a PSS can only be circular when intentionally designed to do so (Michelini *et al.*, 2017; Tukker, 2015; Vasantha *et al.*, 2015). Appendix D gives an examination of the resource-efficiency of companies that uphold a PSS BM, through the three CE principle for action by the EMF. An important factor to help design a PSS BM in a sustainable way, is the Life Cycle Assessment (LCA) tool (Michelini *et al.,* 2017). An LCA will give crucial insights into how the product should be designed in order for recovery and reuse of the product, components or materials to take place. The lack of assessment methods for the evaluation of CE impact is confirmed as hindering its implementation (Bocken *et al.,* 2016b; Bresanelli *et al.,* 2019*).*
In the traditional BM a consumer buys a product and becomes the full owner of the product until it meets its end-of-life (Barquet *et al*., 2017). In a PSS BM, retailers or manufacturers remain the owner of the product during use and in return it will provide services to the consumer such as product use, delivery, maintenance, repair or taking care of the EoL (Barquet *et al.*, 2017; Kühl *et al.,* 2018).

2.2.1 Defining product-service systems

The report by Goedkoop *et al.* (1999) was the first publication that used the term Product-Service system (PSS) (Haase *et al.*, 2017). Before the definition of a PSS was accepted in the literature there was another topic that shared great resemblance in the 1980s, namely servitization (Annarelli *et al.*, 2016; Kristensen and Remmen, 2019). Servitization is a process that provides customer value through services together with the company's offerings (Kühl *et al.*, 2018). Both topics share the concept of adding value through services (Anarelli *et al,* 2016). The difference between them is the meaning behind them and the context in which they are placed. Servitization is mostly used in the literature if there is an interest in the economic potentials of the offerings, whereas PSS is mostly used in a sustainability context (Anarelli *et al,* 2016).

Despite the growing academic interest, so far there is not one definition accepted by the literature for a PSS (Beuren *et al.*, 2013). Annarelli *et al.* (2016: 8) define a PSS as "*a business model focused toward the provision of a marketable set of products and services, designed to be economically, socially and environmentally sustainable, with the final aim of fulfilling customer's needs*". The definition by Annarelli *et al.* (2016) is the most extensive (Kristensen and Remmen, 2019). It includes the three pillars of sustainability and also mentions the three elements of a PSS according to Goedkoop *et al.* (1999) (i.e. product, service and a system).

2.2.2 Product-service system archetypes

Most scholars divide PSS into the three archetypes: product-oriented, use-oriented and result-oriented PSS (Baines, 2007; Kristensen & Remmen, 2019; Kuo *et al.*, 2019; Tukker, 2004; Tukker, 2015; Yang & Evans, 2019). Their ranking is based on the number of services that are offered and the type of ownership of the product in the category (Yang & Evans, 2019). Besides the three archetypes, Tukker (2004) has also proposed subcategories under each archetype, as shown in figure 2.6. The structure of these eight subcategories is frequently used in literature (Annarelli *et al.*, 2016; Bocken *et al.*, 2014; Reim, 2015). Appendix E gives a detailed explanation behind all eight PSS subcategories and business examples within the categories are given.

> ***Product-oriented PSS***: The provider focuses on the sales of products and offers some extra services, such as maintenance, consultancy, insurance, repair and training.
> ***Use-oriented PSS****:* In use-oriented PSSs the business model has shifted from traditional ownership by the customer to an ownership remaining with the provider and allowing the product to be used by multiple users. Different types of use-oriented PSS are leasing, renting, sharing and pooling.
> ***Result-oriented PSS****:* Result-oriented PSS, does not focus on a product, but a certain result is agreed upon between the provider and customer.

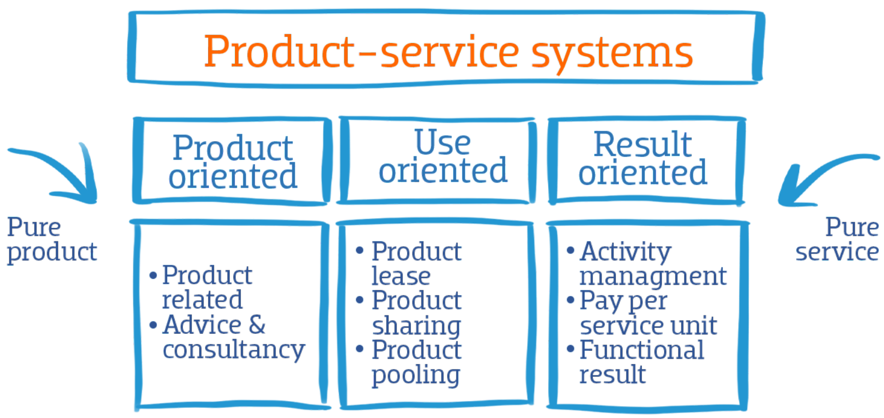


Figure 2.6 Main archetypes and subcategories of PSS (Adapted from Tukker, 2004).

2.3 PSS potentials and barriers towards a Circular Economy

This subparagraph is divided into three parts. First the sustainability potentials of PSSs are outlined. The second part holds information about the barriers that can occur in a PSS BM for manufacturer, provider and customer. The third part explains five strategies that PSS providers can follow to achieve absolute resource decoupling.

2.3.1 PSS sustainability potentials

Chapter 2.1.2 outlined drivers and barriers for transitioning towards CE. In order for PSS, a concept of CE, to be successfully implemented, it is important to understand which beneficial sustainability potentials can be achieved. A distinction is made between the three pillars of sustainability, namely Environment, Economy and Social. The environmental pillar is subdivided in the three PSS categories and the corresponding archetypes by Tukker (2004). This distinction is made because the environmental potential of each PSS archetype is different.

The social and economy pillars are explained by the three PSS categories together. This choice was made because the main focus of this thesis is on the environmental impact of PSSs and the three different PSS categories present different BM element combinations (De Pádua Pieroni *et al.*, 2018; Tukker, 2004). Table 2.1 summarises all scientific findings concerning the sustainability potentials for companies and table 2.2 summarises all potential experienced by the consumer.

1. ***Environment***

Tukker (2015: 78) mentioned that the environment was not "*the main subject of papers on PSS*" in current literature. Most papers concerned engineering, computer science and business, management and accounting. From this information Tukker (2015) concludes that PSS research is more focused on a business perspective than on the environmental impact. The information concerning the environmental impact of PSS deals with the potential sustainability benefits of PSS for both providers and customers.

<u>Product-oriented</u>

When looking at the environmental impact of the product-oriented archetype, Tukker (2004: 255) states that environmental impact reductions could occur, but that they "*are likely to be incremental at best'.* For both the product-oriented subcategories additional efficiency improvements could occur due to improved maintenance, suggestions on product use or take-back arrangements.

<u>Use-oriented</u>

Because the provider remains the owner in the use-oriented category, the incentive is to use the product as much as possible. This will ensure that the product is monitored to make collection at the end of use possible (Kühl *et al.*, 2018) and reuse products, components or materials.
The environmental impact of the archetype product lease is not clear, as it can show both reductions or not. Maintenance, repair and control can prevent a product from being thrown away unnecessarily (Tukker, 2004). The provider is motivated to increase the product life span because when the user is at the end-of-need stage the product can be passed on to another user (Yang and Evans, 2019). This all can lead to efficiency improvements. Data on defaults and repairs are sometimes transferred back to the manufacturer in order to improve the products design so that less defaults and breakdowns happen (Azcarate *et al.*, 2018; Personal communications, 2019). In most cases however providers purchase products for third parties. Therefore the incentive to improve product design is not always passed on directly from provider to the design team (Tukker, 2004). Because the user does not own the product, the quality could be degraded as customers feel less obliged to take good care of them (Sumter *et al*, 2018; Tukker, 2015). Both cases can lead to a negative outcome.

Product renting and product sharing indicate that multiple users are met with one product. This can lead to severe environmental impact reductions, especially if the life-cycle impacts are linked to the production phase (Tukker, 2004). The fact that the user only has access to the product when paid can discourage the use of the product. When the product is used less this could lead to environmental reductions. It could also promote environmental friendly alternatives. For example choosing to use public transport instead of renting or sharing a car.
The environmental impact of product pooling is similar to product renting and sharing. Pooling however suggests that multiple users are using a product at the same time. This can result in even more environmental reductions than for product renting or sharing.

Result-oriented
According to Tukker (2004) there are no real environmental reductions that can be achieved with the archetype activity management/outsourcing. Perhaps making more efficient use of capital goods, materials or personnel can lead to some reductions, but no radical changes are expected.
The environmental impact of the pay-per-service-unit archetype is considered to consist of two aspects (Tukker, 2004). First the provider remains the owner of the product and it therefore responsible for all life cycle costs. This motivates the provider to design products that have an optimal cost to lifetime ratio. This could lead to environmental reductions. The second aspect is that in some circumstances consumers will use the service more attentively (e.g. pay-per-wash), whereas in other circumstances this concern does not arise (e.g. copy machine at the office).
The functional result archetype is considered to be the most promising to reduce environmental impact (Tukker, 2004; Yang and Evans, 2019). This is because in the end only a result is promised and how this promise is met, is up to the provider.
The provider will therefore try to meet this promise as cost- and material-efficient as possible (Kristensen and Remmen, 2019; Kühl *et al.*, 2018; Tukker, 2015; Yang and Evans, 2019).

The customer can experience an environmental benefit from the PSS BM as the products are of high quality and efficiently manufactured (Personal communications, 2019; Yang and Evans, 2019). Furthermore, the customer has now an option to actively choose for a sustainable alternative (Van der Meer, 2019; Tukker, 2015; Yang and Evans, 2019).

2. Economy

As the contact between the provider and customer is more frequent, longer and more direct, a stronger bond can arise (Kühl *et al.*, 2018; Yang and Evans, 2019). The option of tailor made products and services is also possible (Yang and Evans, 2019). By stimulating producers to prolong the life cycle of their products, they become more cost effective (Kristensen and Remmen, 2019; Tukker, 2015). Companies can settle in other service markets (Azcarate *et al.*, 2018; Yang and Evans, 2019). Companies can promote themselves by creating a unique service and product (Yang and Evans, 2019). This can sometimes offer them a more profitable margin in comparison to profits obtained through traditional sales (Kühl *et al.*, 2018; Yang and Evans, 2019). Because of the increased certainty of frequent payments in long term contracts PSS can offer a continuous income (Azcarate *et al.*, 2018). Also service data on defaults and repairs can be sold back to the manufacturer and offer an extra income flow (Personal communications, 2019; Yang and Evans, 2019). This in return challenges producers to improve their technology and look for innovations (Azcarate *et al.*, 2018; Personal communications, 2019; Yang and Evans, 2019).

The customer also encounters some economic benefits, such as the fact that no upfront investments are needed (Tukker, 2015), besides a possible deposit. Customers are happier when the user phase is extended through services and they don't have to worry about the EoL phase (Van der Meer, 2019; Yang and Evans, 2019).

3. Social

Because of the services provided in a PSS BM more jobs can be created for all levels of education (Yang and Evans, 2019). The customer can benefit from customization (Tukker, 2015) and not having to worry about ownership responsibility (Yang and Evans, 2019).

Table 2.1 PSS sustainability potentials for companies (Adapted from Yang and Evans, 2019).

Pillar of sustainability	Sustainability opportunities	Literature source
Environmental	*Extended product life cycle*	Kjaer *et al.* (2018); Yang and Evans (2019)
	Dematerialisation	Yang and Evans (2019)
	Resource and energy efficiency	Yang and Evans (2019); Kühl *et al.* (2018); Kjaer *et al.* (2018); Kristensen and Remmen (2019); Tukker (2015)
	Increased product usage	Yang and Evans (2019)
	Keep track of product	Kühl *et al.* (2018)
	Freedom to design for sustainability	Yang and Evans (2019)
	Incentivise innovation and quality	Azcarate *et al.* (2018); Van Der Meer (2020)
Economic	*Cost effective*	Kristensen and Remmen (2019); Tukker (2015); Yang and Evans (2019)
	Stronger and longer customer bonds	Kühl *et al.* (2018); Yang and Evans (2019)
	Tailor made needs for the	Yang and Evans (2019)

	customer	
	Competitive advantage through differentiation	Yang and Evans (2019)
	Expansion of markets	Azcarate *et al.* (2018); Yang and Evans (2019)
	Expanded revenue streams	Yang and Evans (2019); Kühl *et al.* (2018)
	Stable cash flow	Azcarate *et al.* (2018)
	Access to service data	Van Der Meer (2020); Yang and Evans (2019)
	Improved technology and incentivise innovation	Azcarate *et al.* (2018); Van Der Meer (2020); Yang and Evans (2019)
Social	*More jobs*	Bresanelli *et al.* (2017); Yang and Evans (2019)

Table 2.2 Sustainability potentials of PSS for the consumer (Adapted from Koukopoulou, 2020)

Pillar of sustainability	Sustainability opportunities	Literature source
Environmental	*High efficiency and quality*	Van Der Meer (2020); Yang and Evans (2019)
	Sustainable alternative	Van Der Meer (2020); Tukker (2015); Yang and Evans (2019)
Economic	*Low (investment) costs*	Tukker (2015);
	Better customer experience	Van Der Meer (2020); Yang and Evans (2019)
Social	*Customization*	Tukker (2015)
	Reduced ownership responsibility	Yang and Evans (2019)

2.3.2 Barriers of PSS

After establishing all the potential sustainability benefits for PSS providers and consumers, it is interesting to see which barriers can arise when implementing a PSS. The CE barriers, outlined in 2.1.2, are different from the barriers when implementing a PSS. In order for PSS to be successful, suppliers, providers and consumers must show willingness and commitment for this type of BM (Annarelli *et al.*, 2016). A shift is needed in companies. For both the providers and consumers a new social infrastructure is needed to make PSS feasible (Annarelli *et al.*, 2016; Goedkoop *et al.*, 1999). Providers need to revise their organisational culture and consumers must change their traditional consumption habits (Annarelli *et al.*, 2016; Sakao *et al.*, 2013). A PSS BM asks for high investments for all the products at the beginning. Only after a longer period of time will the provider make a profit (Annarelli *et al.*, 2016; Personal communications, 2019). Providers must be willing to make this investment. In some PSS BMs a reverse logistics system must be installed (Koppius *et al.*, 2014) and retailers must be educated and trained to handle all the problems brought to them by the consumer. A lack of experience in service design or personnel can hinder the implementation of PSS (Barquet *et al.*, 2013; Kuo *et al.*, 2010). Rebound effects however could occur. For example because customers think they are saving energy and money in one area, they can be using more energy by buying other products (Kjaer *et al.*, 2016; Kjaer *et al.*, 2018; Tukker, 2015). Quality degradation of the returned product can also occur as customers feel less obliged to take care of them without ownership (Sumter *et al*, 2018; Tukker, 2015). Although a PSS subscription can be financially advantageous for some consumers (e.g. expats), other consumers might pay more in the end than they would have had to pay in a linear BM. When the product is recycled there must be a market to sell those downstreamed/recycled goods in order for the PSS to be fully circular (Annarelli *et al.*, 2016). All barriers are summarised in table 2.3.

Table 2.3 Barriers of implementing a PSS (Adapted from Koukopoulou, 2020)

Barriers	Literature source
New social infrastructure	Annarelli *et al.* (2016); Goedkoop *et al.* (1999)
Reverse logistics infrastructure	Koppius *et al.* (2014)
Rebound effects	Kjaer *et al.* (2016); Kjaer *et al.* (2018); Tukker (2015)
Quality degradation of returned products	Sumter *et al.* (2018); Tukker (2015)
High investments	Annarelli *et al.* (2016)
Cultural shift for consumer and provider	Sakao *et al.* (2013)
Acceptance from stakeholders	Annarelli *et al.* (2016)
Educating and training for providers	Barquet *et al.* (2013); Kuo *et al.* (2010)
Lack of market	Annarelli *et al.* (2016)

2.3.3 Product-service system strategies for PSS providers

Kjaer *et al*. (2018) developed a two-step framework that enables each PSS archetype to achieve absolute resource decoupling. From the framework, five strategies are identified for PSS providers.

1. ***Operational support***: If PSS providers monitor and optimise the operational side of the BM, the input for new resources could be decreased due to efficiency (Bocken *et al.*, 2014).
2. ***Product maintenance***: By performing predictive maintenance, repairs or upgrades, the PSS provider is able to maintain the product (Bocken *et al.*, 2014).
3. ***Product sharing*****:** The PSS provider remains owner of the product and is thus able to share the same resources amongst multiple users (Mont, 2004). This will decrease the need for producing new products and eventually less resources.
4. ***Take-back / EoL management:*** The provider is responsible for the EoL of the machine. Because of this, the life span of the product can be controlled and reused, remanufactured, refurbished, recycled, etc. (Bocken *et al*. 2014).
5. ***Optimized results***: PSS delivers services and agrees upon a result. This can dematerialise the offering.

2.4 Product-service systems and the washing machine industry

This subparagraph consists of five parts. First the suitability of a PSS BM in the washing machine (WM) industry is explained. Second, business applications in the washing machine industry for the eight archetypes are named. The third part consists of WM functions that have an impact on the environment. The fourth part contains the description of the phases in a WM life cycle. The fifth part describes the main national and international rules and regulations that Dutch companies must obey when producing or recycling a washing machine.

2.4.1 Suitability of PSS in the washing machine industry

Besides the fact that Coolblue is operating in the field of PSS for the washing machine industry, there are other reasons why this study on PSS is focused on the washing machine sector.
A WM contains all the characteristics that make a product suitable for PSS (Tukker, 2015). They are rather expensive and technically advanced; maintenance and repair is required; used infrequently by consumer(s); it is fashion insensitive and a WM is rather easy to transport. In the second place a PSS can be a sustainable strategy if the user phase is the dominating phase, financially and environmentally (Tukker *et al*., 2010). This is the case for WMs as the user phase takes up more than 60% of the total cost (Saccani *et al*., 2017; Yuan *et al.*, 2015) and the environmental impact of the user phase is higher than production and transport (Bresanelli *et al*., 2017). The third reason is that the environmental impact of WMs can still be improved (Bresanelli *et al.*, 2017) even given the fact that the choice for a WM is mainly guided by price and not energy or water efficiency (Codini *et al.,* 2012).

2.4.2 PSS archetypes application in the washing machine industry

The wash subscription by Coolblue can be classified as the *product lease* archetype. When looking at the eight archetypes of PSS (explained in chapter 2.3.3), not every archetype is suitable or feasible for the washing machine industry. Figure 2.7 gives a visual representation of the possibilities of the PSS archetypes in the washing machine industry.

Maintenance contracts or advice on how to prolong the life time would be examples of the *product related* and *advice and consultancy* archetypes (i.e. product-oriented category). The *product pooling* archetype in the washing machine industry means that multiple people are putting their wash into one machine at the same time, whilst it is rented or leased. This does not seem desirable or feasible for the users in the Netherlands.
Perhaps the most well known PSS archetype in the washing machine industry is *product renting/sharing.* The interpretation of this archetype is a laundromat. Laundromat machines have a higher utilisation rate and are twice as expensive to purchase compared to domestic washing machines (Sutherland, 2007). Looking at the environmental impact, water usage of domestic washing and laundry service washing is similar. The embodied resource use however is significantly higher. This is because the domestic washing machines are used less frequently compared to laundry services (Retamal and Schandl, 2017). Amasawa *et al*. (2018) have looked at

interventions that can shift consumers towards sharing a washing machine (i.e. laundromat) instead of owning a private machine in Japan. An interesting finding from their research was that 68% of the respondents mentioned that being the owner of a washing machine was essential for their lifestyle. The ownership rate of WMs in the Netherlands is 98% (Laitala *et al.*, 2018). In both domestic washing and laundromat the manufacturing of detergents and electricity use are the major greenhouse gas (GHG) contributors (Amasawa *et al*., 2018).

Figure 2.7 PSS archetypes in the washing machine industry (Source: Author)

For a business being involved in the *activity management* and *functional result* archetypes (i.e. result-oriented category), it would mean that the washing is outsourced. Dry cleaners are an example of such an archetype.

A pay-per-service-unit business model within the washing machine industry does also exist. Bocken *et al.* (2018) state that the pay-per-use model can have a more positive environmental impact than the more conventional product-oriented model. This is because sustainable consumption (i.e. number of washes and program temperatures) can be stimulated. Especially consumers who usually washed at higher temperatures seemed to significantly decrease their washing temperatures after installation of the pay-per-use model. Not only a shift in washing temperatures was observed, but also the frequency of washing went down (Bocken *et al.*, 2018). Consequently, this leads to a decrease in energy consumption and therefore their findings conclude that a pay-per-use BM can serve as a trigger to change the energy consumption of energy-demanding appliances. Apart from the environmental benefits, economic savings and flexibility are also mentioned as benefits of the BM. It is important however to make sure that these cost savings do not result in rebound effects.

2.4.3 Life cycle of a washing machine

Lee *et al*. (1995) mention four different activity boxes for the life cycle of a washing machine (see figure 2.9). The production process includes extracting raw material up to the assembly of the product and services that come with it. The second process is the distribution process, which measures the impact from packaging the machine up to transport. In the third activity the utilisation stage of the washing machine is examined. The impact of operation is taken into account in the form of water use, energy use, maintenance, etc. The fourth step looks at the End-of-Life process of the washing machine. This means evaluating the collection and transport of the machine up to the waste management process.

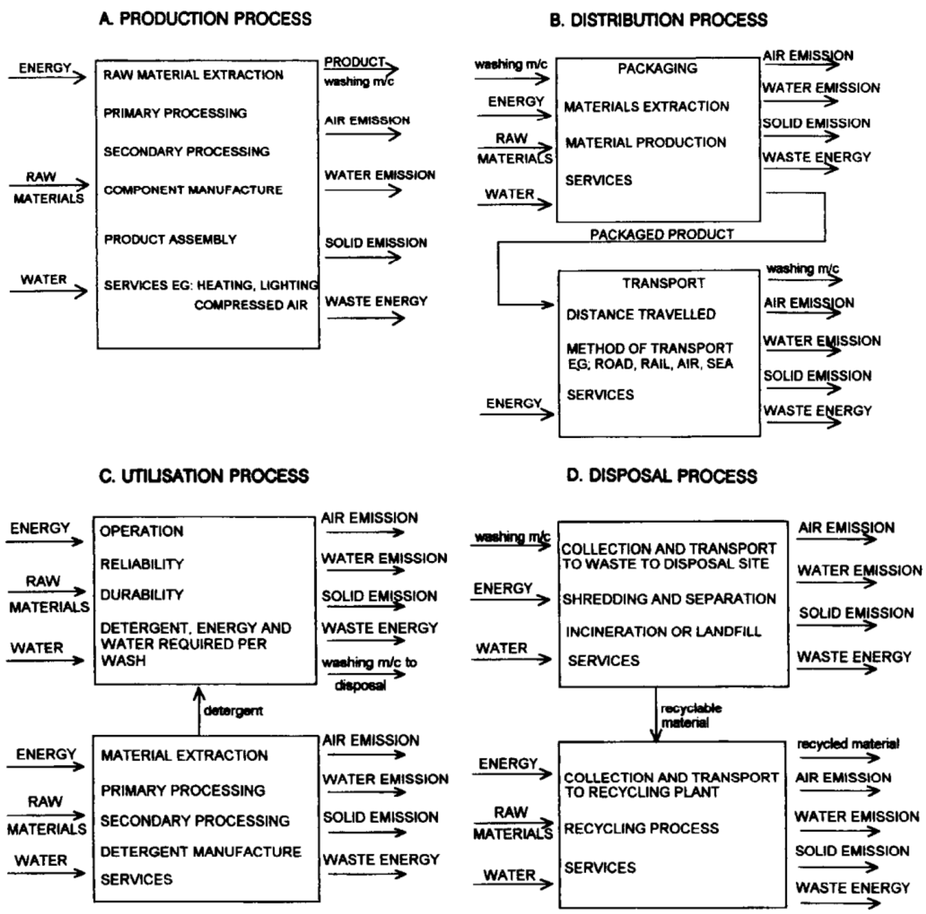


Figure 2.9 Activity boxes for the life cycle of a washing machine (Lee *et al.*, 1995)

These four processes described by Lee *et al*. (1995) are a representation of the traditional BM. In a PSS BM it is assumed that the utilisation process is divided into two processes: Use and Life extension. This adaptation will be used when analysing the PSS in this study which is further explained in chapter 3.

2.4.4 Activities in the WM life cycle impacting the environment

Apart from the fact that the type of business model has an effect on the environmental impact, there are functions and prerequisites on a machine that can influence the environmental impact of a WM life cycle. Especially the user phase shows many variables.

Production

The production phase is said to contribute around 38% of the Global Warming Potential (GWP) in a WM life cycle (Yuan *et al,* 2016). The GWP from the production phase are mostly because of the plastic parts (65%) adn 20% electronics.

Washing temperature

The average washing temperature in the Netherlands is around 41 degrees (Laitala *et al.,* 2018). At 40 degrees the user phase takes up more then 60% of the total energy demand (A.I.S.E., 2015). The International Association for Soaps, Detergents and Maintenance Products (A.I.S.E.) (A.I.S.E., 2015) have stated that the frequency of washing and the temperature of the wash are regarded as the main contributors of the overall environmental impact of washing machines. This statement is backed up by the study by Laitala *et al.* (2011). The study showed that a washing temperature of 40 degrees would make textiles 1.9% more clean in comparison to washing at 30 degrees. But this increase in temperature resulted in 29.6% more energy use.
Nevertheless, it is important to perform a high temperature (e.g. 60 degrees celsius) wash from time to time in order to avoid detergent residue from building up. This can cause bacteria to grow which could cause malodours and lower washing quality (Stamminger *et al.*, 2020).

RPM

Furthermore, the choice of rotations per minute (rpm) can have an influence on the environmental impact. A higher rpm results in dryer clothes. The higher the rpm however, the more energy is used. Therefore the customer could choose a shorter drying program or make no use of the dryer at all (Van der Meer, 2020).

Washing machine type

Washing machines can be divided into vertical- and horizontal-axis WMs. Most machines manufactured these days are horizontal-axis. In Europe it is the more popular choice (Daystar *et al.,* 2019) because they can be combined with a dryer on top. Horizontal-axis WMs use less water and are more efficient in removing stains (Seiphetlheng, 2011).

Lifespan & build quality

Hennies and Stamminger (2016) found that in Germany there was a correlation between the price for a WM and its lifespan. WMs that cost over €700,- are three times less likely to fail than WMs that cost less than €550 (Stamminger *et al.*, 2020). The price however does not only reflect the quality of the material, but also the services that are provided.

The lifespan is of course highly subjective to the WM usage. For example the number of washing cycles the appliance can perform. The number of washing cycles is mostly correlated to the building quality of the WM. The build quality of WMs can be subdivided into three categories: high-end WMs, mid-range and basic. The manufacturer Miele, known for its high-end WMs, mentioned that their WMs are designed to last 5000 cycles. This would correspond to a lifespan of 20 years (Stamminger *et al.*, 2020). The number of wash cycles that a mid-range and basic WM can perform is unknown. The average lifespan of a WM in the Netherlands is 11.7 years (Prakash *et al.,* 2016).

Number of wash cycles

The number of wash cycles also has an effect on the lifespan of a WM. EMF (2013) states that on average domestic washing adds up to 250 cycles a year. Pakula and Stamminger (2010) state that in the Netherlands households perform over 165 wash cycles per year.
Bocken *et al*. (2018) however think that the actual number is higher because people wash more than they report during interviews. One study even estimated that in Japan the yearly number of washes per household is 520 cycles (Amasawa *et al*., 2018) and 392 cycles in America (Sutherland, 2007). These differences could be explained by the type of textiles, climate differences or access to a WM.

Detergents

Other scholars also state that besides the washing temperature, the detergent volume also has a major influence on the environmental impact of doing laundry (Amasawa *et al.*, 2018; Laitala *et al*., 2018). The study by Giagnorio *et al.* (2017) confirms that detergents play a predominant role in the life cycle of a washing machine. Detergents that work better at lower temperatures make it possible to obtain similar washing results (i.e. cleanliness) while reducing energy use (Hoof *et al.*, 2001). The impact of detergents is especially visible when measuring the following impact categories: Eutrophication Potential (EP), Abiotic Depletion elements (ADP elements) and Terrestrial ecotoxicity potential (TETP). The impact of detergents on the Global Warming Potential (GWP) is around 5% (Yuan *et al.,* 2015).

Waste management

In the paper by Yuan *et al.* (2016) the End-of-Life phase of the WM is accounted for as recycling credit. The contribution to the GWP is estimated around 18%. The main impact holders are the disposal of plastic and steel. The steel frame takes up around one fourth of the total WM weight (Park *et al.,* 2016).

From these studies it becomes clear that there are multiple activities in a WM that can influence the environmental impact (see figure 2.9).

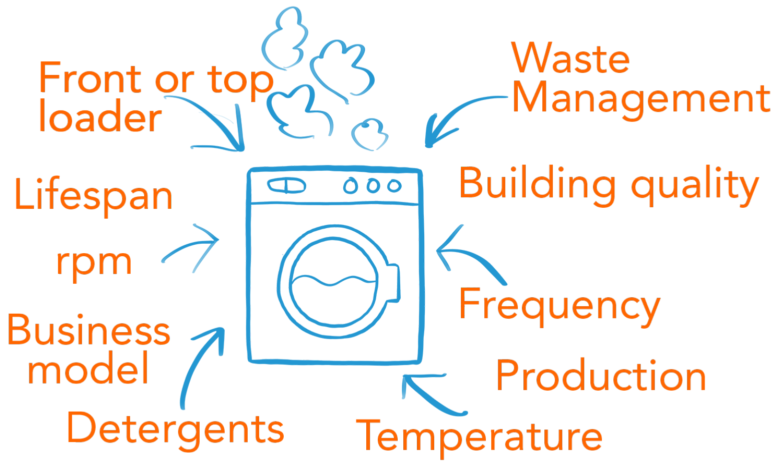


Figure 2.9 Washing machine life cycle activities impacting the environment (Source: Author)

2.4.5 Institutional context within the washing machine industry

In Europe each washing machine should carry the EU Energy Label (figure 2.10). This label shows the energy efficiency of the apparatus from A+++ to D, with A+++ being the most energy efficient. Other energy and non-energy information is also visualised, such as water use per cycle, storing capacity, noise emitted. (European Commission, 2019a). The European Commission (2019a) has decided that the energy label will be updated in March 2021. This is because the label has driven many innovative developments, which has resulted in newer models being labeled with A+++-40% and the A class sometimes being the lowest class. In order to simplify the understanding of the energy label, the scaling system will be revised. In this revision seven differences are visible. First the labels are graded from A (most efficient) to G (least efficient). Second, QR codes (i.e. Quick Response) will be visualised. These codes can be scanned by a smartphone and will provide consumers with additional information to make a better informed purchase choice (European Commission, 2019a). The third and fourth difference is that the duration and rated capacity of the “Eco 40-60” programme are displayed. The energy consumption (kWh) is specified per 100 wash cycles and the water consumption per wash cycle. The seventh difference is that the noise emissions are given only for spinning.

In 2019 the European Commission also announced new ecodesign requirements (European Commission, 2019b). These requirements are related to the reparability and recyclability of the WM. They should also facilitate the re-use, disassembly and recovery of WEEE.

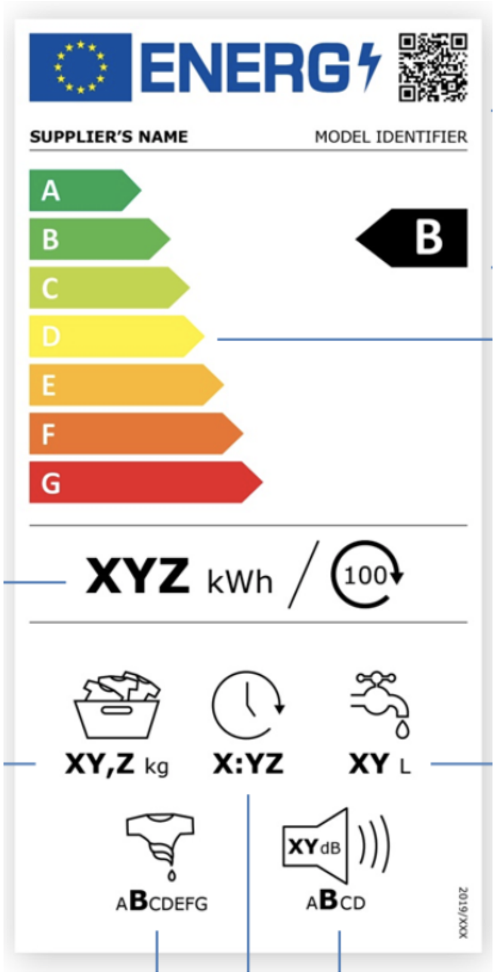


Figure 2.10 Updated EU energy label (European Commission, 2019b)

Another regulation is the 1015/2010 regulation that holds generic and specific requirements that need to be met in the design of domestic washing machines (Verordening EU, 2010). This regulation shows the implementation of the European Directive Ecodesign 2009/125/EG, which represents a framework holding mandatory requirements for energy-using and energy-related products sold in the EU.

Furthermore, there is a Waste Electrical and Electronic Equipment (WEEE) Directive that regulates the collection and recycling of WEEE waste. According to the WEEE Directive every producer and importer of electrical goods is legally obliged to take in, recycle and environmentally friendly eliminate e-waste (WEEE, 2015). This directive is monitored by the association NVMP (Nederlands Verwijdering Metalelektro Producten). The execution of collection and recycling of the waste is done by the organisation WeCycle. A historical and socio-cultural background of washing can be found in Appendix F.

2.5 PSS BM frameworks towards a Circular Economy

Product-service systems can only be circular if they are intentionally designed to do so (Michelini *et al.*, 2017; Tukker, 2015; Vasantha *et al.*, 2015). By first identifying influential factors on the environment in a WM life cycle, the PSS BM can be designed properly. A framework can help to identify all the relevant characteristics, networks and environments of the two BMs by Coolblue in order to examine the environmental impact in a structural way. The framework will also be put to use to analyse the inspirational cases with an alternative PSS BM (i.e. subquestion 3). Therefore a literature search was carried out to find suitable frameworks that could be used for this study. From this search the following four frameworks were considered suitable:

1. Circular business model canvas by Lewandowski (2016)
2. The PSS business model framework by Adrogedari *et al.* (2017)
3. Sustainable business model canvas by Case (2018)
4. Sustainable Value proposition network by Kristensen and Remmen (2019)

2.5.1 The Circular BMC by Lewandowski (2016)

Partners
- Cooperative networks
- Types of collaboration

Activities
- Optimising performance
- Product Design
- Lobbying
- Remanufacturing, recycling
- Technology exchange

Key Resources
- Better-performing materials
- Regeneration and restoring of natural capital
- Virtualization of materials
- Retrieved Resources (products, components, materials)

Value Proposition
- PSS
- Circular Product
- Virtual service
- Incentives for customers in Take-Back System

Customer Relations
- Produce on order
- Customer vote (design)
- Social-marketing strategies and relationships with community partners in Recycling 2.0

Channels
- Virtualization

Take-Back System
- Take-back management
- Channels
- Customer relations

Customer Segments
- Customer types

Cost Structure
- Evaluation criteria
- Value of incentives for customers
- Guidelines to account the costs of material flow

Revenue Streams
- Input-based
- Availability-based
- Usage-based
- Performance-based
- Value of retrieved resources

Adoption Factors
- Organizational capabilities
- PEST factors

Figure 2.11 Circular BMC (Lewandowski, 2016).

The Business Model Canvas (BMC) BMC by Ostenwalder and Pigneur (2010) is one of the most well-known BMs. The BMC is easy-to-use, allows the analyst to be intuitive and it covers all the crucial components of a successful BM (Adrodegari, 2016; Song *et al.*, 2014; Wallin *et al.*, 2013). Because of these benefits, it has frequently been used as a base for other frameworks (Adrodegari *et al.*, 2017; Azevedo and Ribeiro 2013; Barquet *et al*. 2013; Gelbmann and Hammerl 2015; Van Ostaeyen *et al*. 2013; Witell and Löfgren 2013). From here on it will be referred to as the original BMC. The circular business model canvas as shown in figure 2.11 is an adaptation of the original BMC. Lewandowski added two elements: the 'Take-back system' and 'Adoption factors'. Containing materials is the core idea of the CE which requires a take-back system. Furthermore, the adoption factors take positive or negative external factors affecting the adaptation of a BM into account (Lewandowski, 2016). Internal factors can be explained by organisational capabilities to transition towards the CE BM. External factors concern Political, Economic, Sociocultural and Technological (PEST) issues.

2.5.2 The PSS business model framework by Adrogedari *et al*. (2017)

Component	Variable	Component	Variable
Value proposition	• Value for the customer • Creation of value • Product ownership • Service offering	Key partners	• Partners network • Supplier relationship

Customers	• Customer interactions • Customers' information sharing • Customer and market insight • Target customers and segments	Channels	• Sales channel configurations • After-sales channel / field service network
Key resources	• ICT monitoring technologies • Installed base information • Human • Financial	Cost	• Risk • Cost structure composition and management
Key activities	• Product development and design • Service design and engineering • Offering configurations • Products and services delivery • Intra-firm collaboration and integration	Revenue	• Revenue stream • Contractual agreements

Figure 2.12 PSS business model framework (Based on Adrogedari *et al.*, 2017)

The PSS business model framework (Adrodegari *et al.*, 2017) shown in figure 2.12 is based on the original BMC. In order to provide a thorough research of a PSS BM Adrodegari *et al.* (2017) adapted the BMC perspective by converting the components 'Customer segments' and 'Customer relations' one component, namely 'Customers'.

2.5.3 The sustainable BMC by Case (2018)

The third framework is also based on the BMC by Ostenwalder and Pigneur (2010). The Sustainable BMC by Case (2018) holds the same nine elements that the original BMC has(figure 2.13). There are two supplementary elements: the 'Eco-social costs' and the 'Eco-social benefits'. These two elements highlight the importance of the ecological and social costs and benefits that the BM can generate.

Component	Variable	Component	Variable
Value proposition	• Value for the customer • Bundles of product and services		

Key partners	• Key partners • Key suppliers	Customer segments	• Target group
Key resources	• Physical • Intellectual • Human • Financial	Customer relationship	• Customer relationships • HIntegration inside the BM
Key activities	• Production • Problem solving • Platform/Network	Channels	• Sales channel integration • Which channels are there
Cost	• Risk • Cost structure composition and management	Revenue	• Revenue stream • Contractual agreements
Eco-social costs	• Ecological costs • Social costs	Eco-social benefits	• Ecological benefits • Social benefits

Figure 2.18 Sustainable BMC (Case, 2018).

2.5.4 The sustainable value proposition framework by Kristensen and Remmen (2019)

Kristensen and Remmen (2019) argue that traditional business models mostly focus on the economic performance (Evans *et al.*, 2017) which leaves the environmental and social value undervalued. A sustainable business also requires the integration of social and environmental objectives (Bocken *et al.*, 2013; Evans *et al.*, 2017). Therefore a sustainable value proposition framework was developed which investigates the economic, environmental, social and type of interaction built upon the three core PSS elements (i.e. product, service and system) (figure 2.14). The FW mainly gives insights into the expansion of the value, when the "*focus shifts from product to service to system*" (Kristensen and Remmen, 2019:1)

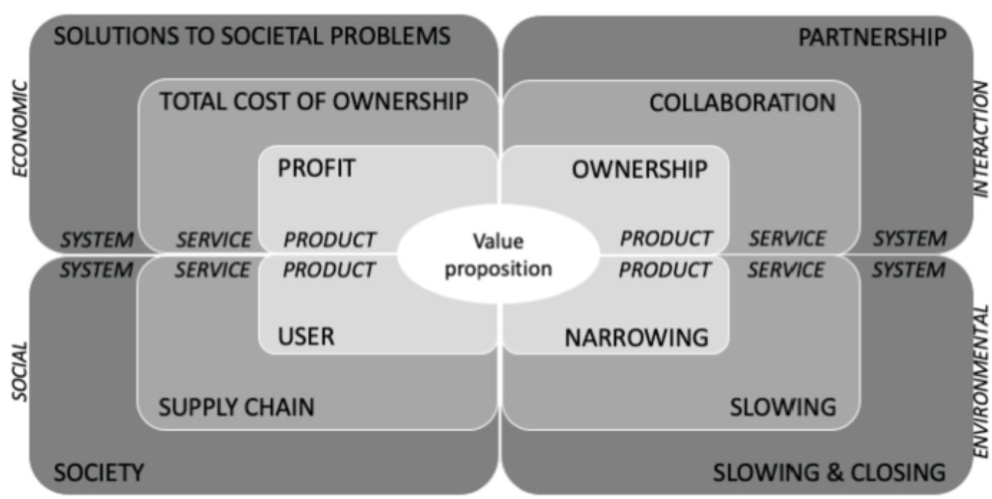


Figure 2.13 Sustainable value proposition framework (Kristensen and Remmen, 2019)

2.5.5 Summarizing the frameworks

All four frameworks are designed for a PSS or have been applied in a case study that analyses a PSS. The sustainable value proposition framework by Kristensen and Remmen (2019) is relatively new and the framework has only been applied to one single case-study. This does not yet show the applicability of the framework for other industries. The PSS business model framework by Adrodegari *et al.* is partially based on the BMC of Ostenwalder and Pigneur (2010) which is renowned for its clarity and simplicity (Adrodegari *et al.*, 2017; Barquet *et al*., 2013). Numerous papers have been reviewed and the 25 variables represent a holistic representation of all the PSS characteristics. The framework is especially useful for companies that want to implement and adopt a PSS into their BM and identify the opportunities that come along with it. Another framework based on the original BMC is the circular BMC by Lewandowski (2016). This framework has distinguished itself by adding two circular elements. The additions seem to be superfluous for the purpose of this study. The fourth framework is the Sustainable BMC by Case (2018). Two elements are added that focus on the ecological and social factors of a BM. The application to a PSS BM is unknown and the FW is not retrieved from the literature. Therefore its scientific contribution to this study is considered to be insufficient.
For the case studies in this research a combination of the Circular BMC by Lewandowski (2016) and the PSS BM framework by Adrodegari *et al*. (2017) is used. Both frameworks are based on the original BMC which makes integration possible. The framework is renowned for its easy-to-use. The framework by Adrodegari *et al*. (2017) is specifically made for PSSs and the Circular BMC (Lewandoski, 2016) highlighting the importance of adoption factors for a PSS BM. Not all elements of the frameworks are used. The integration and interpretation of the final framework is explained in chapter 3.2.2.

2.6 Conclusions

The literature has acknowledged the importance of the Circular Economy and its potential to decouple economic prosperity from resource consumption. The CE can maximise the value of products and materials, decrease the depletion of natural resources and create a positive social and environmental impact (Bocken *et al*., 2018; Kraaijenhagen *et al*., 2016). PSS has often been labeled as the pioneering BM to shift manufacturing and consumption from a linear model to CE in order to enhance the circularity of a business (Goedkoop *et al.*, 1999; de Pádua Pieroni *et al.*, 2018; Pieroni *et al.*, 2018; Spring and Arauja, 2017; Tukker, 2015; Yang *et al,* 2018; Yang and Evans, 2019).

Most scholars divide PSSs into three archetypes, namely: product-oriented, use-oriented and result-oriented PSS (Baines, 2007; Kristensen & Remmen, 2019; Kuo *et al.*, 2019; Tukker, 2004; Tukker, 2015; Yang & Evans, 2019).
In a PSS BM for example, resource use can be reduced as more users' needs can be met with one product (Baines *et al.*, 2007). Companies also become more responsible for the through-life and end-of-life scenario and the system encourages manufacturers to prolong the service life of their product (Bocken *et al.*, 2014; Tukker, 2015).

Not all scholars however are convinced that PSS automatically leads to resource reduction (Kjaer *et al*. 2016; Tukker 2004; Tukker and Tischner 2006b) and it should not be seen as the "*sustainability panacea*" Tukker, 2015: 88). Michelini *et al*. (2017) say that a PSS can reduce the environmental impact only when intentionally designed to do so.
A Life Cycle Assessment (LCA) provides crucial insights needed for designing a PSS, so that recovery and reuse can take place (Michelini *et al.,* 2017). The lack of assessment methods for the evaluation of CE impact is confirmed as hindering the implementation of the CE (Bocken *et al.,* 2016b; Bresanelli *et al.,* 2019*).*

Washing machines present themselves as a perfect candidate for a PSS BM. The machines are rather expensive, technically advanced and maintenance and repair is required throughout the life cycle. They are infrequently used by consumer(s), fashion insensitive and rather easy to transport. Furthermore, an ownership rate for WMs of 98% in the Netherlands creates business opportunities for a PSS.

2.6.1 Knowledge gap

From the literature review it becomes clear that there is not one unanimous view on which activities in a WM life cycle have an effect on the environment. Particularly the user phase shows many variables. Some scholars state that washing behaviour and prerequisites (Amasawa *et al*., 2018; Bocken *et al*., 2018) have an impact on resource consumption. Others mention that the frequency of washing, the washing temperature or detergent volume have a decisive influence on the environmental impact of doing laundry (A.I.S.E., 2015; Amasawa *et al*., 2018; Laitala *et al.*, 2018). Material supply during production is also said to significantly impact the environment (Amasawa *et al*., 2018; Rüdenaur *et al*., 2005). These different outcomes are probably due to the different scope of the studies.
Furthermore, the LCAs found are based on a linear life cycle and no LCA's were found on the life cycle of a WM in a product lease PSS BM. It is expected that differences will occur in the environmental impact between a traditional and PSS BM, due to extra transport and the services that are offered. The environmental impact and life cycle hotspots of a WM in a product lease PSS BM is yet unknown.

From the literature review it became clear that a lack of assessment methods for evaluating the CE impacts is hindering the implementation of CE (Bocken *et al.*, 2016b; Bresanelli *et al.,* 2019*)*. Life Cycle Assessment (LCA) is a way to analyse the environmental impact of a product or service over its full life cycle (Guinée, 2002). Therefore this thesis aims to evaluate the main environmental impact holders in the life cycle of a washing machine with a product lease PSS BM through a screening LCA. The outcome of this study is of interest to Coolblue in order to improve the environmental impact of their PSS BM.

03.

METHODOLOGY

In this chapter, all the methods that are used to answer the sub questions of this research are described. The outline is as follows (figure 3.1): Paragraph 3.1: *Literature study selection criteria,* will answer subquestion 1. Paragraph 3.2: *Coolblue business models,* will answer sub question 2. It introduces the framework of the study, explains the case study design and how the data is collected for both Coolblue cases. Paragraph 3.3: *Alternative PSS cases,* will answer sub question 3. It holds information on how the alternative PSS cases were selected, how the framework was adapted and how data was collected to fill in the framework. And lastly, the fourth sub question is answered in paragraph 3.4: *PSS design approach,* which introduces the morphological chart to design new alternatives for Coolblue to improve their impact.

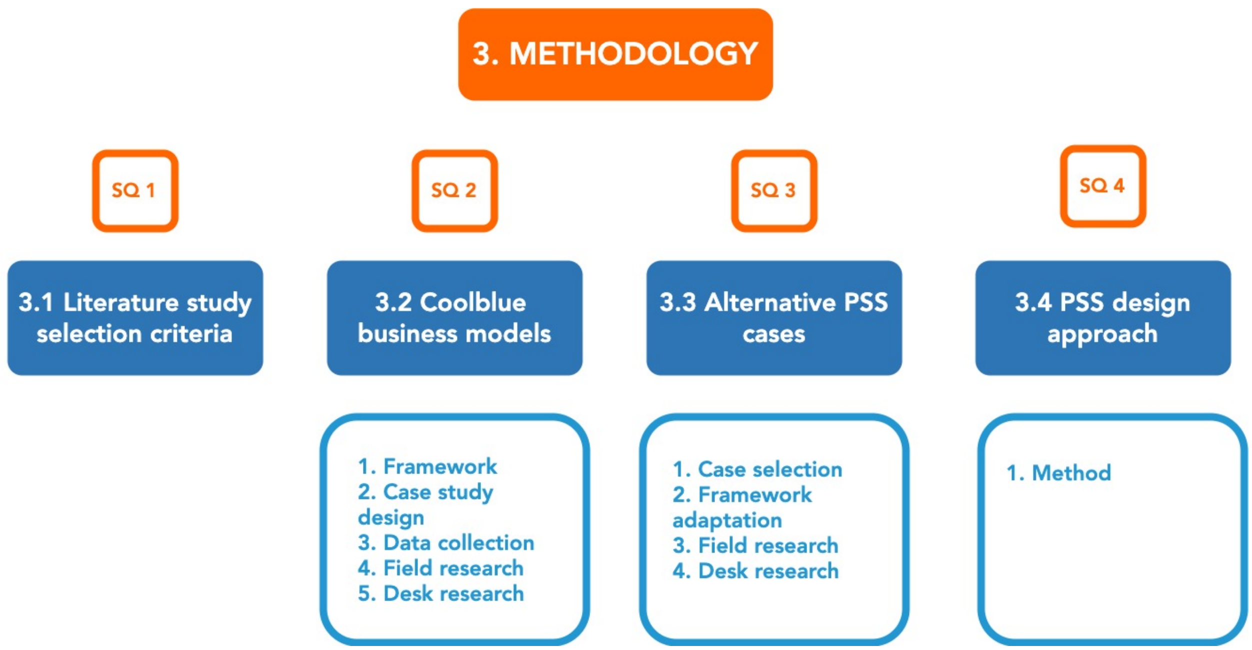


Figure 3.1 Methodology outline (Source: Author).

3.1 Literature study selection criteria

A literature study was performed in order for the writer and the reader of this study to be up to date with all the literature concerning this topic. In this paragraph all choices made for the literature study are explained. The literature study is made up of five different subjects namely the Circular Economy, (circular and sustainable) business models, product-service systems, the combination of PSSs and the washing machine industry and suitable frameworks to analyse a PSS. Several databases were consulted namely: Scopus, ScienceDirect, TU Delft online library, Wiley online library and the TU Delft repository. Strings (i.e. keyword combinations) were used to search the articles' title, abstract or keywords. As the literature study was an iterative process there is not an exact number of papers that were found by the keyword search, however an estimate will be given. Although these keywords resulted in a lot of suitable literature, the search sometimes ended up in a dead-end or no relevant data was found from the papers. New articles were examined or the tactic of snowballing was adopted. Table 3.1 shows the strings that were used, which limitations were used to narrow down the search and eventually which number of suitable articles were found.

Circular Economy

As the Ellen MacArthur Foundation (EMF) is one of the most well-known names in the Circular Economy, the literature study started here. Multiple reports were released on the CE, concerning a transition from a linear economy, the benefits it could generate and just as important, the limits of this transition. Besides the papers by EMF, the databases were consulted with the following strings: "*Circular Economy", "Circular Economy* AND *Transition", "Linear Economy* AND *Transition"* and *"Circular Economy* AND *definition".* The search was narrowed down by looking at the articles that were most cited, were published in English and were in the timeframe 2010-2020. Together with the papers by EMF and snowballing this led to approximately 20 suitable articles.

Sustainable and Circular Business Models

Similar papers from the previous subject were used when gathering information on this subject. Furthermore, the strings "*Circular Business Model", "Sustainable Business Model"* were typed into the databases. The search was narrowed down by looking at the articles that were most cited, were published in English and were in the timeframe 2015-2020. Together with some of the papers found for the previous subject and snowballing around 10 new articles were identified.

Product-service systems

From the database search with the key words "*Circular Economy; Circular Economy Transition; Linear Economy* AND *Transition* and *Circular Economy definition"* some suitable papers were already retrieved on PSS. Furthermore, the keywords *"Product-service system"; "Product-service system* AND *Review"; "Product-service system* AND *Circular Economy"; "Product-service system* AND *Circular Economy transition"; "Product-service system* AND *Sustainability Potentials* OR *Benefits"; "Product-service system* AND *Challenges* OR *Barriers"*.

The search was narrowed down by looking at the articles that were most cited or most up to date, were published in English and were in the timeframe 2000-2020. For this subject also the repository of TU Delft was consulted to make sure the literature was as thorough as possible. The same strings were filled and narrowed down to the most up to date papers. After narrowing down the search and snowballing approximately 35 papers were found useful.

PSS adopted in laundering

In order to find literature on the fourth subject 'PSS adopted in laundering', the following strings were filled into the databases: "*Product-service system* AND *Laundry* OR *Laundering* OR *Wash"; "Product-service system* AND *Washing machine"; "Product-service system* OR *service* OR *Sustainable consumption* AND *Washing machine"; "Pay-per-use* AND *Washing"; "Product-service system* AND *detergent"; "Laundry* OR *Laundering* OR *Wash* OR *Washing Machine".* The search was narrowed down by looking at the articles that were most cited or most up to date, were published in English and were in the timeframe 2000-2020. For this subject also the repository of TU Delft was consulted to make sure the literature was as thorough as possible. The string "*Washing Machine*" was filled in and limited to the most up to date papers. The tactic of snowballing was applied a lot on this subject. Also the previous subjects offered a lot of useful insights already on this topic. After narrowing down the search and snowballing approximately 30 papers were found useful.

PSS BM frameworks
The strings "*Product-service system* AND *Sustainable Business Model*"; "*Product-service system* AND *Framework*"; "*Sustainable Business Model*"; *Circular Business Model*". The search was bounded by limiting the papers to those who are most cited, were published in English and were in the timeframe 2000-2020. After narrowing down the search and snowballing approximately 20 papers were found useful.

Table 3.1 Literature study selection criteria (Source: Author)

Topic	Strings	Narrowing down	# selected articles
Circular Economy	"*Circular Economy*", "*Circular Economy* AND *Transition*", "*Linear Economy* AND *Transition*" and "*Circular Economy* AND *definition*"	Most cited English Timeframe: 2010-2020 Snowballing	+- 20
Sustainable and Circular Business Models	"*Circular Business Model*", "*Sustainable Business Model*"	Most cited English Timeframe: 2015-2020 Snowballing	+- 10
Product-service systems	"*Product-service system*"; "*Product-service system* AND *Review*"; "*Product-service system* AND *Circular Economy*"; "*Product-service system* AND *Circular Economy transition*"; "*Product-service system* AND *Sustainability Potentials* OR *Benefits*"; "*Product-service system* AND *Challenges* OR *Barriers*"	Most cited Most up to date English Timeframe: 2000-2020 Snowballing	+- 35
PSS adopted in laundering	"*Product-service system* AND *Laundry* OR *Laundering* OR *Wash*"; "*Product-service system* AND *Washing machine*"; "*Product-service system* OR *service* OR *Sustainable consumption* AND *Washing machine*"; "*Pay-per-use* AND *Washing*"; "*Product-service system* AND *detergent*"; "*Laundry* OR *Laundering* OR *Wash* OR *Washing Machine*"; *Washing machine*"	Most cited Most up to date English Timeframe: 2000-2020 Snowballing	+- 30

PSS BM frameworks	*"Product-service system* AND *Sustainable Business Model"; "Product-service system* AND *Framework"; "Sustainable Business Model"; Circular Business Model"*	Most cited English Timeframe: 2000-2020 Snowballing	+- 20

3.2 Coolblue Business Models

The WM BMs that are currently used by Coolblue are the traditional selling BM and PaaS (i.e. product lease). Both cases by Coolblue are analysed in-depth. For the analysis of the two cases a combination of the Circular BMC by Lewandowski (2016) and the PSS BM framework by Adrodegari *et al*. (2017) was chosen as the most suitable framework for this thesis. Because both frameworks are primarily based on the original BMC by Ostenwalder and Pigneur (2010) integration is possible. The PSS BM framework by Adrodegari *et al*. (2017) is specifically made for PSSs and the Circular BMC highlights the importance of analysing the adoption factors of a PSS BM. Furthermore, the writer of this thesis is familiar with the original BMC which is widely known for its ease of use. The adapted framework is called the *Sustainable Product-service System Business Model Framework (SPSS framework)* and is shown in figure 3.2. The explanation behind the integration can be found in chapter 3.2.2.
Beside the two in-depth cases of Coolblue, alternative cases in the PSS washing machine industry were also analysed with the SPSS framework. These cases however are less thoroughly analysed as they serve more as an inspiration for environmental improvements.
The SPSS framework is therefore slightly adjusted. Which alternative cases have been chosen, what framework adaptations were made and how the data is collected will be further explained in chapter 3.3.

3.2.2 Sustainable PSS BM framework interpretation

The Circular BMC and PSS BM framework are made up of eleven and eight elements respectively. Not all elements are relevant for the use of this thesis.
From both frameworks the *Value proposition, Customers, Key activities and Key resources* elements were chosen as they give an overview of what the PSS offers, what is needed to make it exist and what the interaction with the customer is. The elements *Key partners, Channels, Cost and Revenue* were left out because the financial part of the PSS is already shortly touched upon in the *Key resources* element and it is not the main focus in this study. The relevant areas of the elements *Channels* and *Key partners* are also elaborated in the *Customers* and *Key activities* element. The element *Adoption factors* was seen relevant for this thesis and subdivided into drivers and barriers for the BM. The sixth element is the *Life Cycle impact assessment* in which the environmental impact of the BMs will be estimated*.* The six elements and corresponding sub categories can be found in figure 3.2. The text below elaborates on how the elements and its subcategories should be interpreted for the two Coolblue cases.

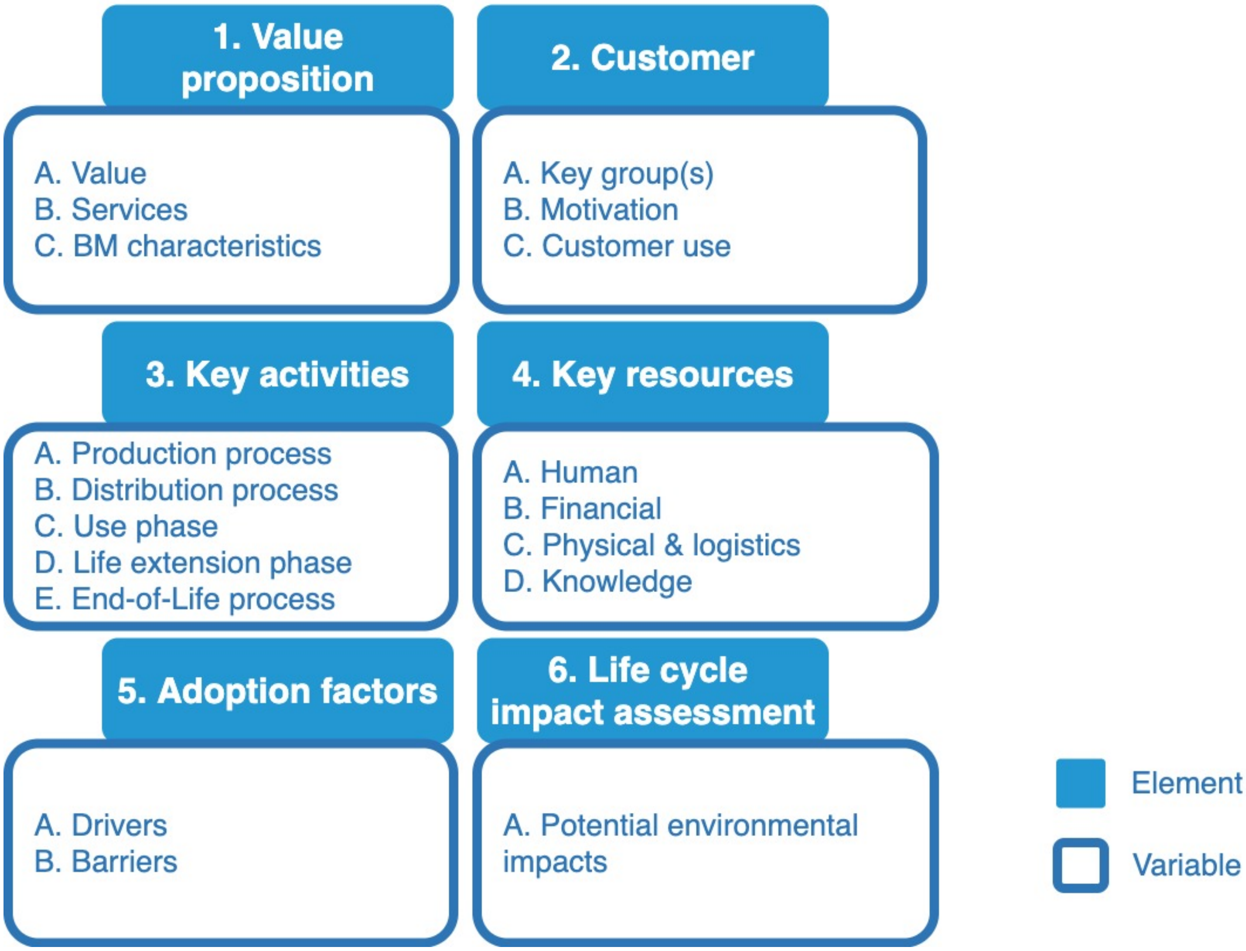


Figure 3.2 Sustainable PSS BM framework (Source: Author).

1. Value proposition

Ostenwalder and Pigneur (2010) have mentioned that a value proposition is what sets a company apart from its competitors. The element *Value proposition* contains three subcategories. First, determining the exact value that is delivered to the customer. Defining this value is the starting point for every PSS (Adrodegari *et al.*, 2017). Second, which bundle of services are being offered by the company. And lastly, which characteristics make up the BM offered by the company. For example, which measures are implemented by the company to assure the product stays in good condition.

2. Customers

The element *Customers*, consists of three subcategories. First, the key group(s) of the BM are analysed. Information such as age groups and household composition. In the second subcategory the motivation of the customer to choose a certain (PSS) BM is outlined. Research has shown that customer behaviour is also important in a PSS. Therefore the last subcategory will look at how the customers use the product (e.g. repair rate) and what information the company has on the washing behaviour. This last subcategory is not applicable to the traditional BM of Coolblue.

3. Key activities

The component *Key activities* will give an illustrative overview of all the steps that are needed to accomplish the PSS. The element consists of five subcategories. Chapter 2.5.1 elaborated on the four different activity boxes in the life cycle of a wasmachine (see figure 2.9): the Production process, Distribution process, Utilisation process and the End-of-Life process. The production process entails the activities that are taken place to manufacture the WM up to the distribution process. During this latter process the WM is distributed to the customer. From now on the utilisation process is divided into two parts: the user phase and the life extension phase. The user phase provides information when the WM is at the user and the life extension phase refers to the activities that are taken to extend the life cycle after it has been used by one user. All life extension activities are explained in the hierarchical cycles in Appendix B. It is assumed that in the utilisation process the most differences in the BMs occur. The End-of-Life phase

4. Key resources

The element *Key resources* embodies all resources that are needed to carry out the PSS, from beginning to the EoL. These resources are divided into four subcategories, namely human, financial, physical & logistics and knowledge. Human resources are made up of key partners that are needed to set up the BM. The subcategory financial resources elaborates on the financial aspects of the BM. The third category mentions all the physical and logistic resources that are needed to realise value proposition. The final subcategory defines the intellectual knowledge that helps to carry out the BM (e.g. brand patents, copyrights, data).

5. Adoption factors

The element *Adoption factors* is divided into two categories: drivers and barriers. It is interesting to see which barriers and drivers the companies experience. In the literature review sustainability potentials of PSSs have been thoroughly outlined. Therefore they are not examined any further in the interviews. It is more interesting to see if the barriers found in the literature correspond with what the companies experience and which drivers are mentioned.

6. Life Cycle Impact Assessment

This study aims to give an estimate of the environmental impact of two issues. The first estimate is a comparative LCA study between the WM product lease BM and the traditional BM (SQ 2). By screening the results of Life Cycle Assessments in other studies on corresponding activities in the WM life cycle an estimation on the environmental impact of the Coolblue product lease and traditional BM will be given. The second issue focuses on a hotspot analysis of the product lease BM and the different activities in a WM life cycle. A phase that contributes to more than 10% of the total impact is considered a hotspot (Yuan *et al.*, 2015). After capturing the hotspots it will become clear which activities have a significant impact on the environment. This will be an input for the design concepts (SQ 4). It should be noted that, given the explorative character of the assessment this study cannot be used for a comparative assertion disclosed to the public. The method of the comparative LCA and hotspot analysis are further explained in chapter 3.2.5.

3.2.2 Case study design

In order to answer the main research question a case study design approach was used. A case study method is used when you want to achieve a deep and better understanding of certain phenomena that are new or have not been examined or understood yet (Yin, 2003). A case study can be defined as "*an empirical enquiry that investigates a contemporary phenomenon within its real-life context, where the boundaries between the phenomenon and context are not clearly defined, and in which multiple sources of data collection are used*" (Yin, 2009: 18). There are several reasons when a case study design should be considered. One of the reasons being when the focus of the study is to answer "how" and "why" questions (Baxter and Jack, 2008). This is applicable to this thesis as the focus of the case study is to answer the research question: *How can Coolblue improve the environmental impact of their current and future washing machine leasing subscription*.
An in-depth case study will be made of the two business models of Coolblue (i.e. PaaS and traditional selling BM). After analysing both Coolblue cases a cross-case results summary is given. This summary contains the comparison of the two BMs, the comparative LCA study and the hotspot analysis of the PaaS case. The cross-case analysis method is chosen because it helps to compare the differences and similarities between events, activities and processes of two or more case studies (Cruzes *et al*., 2014).
A less thorough case study is made of the alternative PSS cases in the washing machine industry because they will only serve as inspiration for environmental improvements. The key differences between the inspirational companies are summarised in a cross-case results summary. This summary will be the input for the design concepts that can decrease the environmental impact of the Coolblue PaaS BM.

3.2.3 Data collection

Figure 3.3 illustrates that the first five elements of the SPSS framework will be answered with the help of field research which consist of company interviews and field visits.
After reporting on the first five elements of the BMs it becomes clear which activities need to be taken into account for the last element: the *Life Cycle Impact Assessment.* Quantifying the impacts will be done by performing a desk research. This desk research entails consulting (grey) literature, software databases, thesis reports, company websites and company information retrieved throughout the internship. This is illustrated in figure 3.3.

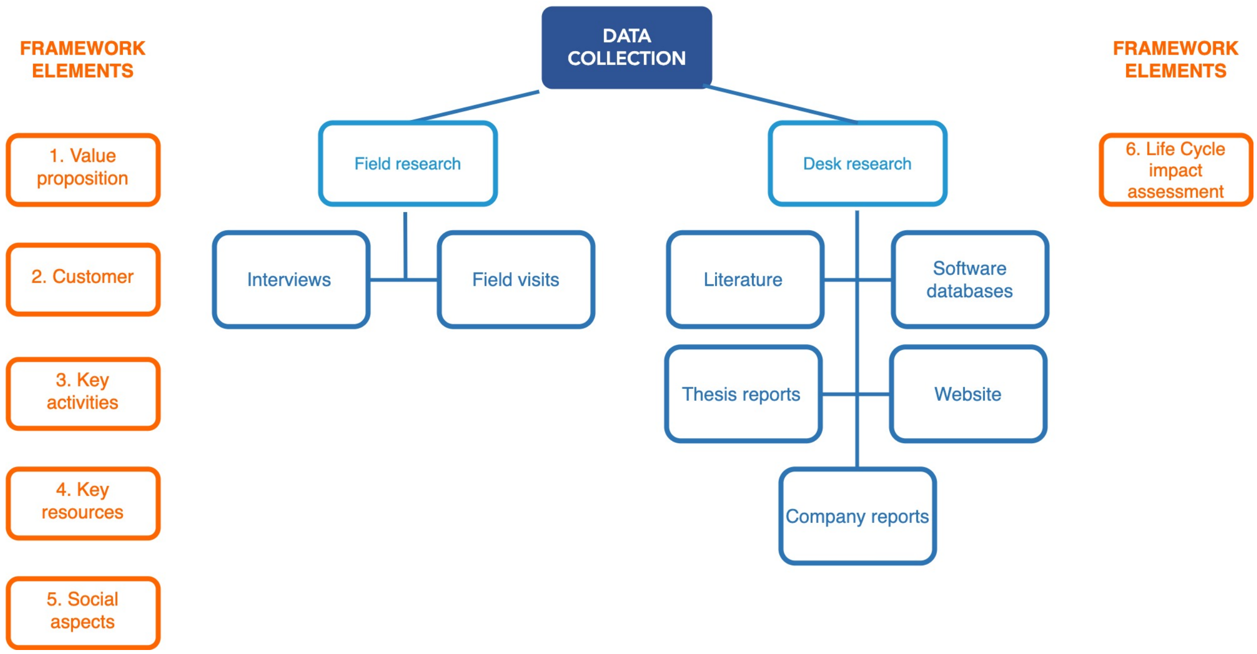


Figure 3.3 Data collection (Source: Author)

3.2.4 Field research

A field research is conducted in order to give an overview of the first five elements of the framework. This field research consists of semi-structured interviews and field visits. Table 3.2 and 3.3 respectively show all interviews and field visits that are performed with Coolblue.

Semi-structured interviews

Libakova and Sertakova (2015) mention six steps that should be followed to successfully conduct an interview: 1. Choice of research topic; 2. Preparation and planning; 3. Interview; 4. Transcription of records; 5. Analysis and interpretation of data and
6. Preparation of the report. All six steps are elaborated upon in Appendix G. The goal of the interviews is to fill in the Sustainable PSS BM Framework as much as possible. Both qualitative as well as quantitative information can be retrieved from the interviews. Because it is possible to perform interviews and field visits more in depth information can be retrieved from Coolblue.
For the traditional Coolblue BM an interview with Jill Verhaag (Productmanager Washing Machine) will be performed. And for the PaaS BM Sietse van der Meer (Manager of the PaaS department) will be interviewed. The interview questions have been slightly altered for each department and can be found in Appendix H. Before commencing the interviews a consent form with the interview questions are sent by email. This consent form (see Appendix I) holds information on research ethics such as permission to record the interview, anonymity of the interviewee and allowing the interviewee to review the text before it is published. Both interviewees agreed to the research ethics.
Because the interviews are semi-structured, the interviewer can change the order of the questions when it seems more suitable and to keep the conversation flowing. The open format allows the interviewee to answer questions in their own way (Walliman, 2006).

Afterwards, an intelligent transcription method will be applied, which means that irrelevant phrases, such as "uhm" and "ah" are excluded from the text. After transcribing the data is broken down into concepts. These concepts are labeled with the six framework elements and the subcategories. These concepts will then help to fill in the Sustainable PSS BM framework. Because of confidentiality the transcribed and coded interviews for Coolblue can be found in an External Appendix.

Table 3.2 Coolblue semi-structured interviews (Source: Author)

Department	Name	Function title	Appendix
Traditional BM	Jill Verhaag	Productmanager Washing Machines	H.1
PaaS	Sietse van der Meer	Manager Product-as-a-Service	H.2

Field visits

For the field visits a participating observation method is used. This method is chosen because it allows the researcher of this thesis to be more informal in the workplace, which is more suitable to Coolblue. This means that some topics are established beforehand that will be discussed during the interview, but how and in what order is free for interpretation. As it is not that clear in advance as to what can be expected, this method gives the researcher the chance to be inspired by the surroundings and ask questions accordingly.

Three field visits will be made. First a field visit to the warehouse, also known as 'De Schuur', will be made. The warehouse is where all Coolblue goods are stored and shipped or returned to. Due to the size and weight WMs are first transported to a depot,before delivering it to the customer. Due to the location preference of the researcher a choice is made to visit the Rotterdam depot. The third field visit is the Utrecht depot, because this depot is also active in refurbishing white goods. The visits are not coded, but will be used as a reference throughout the report and help with making assumptions. The reports of the visits can be found in an External Appendix.

Table 3.3 Coolblue field visits (Source: Author)

Location	Guided by	Function title
De Schuur	Ferdy Klerks	Teamlead Warehouse Day Shift
Depot Rotterdam	Stefan van der Tang	Team Lead CoolblueDelivers
Depot Utrecht	Marnix Boon and Arthur Dieteren	Owner Disposed Appliances and Operational Manager Disposed Appliances

3.2.5 Desk research

In order to investigate the environmental impact (i.e. the sixth element of the framework) a desk research approach was chosen. Results provided by Life Cycle Assessments (LCAs) will be used. Due to the broad scope of this study it is appropriate not to perform an LCA. Instead, a screening LCA study is performed. Here results from other LCA studies are interpreted with assumptions as the environmental impact for the two Coolblue cases. For this study LCAs that will be used must be about an activity within the life cycle of a consumer good, preferably a washing machine. When specific data is not found, corresponding estimates will be made within the scope of this study. The databases Scopus, ScienceDirect, TU Delft online library, Wiley online library and Ecoinvent will be used to search for suitable literature and the following keywords and strings are used: "*Life Cycle Assessment* OR *LCA* OR *Environmental impact* AND *Washing machine* OR *Wash* OR *Washing* OR *Laundry* OR *Laundering* OR *Detergent(s)* OR *Distribution* OR *Delivery* OR *Logistic(s)* OR *Consumer good".*

Two types of analysis are performed. First, the environmental impact of different phases in the life cycle of a washing machine will be identified and then compared between the two Coolblue cases. Then a hotspot analysis on only the PaaS BM is performed. A phase is considered a hotspot if it contributes to more than 10% of the total impacts measured (Yuan *et al.*, 2016). The data that is needed for the assessment is mainly collected from (grey) literature or information provided by the companies themselves. Public institutions, organizations or databases included within the software can also hold relevant assessments, however retrieving information from these is more difficult. Additional data is collected throughout the internship, from Coolblue yearbook reports or the Coolblue website.

Good practice in LCA

In order for the LCAs retrieved in literature to be of good practice, they should meet the ISO 14040 or 14044 standard. According to these standards, the LCA framework is made up of the four following phases, illustrated in figure 3.4; *goal and scope definition, inventory analysis, impact assessment and interpretation*. The arrows allow for an iterative process to occur, which is often necessary (Klöpffer, 2014). The exact LCA structure has been examined and can be found in Appendix J. From this examination it has become clear that the elements illustrated in figure 3.4 need to be mentioned in the study in order for the results to be of good practice:

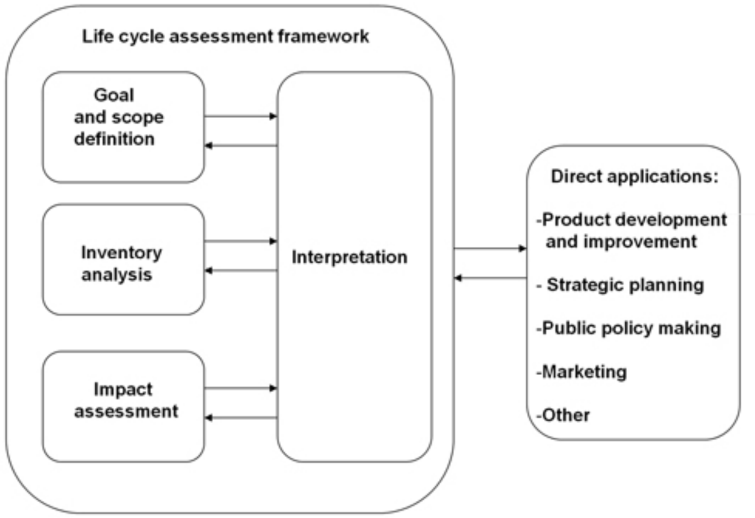


Figure 3.4 General LCA framework (Based on ISO 14040, 1997)

Perhaps the most important element that makes the LCA fit the ISO standard is the Functional Unit (fU). The function is the operation of the system and the fU is a measure of the goods or service that make up the product, whose environmental impacts are assessed and compared (e.g. 1kg of clean clothes) (Guinée, 2002). In order to compare the results from studies with each other the fU should be comparable. Furthermore, technical details of the washing machines (e.g. brand or type) and information on the userphase (e.g. washing temperature, water usage, washing frequency, etc.) must be reported in the Life Cycle Inventory (LCI) list. The LCI shows in what matter the inputs are weighed into the calculation that result in the different impact categories which are highly essential to make a thorough and legitimate comparison.

Method using LCA studies

The difference from a linear selling model in comparison to a PSS, is assumed to lie mainly in the user phase. This is also where PSS BM can differ between each other. This is expressed in different services that are offered to the customer. Figure 3.5 gives a visual representation of the system boundaries of a product life cycle. When the PSS BM adds to the life cycle of the washing machine by offering different services in the user phase it changes the BM. The dark blue component on the right in the figure is based on the hierarchical circles of the technical cycle in the Butterfly diagram by the Ellen MacArthur Foundation, described in Appendix B. For each of the process steps the researcher will examine the literature by searching relevant quantitative numbers. The End-of-Life phase will be a recycling credit. All calculations can be found in an External Excel spreadsheet. This Excel sheet holds confidential information and is therefore presented as an external addition to the report.

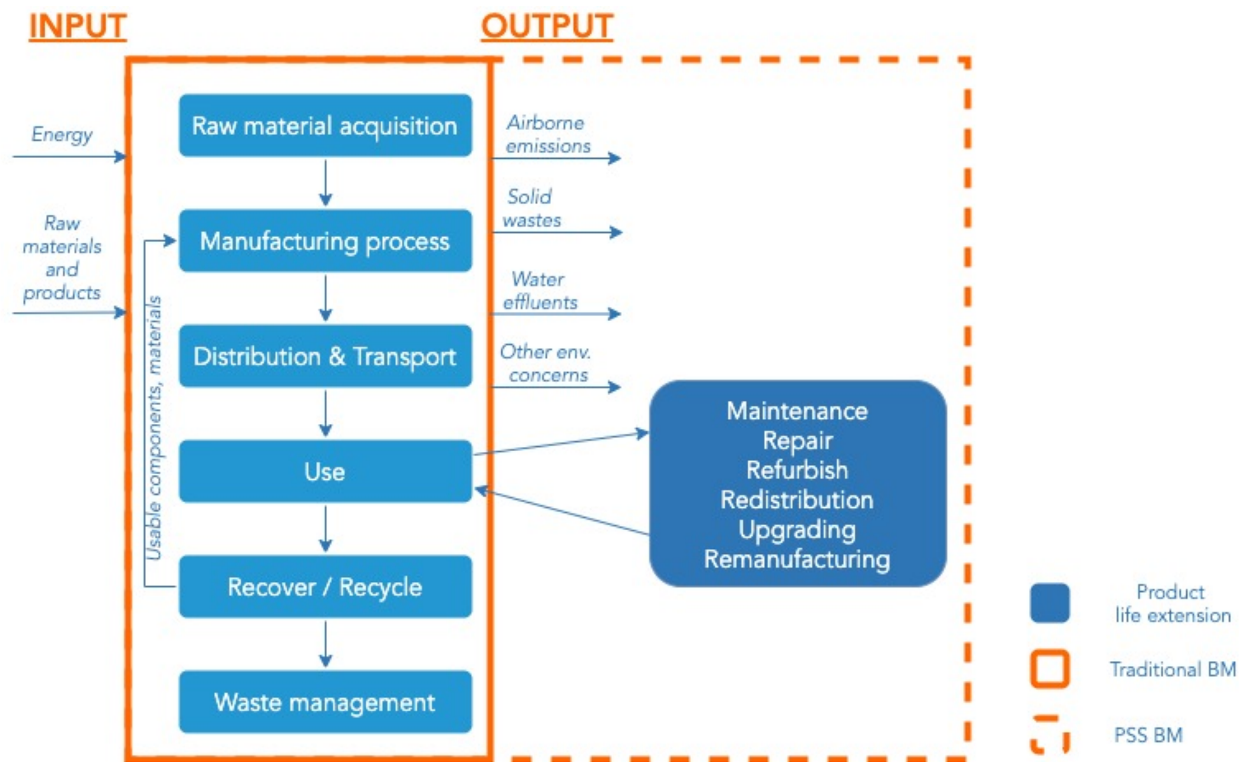


Figure 3.5 Life cycles of a WM in traditional BM and PSS BM (Source: Adapted from Lee *et al.*, 1995)

The environmental impact is measured in carbon dioxide (CO_2) emissions. The impact category Global Warming Potential (GWP) was chosen as it is one of the most well-known emissions metric. Considering the explorative nature of this screening LCA this choice seemed the most suitable. The GWP consists of multiple greenhouse gasses (GHG) . Only CO_2 emissions were analysed. CO_2 emissions is the primary GHG emitted through human activity. Therefore in this analysis it was assumed to be the most relevant GHG emission [kg CO_2].

3.3 Alternative PSS cases in the washing machine industry

3.3.1 Case selection

Alternative PSSs in the washing machine industry will also be analysed besides the two Coolblue BMs. Chapter 2.4.2 already elaborated upon the possibilities of PSS cases in the washing machine industry for the eight archetypes of PSS (explained in chapter 2.3.3). *Product pooling* was already seen as not feasible. It would mean that multiple people put their clothes into one machine at the same time, whilst it is rented or leased.
Product related and *advice and consultancy* archetypes (i.e. product-oriented category) do not really distinguish themselves that much from a *product lease* archetype in the washing machine industry. Therefore, a PSS case in the washing machine industry for these two archetypes was seen as similar to *product leasing*. *Product renting/sharing* in the washing machine industry is a form of a laundromat, which makes use of industrial size washing machines. Results from these types of

machines will be different from domestic washing machines. Therefore this archetype is also left out of scope. Lastly, dry cleaners are an example for the *activity management* and *functional result* archetypes (i.e. result-oriented category). The type of WMs in these two archetypes are very different to *product leasing*. Making a comparison between these two archetypes and product lease archetype would take a lot of assumptions. Therefore these two archetypes are considered to be not suitable for this study. This means that WM cases will be chosen from the archetypes *product lease* and *pay-per-service-unit,* as shown in figure 3.6.

For the two remaining archetypes, product lease and pay-per-service-unit, current company cases were searched. The words '*wasmachine abonnemen*t, *wasmachine huren, wasmachine leasen, wasmachine & pay-per-wash/service/performance*' were Googled. This has led to a list of possible cases and characteristics (see Appendix K). It was deliberately chosen to google the words in Dutch in order to exclude the foreign businesses.

To make a selection from this list six criteria were set up (table 3.4). The first five criteria were based on a paper by Cha (2017) and the latter criteria was chosen by the researcher self. The case must be operating in the Netherlands and as expected it should be active in the washing machine industry and operate one of the two PSS archetype business models. Moreover, the case should be Business to Customer (B2C) and not operate industrial size washing machines. The case has to be past a start-up phase and the final criteria is based on the sustainable actions of the company. Are they actively trying to reduce their impact?

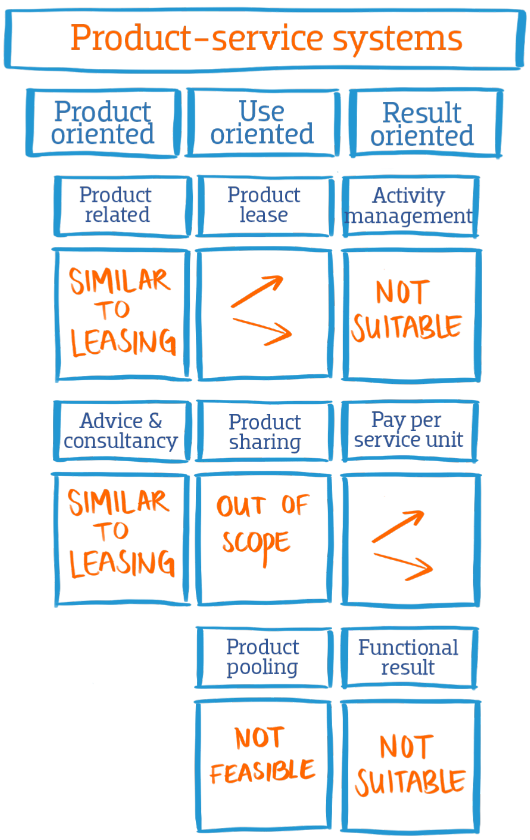


Figure 3.6 Case selection within the 8 types by Tukker (Source: Author).

After taking these criteria in account a total of 17 cases were found (see appendix K). All cases are based in the Netherlands, active in the washing machine industry and operate a PSS BM. A total of three alternative cases were chosen. This makes the total number of cases analysed five (together with the traditional Coolblue BM and Coolblue PaaS BM). To narrow down the selection even further the case selection was predominantly made on how active sustainability was pursued in the case.

Table 3.4 Selection criteria for company cases (Source: Author)

#	Criteria	Explanation
1	Location	Cases must be operating in the Netherlands
2	Type of CBM	Cases must be a Product-service system, specified to the pay-per-service-unit and product lease archetype
3	Industry	The cases must be active in the washing machine industry with a PSS BM
4	Customer	Cases must be on domestic washing, so B2C
5	Business Maturity	Cases must be past a start-up phase
6	Sustainabl e	Cases must be actively busy with reducing the environmental impact of their BM

The three chosen cases are BlueMovement, Homie and Bundles (table 3.5). BlueMovement operates a product lease BM and has actively been busy with promoting sustainability. Homie and Bundles also showed to be actively promoting sustainability. Both cases operate a product lease BM with a pay-per-wash financial model. These two cases have also been chosen because it is interesting to see what the effect of the financial model is on the environment. All three companies will from here on out be referred to as the alternative cases or inspirational cases.

Table 3.5 Company case selection (Source: Author)

#	Company	Business model	PSS category and archetype
1.	Coolblue	Traditional BM	n.a.
2.	Coolblue (PaaS)	Product-service system	Use-oriented > Product lease
3.	BlueMovement	Product-service system	Use-oriented > Product lease
4.	Homie	Product-service system	Use-oriented > Product lease
5.	Bundles	Product-service system	Use-oriented > Product lease

3.3.2 Sustainable PSS Business Model Framework interpretation

The Sustainable PSS Business Model Framework is also used for the alternative cases but in a less thorough manner. There is less information on these cases because the researcher will not perform field visits and has no access to company sensitive data.
Therefore an adaption of the SPSS framework is made, illustrated in figure 3.7. The overall difference is that the information gathered is less detailed and no screening LCA is performed. The main sub category adaptation is that the *customer key groups and motivation* are described together. Lastly, the concluding life cycle impact assessment element is filled in by writing down all current and future actions that decrease the environmental impact of the case. These actions will be the inspiration for the new design concepts.

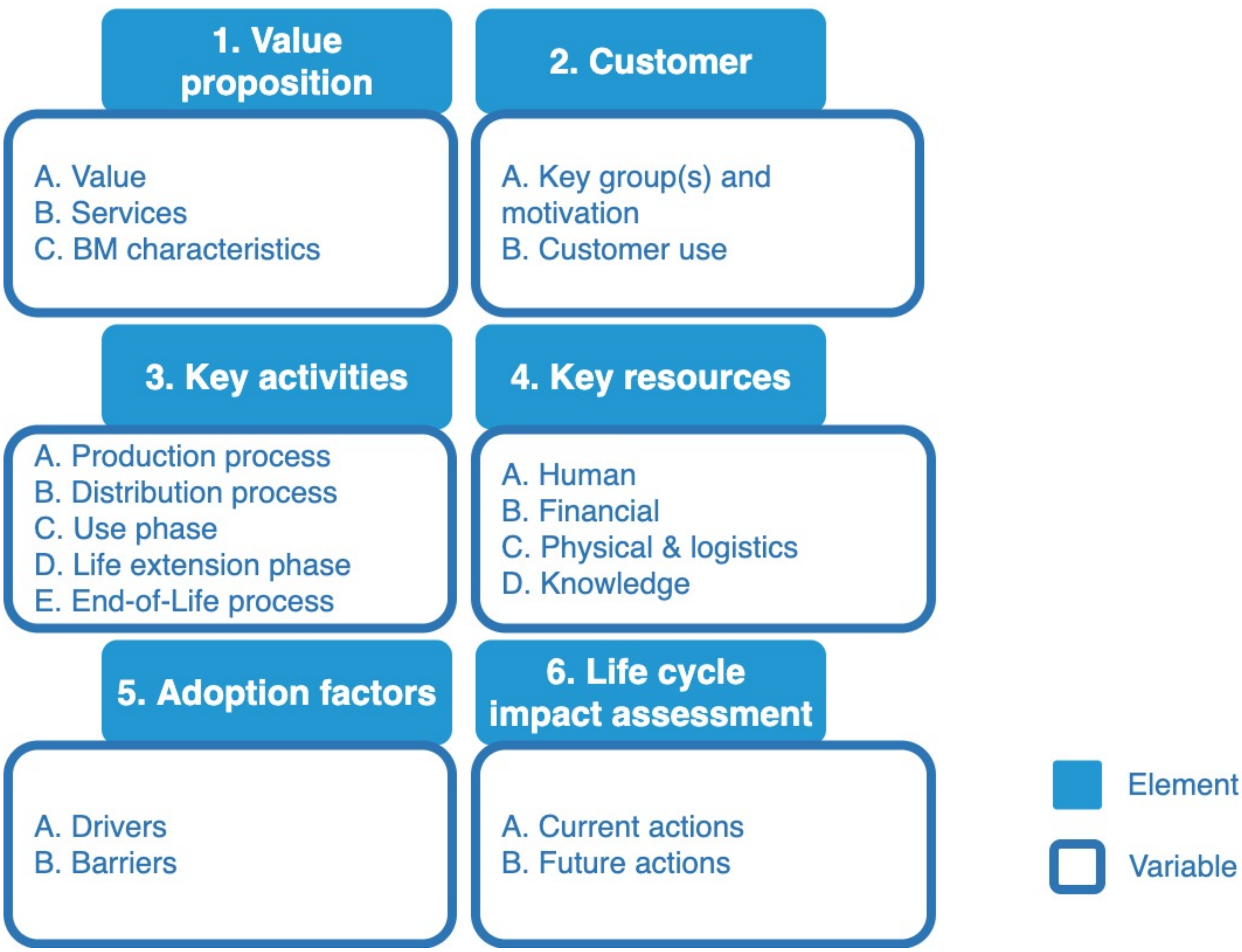


Figure 3.7 Adapted Sustainable PSS BM Framework for inspirational cases (Source: Author).

3.3.3 Field research

For the alternative cases information will also be retrieved through semi-structured interviews and held in open format. The six interview steps in Appendix H are followed. The semi-structured

approach leaves the researcher free to go more into detail for some subjects and keep the conversation flowing. The interviews are assumed to be less detailed, as some insights are company sensitive information. This will result in less profound interview questions. Theys can be found in Appendix L. A consent form is sent along with the research questions to the interviewee in advance. For the selection of the interviewee of the company, the interviewee must talk Dutch or English fluently; have consent from the company to give the interview and have knowledge of the company business model. Table 3.6 shows all interviewees from the inspirational cases.
The same transcription and coding methods used for the Coolblue cases were used for the inspirational cases. The coded transcriptions can be found in an External Appendix.

Table 3.6 Alternative cases semi-structured interviews (Source: Author)

Company	Name	Function title	Interview questions
Homie	Colin Bom	Co-founder & CEO	L
BlueMovement	Dirk Reich	Operations & Finance	L
Bundles	Marcel Peters	Founder & CEO	L

3.3.4 Desk research

Additional data that can be of use will be searched by consulting the company websites or the databases Scopus, ScienceDirect, Google Scholar, Repository TU Delft are consulted. The following keywords are used: "*Homie* AND *Washing* OR *Pay-per-use* OR *pay per use* OR *pay-per-performance* OR *pay per performance, Bundles* AND *Washing* OR *Pay-per-use* OR *pay per use* OR *pay-per-performance* OR *pay per performance; BlueMovement* AND *Washing*".

3.4 PSS design approach

Sub question 4, *What alternative washing machine designs to improve the environmental impact can be made***,** will be answered with the help of a morphological chart method. The method is commonly used when designing a product and establishing its function. Although it is not commonly applied to PSSs, with an adjustment the method can also be applied to this research. The product and services in the PSS BM are considered to be a product and its function is established.

3.4.1 Method

A morphological chart is based on structurally deconstructing the basic function of a product into sub-functions and generating solutions (Boeijen *et al.,* 2014). The method is explained by four steps: describe the (sub-)function(s), construct possible means, combine the means into design concepts and evaluate the concepts.

Describe
The first step is to describe the product, in this case a PSS, in terms of its overall function and sub-functions. Sub-functions describe characteristics that a product should fulfill in order to serve its overall function. A function must contain a verb and an object (Boeijen *et al.,* 2014). For example a beverage container has the following sub-functions: contain beverage, provide access to juice and display product information.

Construct
The second step is to construct possible solutions for each sub-function. These solutions, from now on explained as means, are ways to fill in the sub-functions. The means are based on the outcomes from the literature review and the interviews with the inspirational cases. Both these inputs also helped in brainstorming for other means.

Combine
The third step is to combine possible means into new PSS design concepts that Coolblue could uptake. It should be noted some means restrain the option to choose other means. In total three PSS BM design concepts for the PaaS department of Coolblue will be designed. The three alternatives should be seen as a stepping stone towards circularity, from small steps to more impactful ones. The aim of these concepts is to decrease the environmental impact of the PaaS BM, determined in subquestion 3. Each mean is valued on its effectiveness to decrease this impact.

In order to calculate the effectiveness for multiple sub-functions in one phase an example is given (see table 3.7). If the means A, B and G are chosen, the total effectiveness is calculated as follows: (8% + 12%) x 23% = 5%.

Table 3.7 Example calculation of the total effectiveness (Source: Author)

Sub-functions	Possible means			
Sub-function 1	A	B	C	D
Effectiveness	*8%*	*12%*	*1%*	*20%*
Sub-function 2	E	F	G	H
Effectiveness	*2%*	*15%*	*23%*	*2%*

Evaluate

The fourth and final step is to evaluate the design concept. This is done by assessing the suitability of each mean. Coolblue measures its success in two ways. First its profitability in EBITDA: Earnings Before Interest, Taxes, Depreciation and Amortization. Second they measure success by its customer satisfaction using the Net Promoter Score (NPS). The NPS is measured by how likely a customer is to recommend Coolblue's service to a friend. Customers that score Coolblue between a 1 and 6 are called Detractors. Passive customers give a score of 7 or 8. Promoters would definitely recommend Coolblue to a friend as they give a 9 or 10. The NPS is calculated as follows: % Promoters - % Detractors.

The suitability of each mean is qualitatively described on the basis of these twose requirements and the overall suitability to Coolblue as a company. The suitability is scored based on a 1 to 5 scale, representing respectively 'not suitable', 'limited', 'decent', 'good' and 'excellent'. The tables are coloured based on this score (see table 3.8).

Table 3.8 Suitability steps (Source: Author)

Not suitable	Limited	Decent	Good	Excellent

04.

RESULTS

This chapter consists of four subparagraphs as illustrated in figure 4.1. A total of five PSS cases in the washing machine industry are analysed by the Sustainable PSS Business Model Framework (SPSS framework). The framework consists of six elements, namely: Value Proposition, Customer, Key Activities, Key Resources, Adoption Factors and the Life Cycle Impact Assessment. The two BMs by Coolblue are analysed in depth in paragraph 4.1 *Traditional Coolblue BM* and 4.2 *PaaS subscription Coolblue BM.* Paragraph 4.3 *Cross-case results summary* consists of three subparagraphs. First, the BMs of the two Coolblue cases are summarised. Second, a comparative LCA analysis of both Coolblue BMs is performed. Third, a hotspot analysis is made of a WM life cycle in the PaaS BM. Paragraph 4.4 *Inspirational cross-case summary* holds the key points from the three alternative cases, Blue movement, Homie and Bundles. These cases are used as an inspiration and are therefore less thoroughly examined by an adapted version of the SPSS framework. In the final paragraph 4.5 *Design concepts,* the functions and possible means per life cycle phase are designed into three alternatives and their effectiveness is compared to the current PaaS BM.

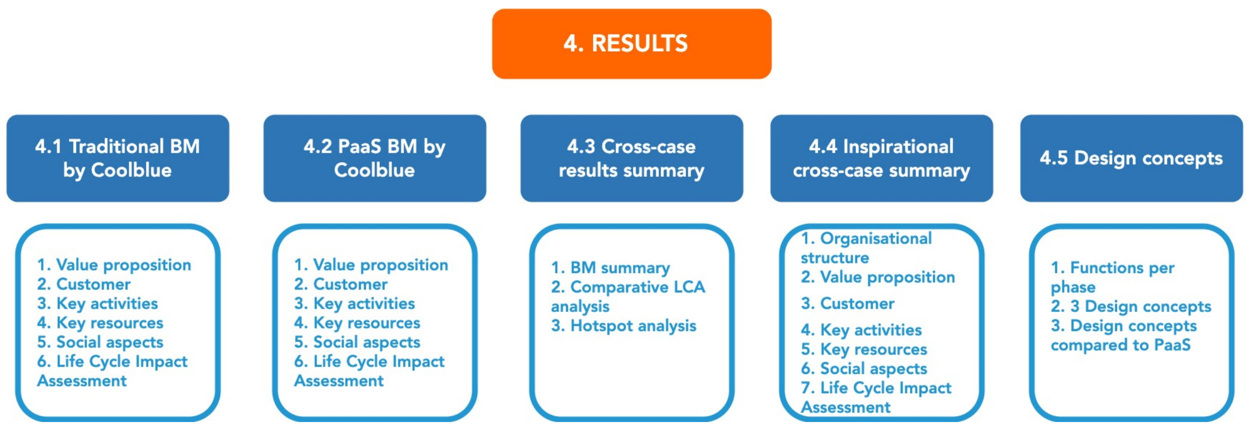


Figure 4.1 Results outline (Source: Author)

4.1 Traditional WM sale by Coolblue

In this subchapter an analysis is made of the traditional selling business model of Coolblue. With a 20% market share in WM sales, Coolblue is one of the biggest retailers on the market (Melkebeke, 2020). The washing machine market is a very saturated market (Verhaag, 2020), as most households require only one washing machine.

Team Whitegoods is responsible for the sales of all the white goods sold by Coolblue. Their job is to make sure that the correct assortment is on the website, the customers' needs are being met and they generate a profit at the same time. Coolblues' success is measured in profit (i.e. EBITDA) and customer satisfaction (i.e. NPS) (see Appendix A). This makes it very important that the customer has a pleasant experience throughout the entire process.
Besides selling electronic appliances, Coolblue is also obliged to take in, recycle and environmentally friendly eliminate e-waste according to the WEEE directive mentioned in chapter 2.4.6 (WEEE, 2015). These returns are called Environmental Returns (ER). Whenever a new WM is dropped off at a customer, the ER is taken in by Coolblue and brought back to the depot and eventually sent to a recycler.

Information on the traditional selling model by Coolblue was retrieved through an interview with Jill Verhaag, Product Manager Washing Machines. Jill has been working at Coolblue for over a year and has also been active as an assortment- and pricing specialist. Together with team Whitegoods, she is responsible for optimising customer journeys whilst at the same time realising a profit for Coolblue. The interview with Jill has been transcribed and coded in the External Appendix. The filled in SPSS framework can be found in figure 4.2.

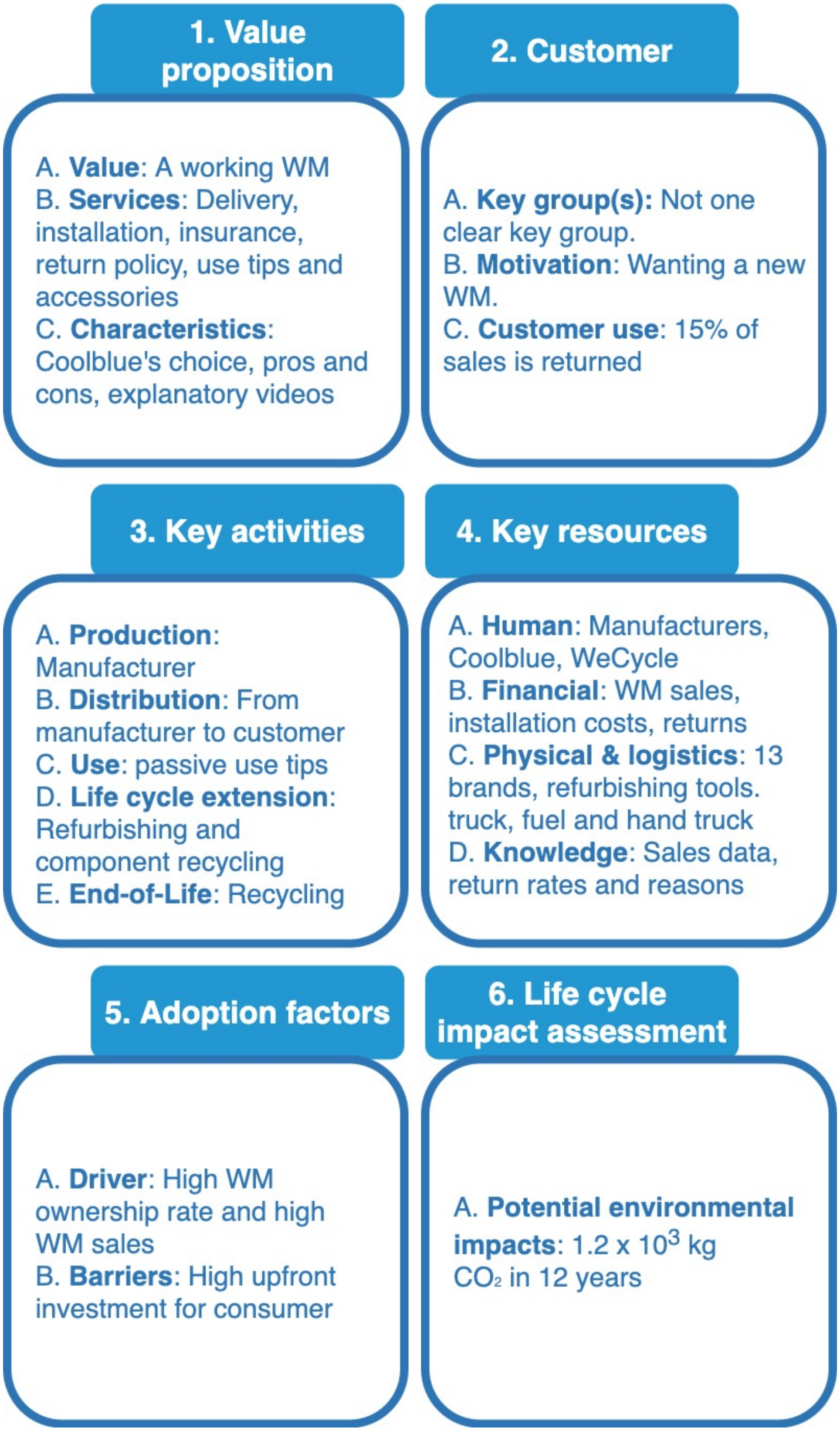


Figure 4.2 Traditional BM SPSS Framework (Source: Author)

4.1.1 Value proposition

A. Value

The exact value that Coolblue offers to its customers is a working WM delivered at home within 24 hours. Coolblue also promises that a customer can return a product within 30 days if he or she is not satisfied with the product. This type of return is called a satisfaction guarantee (SG).

B. Services

There are five types of services offered in the PSS, namely delivery, installation, insurances, use tips and accessories.
Each WM is delivered at the customers doorstep. After delivery, there are four installation options possible. First the customer can choose to have the machine dropped at the doorstep and not installed. For an additional fee of €19,95, the machine is also fully installed at the desired place. For €59,95 the WM is delivered and installed to a pull switch and for a price of €64,95, the customer can choose to get the machine installed together with a stacking kit for the dryer.
Furthermore, Coolblue offers three types of insurance packages. Every product has a quality guarantee (QG) of 2 years at Coolblue. This QG covers any damages or defects that were not executed by the customer self. Coolblue will repair the product or make a direct swap if necessary. This usually falls under the 'factory warranty' of two years. The second type of warranty is the 'Backup Plan of three years'. This entails the two years of QG and one year extra insurance. Damages such as accidents, water damage, or fall and impact damages are covered by the Backup Plan insurance. The third type is the Backup Plan of 5 years, which includes the two year QG and three years extra insurance.
Coolblue also offers tips and videos on the website on how to wash sustainable, how to clean the WM, how to install the WM, etc. Lastly, Coolblue offers accessories on the website for WMs (e.g. stacking kits, detergents, pull switch).

C. BM characteristics

Coolblue offers WMs from 13 different brands ranging from €329 to €1999. Coolblue helps the consumer with the 'Coolblue's choice' label. This label suggests the products with the best price quality ratio and low return rates. Furthermore, the customer is helped in the purchasing process by showing pros and cons points for every WM together with explanatory videos on different features.

4.1.2 Customer

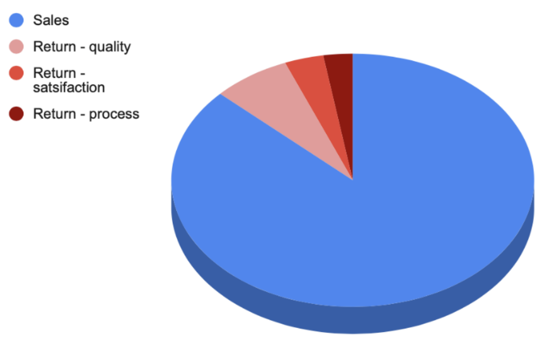
A. Key group(s)

There is not one specific type of customer that buys a washing machine at Coolblue. It is a product that is purchased by every age group (Verhaag, 2020). However, customer characteristics known to Coolblue are, customers with a bigger household and earning more money, spend more money on a WM (Verhaag, 2020). Furthermore, Verhaag (2020) was able to state that the age group of 40 years and up is more Miele minded, whereas the younger age groups mostly choose from the lower price segments.

B. Motivation

From an internal research it was found that 80% of the customers buy a new WM because their current WM is beyond repair, 10% wants to upgrade their machine and for the remaining 10% the machine is their first WM purchase (Verhaag, 2020). Every customers' primary reason to buy a WM is the desire to have a new washing machine rather than to use a second hand washing machine. It is assumed that this choice is partially made due to the high quality services and pleasant customer journey of Coolblue.

C. Customer use



Little is known about the customer use of the traditional WM sale, as the contact with the customer ends when the product is purchased, except for when it is returned. Around 15% of all WM sales is returned (see figure 4.3). 8% Of the products that are returned, qualify as quality returns. 4% Falls under the satisfaction guarantee (SG) of 30 days and around 3% are damaged during the process (e.g. distribution).

Figure 4.3 WM returns in traditional BM (Source: Author)

4.1.3 Key activities

A. Production

Coolblue has no direct influence on the production phase of washing machines. The WMs are purchased directly from manufacturers. Coolblue does however have contact with manufacturers and give feedback when needed. For example, if there is a WM that has a high return rate because the motor keeps on giving problems, they can communicate this to the manufacturer. If manufacturers act upon this feedback is outside of Coolblues reach.

B. Distribution

Figure 4.4 Exterior of de Schuur (Source: Coolblue Beeldbank)

When a WM is manufactured, there are three distribution steps in between manufacturer and customer. First, the machine is transported from the manufacturer to the Coolblue warehouse in Tilburg, better known as 'De Schuur' (see figure 4.4).
From the warehouse, the WMs are transported to smaller depots, which are situated all over the Netherlands, by big lorries (i.e. 15 to 20 tons). 35 to 40 full lorries transport goods to corresponding depots daily. From the depots the WMs are delivered and installed at the customer by the Coolblue 2M truck (see figure 4.5). Coolblue 2M trucks deliver everything that is above 30 up to 170 kilograms (kgs). Everything above this weight needs to be carried by two people. Information on the other delivery types and the exact size and weight classification per type can be found in Appendix M.
Also old appliances (i.e. ERs), discarded by the customer, are taken back to the depot in the 2M truck. These ERs do make the distribution process less efficient, as space for such products must be taken into consideration when planning the route. More information on the exact steps within the warehouse and depot can be found in the field visit reports in the External Appendix.

Figure 4.5 The 2M Coolblue truck (Coolblue Beeldbank, 2020)

C. Use

There are few actions that Coolblue can undertake, when a WM is bought and at the customer. For example, online tips on how to clean a washing machine or tips during use to extend the life of your machine and laundry. These tips are considered passive, as Coolblue has no direct control if the customer will put these tips into practice.

D. Life cycle extension

There are three active ways how Coolblue prolongs the product life time, namely through reselling the machine in SecondChance (i.e. Tweedekans), refurbishing the machine and taking out usable components when it is at is End-of-Life. When the used WM is sent back by the customer, they end up at the warehouse. Here they are visually checked to see which destination they can end up at, in hierarchical order. The first option is that the WM is sent to SecondChance. SecondChance products are usually not that old and Coolblue feels confident to still offer a two years warranty on them. The products usually have some surface damages or no packaging. However, these damages have no effect on the operation of the product (Klerks, 2020). In order to get the products ready for sale, small repairs and cleaning activities are performed. Any elements that are out of the ordinary are photographed and mentioned, when they are sold on the Coolblue website with a small reduction. The WMs sold in the traditional BM are assumed to be situated at the customer for 5 to 10 years and therefore life extension through SecondChance is not taken into consideration for this business case.

The second option is refurbishing a WM. If a WM is not new but needs more than some small repairs or a clean up, the product is shipped to one of the two depots that is active in refurbishing, either Amsterdam or Utrecht. The washing machines that are refurbished are environmental returns. Since 2019, Coolblue has been active in refurbishing old white goods. Currently only washing machines from premium brands, (i.e. AEG, Bosch, Miele and Siemens) are being refurbished. Coolblue experiences that there is no market to sell other brands when refurbished. The refurbished WMs are resold to wholesale buyers or thrift stores.

The last way of life extension is when the machine cannot be refurbished, valuable components are taken out and stored. However, as 13 different brands are sold, which all have new WM types coming out every year, it is impractical for Coolblue to store all these components. Therefore they have minimised this storage to the most frequently used parts. Although the life cycle of a WM sold by Coolblue is not directly extended by refurbishing and components recycling, the presumption is made that extending the life of other WMs (e.g. from different providers) will be similar to the sold WM of Coolblue.

More information on the refurbishing and component recycling processes can be found in the field visit reports in the External Appendix.

E. End-of-Life

Whenever the life cycle of the washing machine cannot be prolonged, the machine is at its End-of-Life and considered a write off. At this stage, the product is sent to WeCycle. WeCycle is an organisation that is in charge of the collection and recycling of discarded electric appliances and lamps, better known as e-waste. After collection, the appliances are sorted by type of product (e.g. whitegoods, tv's, small kitchen appliances, etc.). Here the whitegoods stream is sent to a specialised recycling company. The machines are placed in a shredder which cuts up the product into tiny ferrous and non-ferrous granulates. These granulates are then separated and recycled accordingly. More than 75% of the materials in white goods can be used again (WeCycle, n.d.). Coolblue however cannot guarantee that all WMs are recycled properly, as they do not have ownership of the product. Therefore the assumption is made that 90% of all WMs are collected (Boven, 2020).

4.1.4 Key resources

A. Human

In order for Coolblue to get the traditional BM running there are three key partners needed, besides Coolblue. First of all the manufacturers that build the WMs and send a repairman to the customer if needed. The second key partner is a logistics service provider who transports the products from the manufacturer to the Coolblue warehouse in Tilburg. Lastly, the organisation WeCycle who takes care of the recycling process of written off products. Coolblue is responsible for the distribution phase from the warehouse to the customer, organizing the contract and services, creating the website assortment and collecting the WM at the end of use.

B. Financial

Washing machines are sold on the website ranging from €329 to €1999. Furthermore, installation costs can be added for an additional fee of €19,95. When purchasing a WM, the customer can always return it within 30 days (i.e. Satisfaction Guarantee) or when it is after 30 days but still within the 2 years factory warranty, Coolblue will make sure the product is repaired or replaced. These returns are rather costly for Coolblue and thus they try to minimise this number. Showing the pros and cons of every product on the website are an example of how they tackle this.

C. Physical & logistics

There are washing machines from 13 different brands offered on the Coolblue website. The most chosen WM brand is Bosch (Van Melkebeke, 2020). The Bosch WMs are mostly mid-ranged WMs that can withstand 2000 wash cycles. The Bosch WMs available on the Coolblue website have an energy label of A+++-10% or A+++-30%.
Other physical resources are the tools needed to refurbish and clean the ERs before reselling them to wholesale buyers or thrift stores. Lastly, resources concerning the logistics part of the BM are needed. Resources such as trucks, fuel and a handtruck for lifting the WM.

D. Knowledge

Coolblue has a lot of knowledge on the products they sell and which are returned for what reason. This has resulted in a Coolblue's choice label; products with small return rates and a good price quality ratio. Whenever a product is sent back too often, they can remove the Coolblue's choice label (Verhaag, 2020). They can also give information to the manufacturer if a certain product shows high return rates due to a defect.

4.1.5 Adoption factors

A. Driver

Around 98% of all Dutch residents own a WM (Laitala *et al.*, 2018). Also 670000 WMs were sold in 2019 in the Netherlands (Statista, 2020). Both facts drive WM sales for Coolblue.

B. Barriers

A barrier of the traditional Coolblue BM would be that some consumers are not able to pay such large investments at once.

4.1.6 Life Cycle Impact Assessment

For the business case of the traditional BM the Bosch WAN28005NL is chosen as the default WM. The functional unit is defined as "a single horizontal-axis household washing machine during its 12 year service life in The Netherlands". The WM has an A+++-10% energy label and qualifies as a mid-range quality built. It is assumed that the lifespan of a mid-ranged WM in the Netherlands is 12 years (Prakash *et al.,* 2016). The average energy consumption for a household of 1 or 2 people, doing 220 cycles at 40 and 60 degrees with an energy label of A+++-10% is 176 kWh per year (Rowan, 2020).

In order to investigate the environmental impact of a WM sold in the traditional BM eight activities have been taken into consideration (see table 4.1). In summary, the WM is produced in China and shipped to the Netherlands by boat. From the warehouse it passes through a depot and ends up at the customer. Then the WM is used by the consumer for 12 years and when it is at its End-of-Life the appliance is sent to the recycler. Emissions at the EoL phase are seen as a recycling credit. It is important to note that emissions caused by water supply and detergent use have not been accounted for as their GWP was less than 5% (Yuan *et al.,* 2015). Table 4.1 shows the CO_2 emissions that were estimated in kilograms CO_2 with two significant numbers. The total amount of CO_2 emissions consumed in the twelve year life cycle are 1.2 x10^3 kg CO_2.

Detailed explanations and assumptions behind the calculations are explained in Appendix N. The calculations can be found in an External Excel spreadsheet.

Table 4.1 CO_2 emissions of the Coolblue traditional BM (Source: Author)

	Phase	Activity	CO_2 emissions [kg CO_2]	Relative share [%]
1	Production	Producing 1 WM cradle to gate	3.0×10^2	26
2	Distribution	Transporting 1 WM from China to the WH	3.4	0.0
3	Distribution	Electricity and gas use of WH for 1 WM	0.062	0.0
4	Distribution	Transporting 1 WM from WH to depot	0.97	0.0
5	Distribution	Electricity and gas use depot for 1 WM	0.00084	0.0
6	Distribution	Transporting 1 WM from depot to customer	0.36	0.0
7	Use	Energy usage of 1 WM during 12 years (A+++-10% and mid-range)	9.5×10^2	82
8	End-of-life	Recycling one WM unit	-1.0×10^2	-8
CO_2 emissions in 12 year life cycle			1.2×10^3	100

4.2 Product-as-a-Service WM lease by Coolblue

This subchapter elaborates on the business model of the Product-as-a-Service (PaaS) department by Coolblue. Since October 2018 Coolblue started with PaaS BM, to offer different products and services for a fixed monthly price. Recognizing that there was a trend in the market of consumer leasing, inspired Coolblue to give PSS also a try. Coolblue had taken different PSS business models into account, but the product lease subscription made most sense for Coolblue, as they would be able to offer more services to the customer, be sustainable and at the same time make some money (Van der Meer, 2020). The pay-per-use BM was also taken into consideration, but after some thought it was concluded that it did not suit Coolblue. This PSS BM is technically more advanced, which makes the subscription much more complicated. Another reason not to choose a pay-per-wash BM, was because a fixed price per month was considered to be more hassle free. This is because the customer would know what to expect. Coolblue customers confirmed this assumption in a small questionnaire (Van der Meer, 2020).

In the beginning of 2018 Coolblue started a small pilot of, in which they leased Macbooks and washing machines. The pilot showed potential for leasing WM, but there was a relative high fraud rate with the laptops. Therefore the Macbook lease pilot was stopped and the leasing subscriptions were expanded from washing machines, to dryers, wash-dry combinations, dishwashers, refrigerators, freezers and coffee machines. Currently they have started two PaaS pilots for MacBooks and televisions. Coolblue expects that in the future also smart home appliances and workspaces will be leased (Bijl, 2020).

An interview with the manager of the PaaS team was conducted, Sietse van der Meer. He works at Coolblue for over seven and a half years and from the beginning he has been active in the PaaS BM. The transcribed and coded interview can be found in the External Appendix. Figure 4.6 shows the filled in SPSS framework for the PaaS BM.

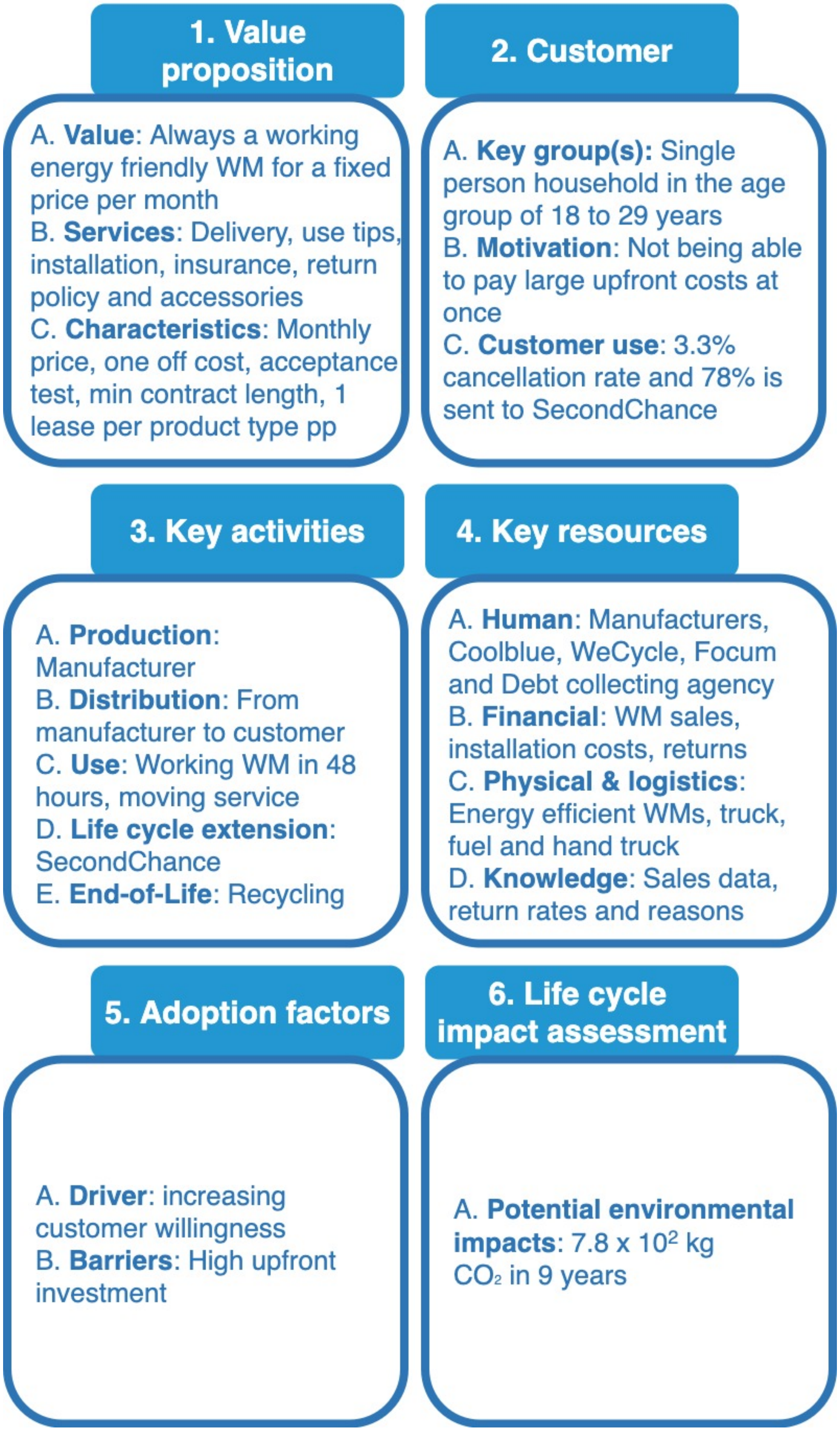


Figure 4.6 PaaS BM SPSS Framework (Source: Author)

4.2.1 Value proposition

A. Value

The value that the PaaS BM offers is an always working washing machine against a fixed monthly price. It is believed that the following three keywords express what a subscription offers the consumer: hassle free, a fixed price per month and sustainable (Van der Meer, 2019).

B. Services

Apart from the washing machine, there are seven services that are included in the lease subscription. The WM is delivered for free to the customer's house and installed by Coolblue. Third, if the WM is not working a new WM is delivered and installed at your house within 48 hours. Another service is the free moving service once every two years. During the subscription use tips (e.g. maintenance, detergent type, installation, etc.) can be found on the Coolblue website. It is also possible to transfer the contract to someone else free of charge. A seventh service is that the WM is collected when the contract is ended, but not before offering to buy the product at a reduced price

C. PSS characteristics

The same characteristics of the traditional BM are applicable to the PaaS BM, except for the pricing. The PaaS department offers WM subscriptions within the price range of €14,99 up to €34,99 a month, depending on the quality of the machine. Furthermore, there is a one-off cost at the beginning that needs to be paid by the customer in order to activate the lease and to give Coolblue some insurance. These costs vary from €49, €75 to €99, depending on the monthly costs. On top of that there are some additional characteristics. To make sure the customer is financially able to pay the lease, each potential customer goes through a Focum 'acceptance test'. This test will limit the financial risks, both for Coolblue and the customer (Van der Meer, 2020). Another way to prevent misuse of the contract is by allowing only one subscription per product type per customer. Unfortunately the PaaS department still encounters some fraudsters, resulting in default payments. Every lease has a minimum contract length of a year. After one year, the contract can be canceled free of charge. Coolblue deliberately decided to offer only one year subscriptions, instead of different contract lengths. One reason was to keep it simple for the consumer. Van der Meer (2020) believes that with such a short contract span, the BM would not weigh up to all the transport costs made.

4.2.2 Customer

A. Key groups

Based on a PaaS customer survey (Smetsers, 2020), six key groups can be distinguished for the subscriptions. The main key group (30%), for the WM lease is the 'single person' household. The two consecutive groups (both 22%) that have a WM lease at Coolblue, are 'Partner with no children' and 'Partner and children'. The keygroup 'Roommates' take up 14%, 'Single parents' 11% and then there is a final 1% 'Other' keygroup that make up the total composition.

The PaaS customers can also be divided into six age groups. The age group 18 to 29 years old is the largest group (29%), of the total composition. The average PaaS customer is younger than the average Coolblue customer and lives mostly in the big cities (i.e. Rotterdam and Amsterdam) (Bijl, 2020). This is not unusual, considering that Van der Meer (2020) called most PaaS customers "*Millenials*". The second biggest age group (21%) is 50 to 59 years old. The age groups 60 to 69, 30 to 39 and 40 to 49 equally make up 42% and the remaining 8% is completed by the age group of 70 to 89 years old. The exact number of the household and age composition can be found in (Appendix O). It should be noted that the survey was filled in by 251 respondents with a WM subscription, which corresponds to a 12% response rate.

B. Motivation

The same survey (Smetsers, 2020) showed that the main reason (57%) for choosing a WM with a lease subscription BM instead of buying one is because customers are not able to pay large investments at once. Different age groups hold different motives for choosing a lease subscription. Young people find the financial reason important as costs can be shared with roommates and the lease is a temporary solution, as their future situation is still unclear.
For elderly people (i.e. 60+), financial reasons also play a big part in decision making. The free and quick repair service are the second most important reasons and also sustainability is becoming more and more important, whereas the moving service and no big upfront costs have less influence on their decision.

C. Customer use

Coolblue has no direct feedback on the use of its customer. However they can measure the return rate. As the subscription has been live since the end of 2018, it is difficult to say what the average subscription duration is. From the subscriptions with a duration of less than a year, 1.6% has been renounced. Subscriptions with a duration of longer than a year show 3.3% of cancellations. Furthermore, data shows that 78% of the WMs that are returned from the PaaS BM can be sent to SecondChance, 7% is written off and 13% has no solution (Bijl, 2020).

4.2.3 Key activities

A. Production

The production phase in the WM life cycle of the PaaS BM is similar to the traditional business model of Coolblue.

B. Distribution

The second phase in the traditional business model is also similar to the PaaS subscription.

C. Use

During the user phase there are a few activities that Coolblue undertakes. Coolblue has promised its leaseholders that whenever the WM is broken, a working WM is delivered at their doorstep within 48 hours. White goods are considered to be essential in a consumer's lifestyle and because Coolblue wants to keep the NPS as high as possible, a direct swap is offered. A direct swap means that the customer receives a complete new washing machine. Currently PaaS is not able yet to offer repair within 48 hours. However, PaaS has started to ask the customer what is the exact problem, before

scheduling a direct swap. Because sometimes the WM still works, but it makes a weird sound. In these types of situations it is not necessary to perform a direct swap and a repairman is sent by the house within a few days (Van der Meer, 2020).
Also during the lease period, the customer has the option to make use of the free moving service once every two years.

D. Life cycle extension

Similar to the traditional BM, the WMs sold in the PaaS BM also experiences life cycle prolonging actions, namely SecondChance, Refurbishing and component recycling. 78% of the returned WMs in the PaaS BM can be sent to SecondChance (Bijl, 2020). WMs in this category have been in use for less than a year (Klerks, 2020). Reasons for could be that the customer has changed its mind or that the product was wrongly delivered. If a PaaS WM is sent back after more than a year, it is usually sent to value recovery in Utrecht or Amsterdam (Klerks, 2020). WMs sent to value recovery (External Appendix) can be refurbished or valuable components will be taken out. A pilot earlier this year on refurbishing 40 white goods, showed a successful refurbishing rate of 60% (Boon, 2020).

E. End-of-Life

The EoL phase is similar to the traditional BM, except for the fact that one can presume that a 100% collection rate is achieved, due to the fact that Coolblue remains owner of the product.

4.2.4 Key resources

A. Human

Most human resources that are needed are similar to those in the traditional BM, but with two additions. The first addition is Focum, who performs a financial acceptance test to make sure that the future customer is creditworthy. The second addition is the debt collection agency, that helps to diminish the number of fraudsters.

B. Financial

To make the PaaS BM possible, big upfront investments are needed. These investments cover the costs for the WMs and the services. These costs are regained with the monthly payments, the one-off costs at the beginning of the subscription and the profits that are made from reselling the WM in SecondChance.

C. Physical & logistics

The WM is one of the physical resources that is needed to realise the lease. According to Van der Meer (2020: 14) the PaaS subscription "*chooses products that are energy efficient and show low defect rates*". The most energy efficient (i.e. A+++ -30% or higher) WMs are available in the PaaS BM as well as those machines that show a relatively low amount of breakage (Bijl, 2020; Van der Meer, 2020). In total twelve different washing machines are offered and they are all horizontal-axis WMs. The subscription which is mostly chosen is by LG. The WM has an energy label of A+++-30% and qualifies within the basic quality build (Bijl, 2020). It is assumed that due to the low monthly costs (i.e. €14.99) this WM is chosen most often. Furthermore, tools are needed to repair and clean the WMs before reselling them in SecondChance. Lastly, the same resources concerning distribution are needed as for the traditional BM, namely trucks, fuel and a handtruck for lifting the WM.

D. Knowledge

The knowledge resources are similar to that of the traditional BM. Coolblue collected a lot of data on defects (Van der Meer, 2020): which products show most defects and for which reasons are they returned. With this knowledge they can actively steer the assortment. Furthermore, with this knowledge they are able to motivate and challenge the producer to manufacture WMs with a longer life span, which consequently will lead to a more sustainable WM.

4.2.5 Adoption factors

A. Driver

An driver experienced by the PaaS department is that the PSS market is growing due to an increasing customer willingness.

B. Barrier

A barrier occurring in the PaaS BM would be the high upfront investments for Coolblue.

4.2.6 Life Cycle Impact assessment

In this paragraph the environmental impact of the WM life cycle in the PaaS BM is investigated. For the business case the LG FH4J5TN8 Direct Drive was assumed. The functional unit is defined as “a single horizontal-axis household washing machine during its 9 year service life in The Netherlands”. Based on information provided by the Coolblue website the basic WM has an energy label of A+++-30%. A basic built WM is approximately three times the price of a high-end. Therefore the assumption is made that a basic quality build WM is said to withstand 2000 wash cycles. This corresponds to a lifetime of nine years. The average energy consumption for a household of 1 or 2 people, doing 220 cycles at 40 and 60 degrees with an energy label of A+++-30% is 136 kWh per year (Rowan, 2020).
A total of ten activities were included in the estimation (see table 4.2). Activities 1 up to 6 were considered to be exactly the same as the traditional BM. The WM is produced in China and from there it is shipped to the Netherlands to the Coolblue Warehouse. From the Warehouse it passes the depot and then ends up at the customer. In the PaaS business case a customer will hold on to the WM for three years on average. After three years the WM does not classify for SecondChance anymore and is therefore refurbished. This refurbishment makes it possible to use the WM for another six years. This makes the total lifespan of the WM nine years. At the EoL phase the WM is recycled. These emissions are seen as a recycling credit.
The total kilograms of CO_2 emitted in the nine year life cycle are $7.8x10^2$ (see table 4.2).
Detailed explanations and assumptions behind the calculations are explained in Appendix P and the External Excel spreadsheet.

Table 4.2 CO_2 emissions of the Coolblue PaaS BM with refurbishment (Source: Author)

	Phase	Activity	CO_2 emissions [kg CO_2]	Relative share [%]
1	Production	Producing 1 WM cradle to gate	3.0×10^2	39
2	Distribution	Transporting 1 WM from China to the WH	3.4	0.0
3	Distribution	Electricity and gas use of WH for 1 WM	0.06	0.0
4	Distribution	Transporting 1 WM from WH to depot	1.0	0.0
5	Distribution	Electricity and gas use depot for 1 WM	0.00084	0.0
6	Distribution	Transporting 1 WM from depot to customer	0.36	0.0
7	Use	Energy usage of 1 WM during 3 years (A+++-30% and basic)	1.8×10^2	24
8	Life extension	Refurbishing 1 WM	32	4
9	Use	Energy usage of 1 WM for 6 years (A+++-30% and basic)	3.7×10^2	47
10	End-of-life	Recycling one WM unit	-1.1×10^2	-14
CO_2 emissions in 9 year life cycle			7.8×10^2	100

4.3 Cross-case results summary Coolblue cases

In this paragraph the results obtained through the field and desk research on the two Coolblue cases are summarised. The summary is divided into three parts. The first part consists of outlining the first five elements of the SPSS framework (i.e. value proposition, customer, key activities, key resources and adoption factors) of both BMs. The second part contains the comparative LCA analysis of the two Coolblue cases and in the third part, the hotspots of the WM life cycle in the PaaS BM are outlined.

4.3.1 Business model summary

1. ***Value Proposition***

The value that the traditional BM offers its buyers is a working WM with a two year guarantee. The PaaS BM promises a working WM during the entire duration of the subscription for a fixed price per month. On top of that there are seven services included in the subscription.

2. ***Customer***

The traditional BM has no particular customer focus, whereas the PaaS BM is mostly targeting young adults who do want to to pay the large upfront costs of a WM. Furthermore, users in both BMs have access to tips on the website or customer service.

3. ***Key activities***

The first two processes in the life cycle (i.e. production and distribution) are more or less the same in both business models, except for the fact that installation is optional in the traditional BM. The assumption is made that this would have no effect on the environmental impact.
During the user phase in the traditional BM, Coolblue has no direct control. Tips and videos can be found on the Coolblue website. In the PaaS BM Coolblue does stay in contact with the user. For example when the machine is beyond repair or when the user wants to move house.
In the traditional BM, the life of a WM can be extended by refurbishment and component recycling. However the assumption is made that the WM will be running at one consumer for eight years. In the PaaS around 78% of the returned WMs can be resold in SecondChance. However, the PaaS business case assumes that on average a WM will stay at the user for three years. The quality of these WM returns are usually not high enough for SecondChance and are therefore sent to refurbishment. It is therefore assumed that the WM is running for three years at one customer, refurbished and then sent to another customer for an additional seven years.
During the final phase in the life cycle, a WM is sent to WeCycle who takes care of the recycling phase. This EoL phase is similar in both BMs apart from the assumption that all WMs are collected in the PaaS and only 90% is collected in the traditional BM.

4. ***Key resources***

The biggest difference between the two BMs is the fact that the PaaS BM only uses WM with the energy label of A+++-30% or higher and that large upfront investments are needed. Other resources needed in both BMs are more or less the same.

5. Adoption factors

The Netherlands has a high ownership rate for WM and a lot of WMs are sold every year. This drives WM sales of the traditional BM by Coolblue. An increased customer willingness for a PSS BM is a driver for the PaaS department.
A barrier in the traditional model is that some consumers are not able to pay big upfront investments. In the PaaS BM it is the provider that has to pay the big upfront investments.

4.3.2 Comparative LCA analysis

In this paragraph the CO_2 emissions of the two Coolblue BMs are compared (see table 4.3 and figure 4.7). The total CO_2 emissions estimated in the PaaS BM are 35% lower than in the Traditional BM by Coolblue. The life cycle of the WM is measured into five phases. The screening LCA shows that the BMs differ in two of the five phases: The use and Life extension phase.
The CO_2 emissions in the traditional BM during the user phase amount in 9.5×10^2kg CO_2 in twelve years. The CO_2 emissions in the PaaS BM during use of nine years accumulate to 5.5×10^2kg CO_2. This 42% difference is solely due to the fact that the WM in the PaaS BM has A+++-30% energy label and the traditional BM a A+++-10%. The second is during the life extension phase. During the traditional BM it is assumed that the WM is discarded after EoU. In the PaaS BM the WM is refurbished.
The total lifespans however in both BMs are not comparable as they are not similar. The lifespan in the traditional BM is considered to be twelve years, whereas the lifespan in the PaaS BM is estimated to be nine years. Taking the CO_2 emissions per year would make the results more comparable (see figure 4.8). Table 4.3 shows the CO_2 emissions emitted during the entire lifespan and the CO_2 emissions per year. The ratio difference between the two BMs per year is 10%.

Table 4.3 Ratio difference of the CO_2 emissions of the two Coolblue BMs (Source: Author)

Coolblue BM	Traditional [kg CO_2]	PaaS [kg CO_2]	Ratio difference [%]
Energy label Lifespan [years]	A+++-10% 12	A+++-30% 9	
Production	3.0×10^2	3.0×10^2	0.0
Distribution	4.8	4.8	0.0
Use	9.5×10^2	5.5×10^2	42
Life extension	-	32	-
End-of-Life	-1.0×10^2	-1.1×10^2	0.0
CO_2 emissions over total lifespan [kg CO_2]	1.2×10^3	7.8×10^2	35
CO_2 emissions per year [kg CO_2]	96	86	10

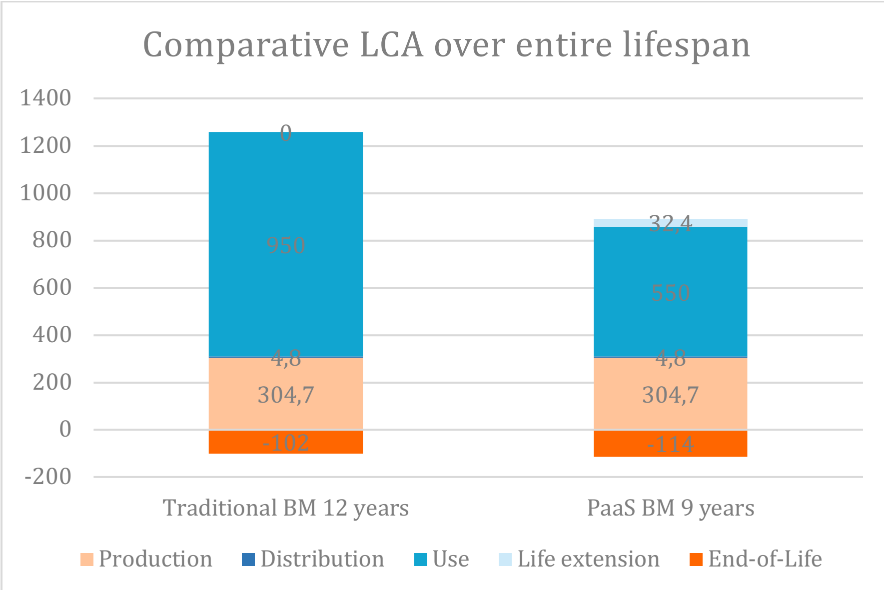


Figure 4.7 Comparative LCA of the two Coolblue BMs over entire lifespan (Source: Author)

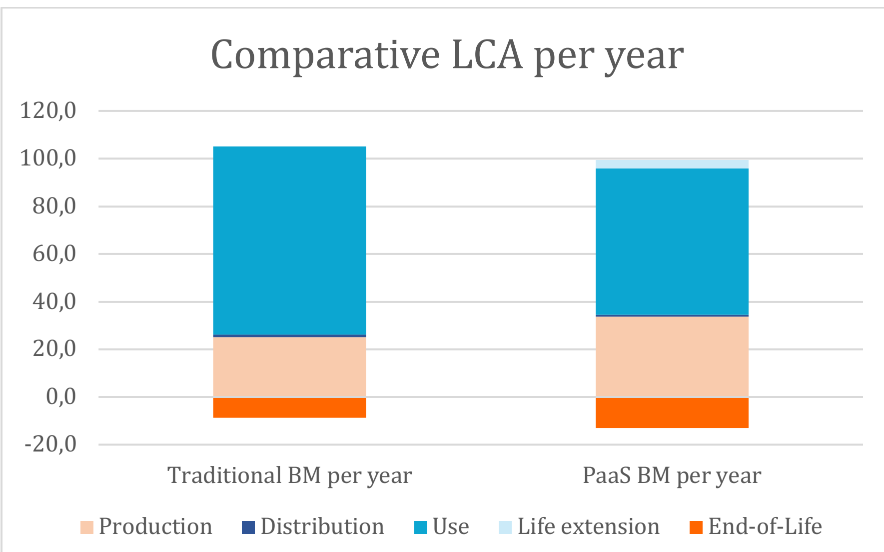


Figure 4.8 Comparative LCA of the two Coolblue BMs per year (Source: Author)

4.3.2 Hotspot analysis

A phase is considered a hotspot if it contributes to more than 10% of the total impacts measured (Yuan *et al.*, 2015). Table 4.4 shows that the main CO2 emission contributor (71%) in the life cycle of a WM in the PaaS BM is the user phase. This business case assumes that the WM is refurbished after three years of use and then will be used for another six years. The user performs 220 cycles of washing per year at 40 and 60 degrees. The second highest contributor is the production phase (39%). The refurbishment process takes up 4% of the total share, distribution phase 1% and the EoL phase results in a recycling credit of 15%. See figure 4.9 for a visual representation.

Table 4.4 CO_2 emissions of the 5 WM phases in the Coolblue PaaS BM (Source: Author)

	Phase	Activity	CO_2 emissions [kg CO_2]	Relative share [%]
1	Production	Producing 1 WM cradle to gate	$3.0x10^2$	39
2	Distribution	Transporting 1 WM from China to the user	4.8	1
3	Use	Electricity use during 9 years (A+++-30%, basic built)	$5.5x10^2$	71
4	Life extension	Refurbishing 1 WM	32	4
5	End-of-Life	Recycling one WM unit	$-1.1x10^2$	-15
CO_2 emissions in 9 year life cycle			$6.0x10^2$	100

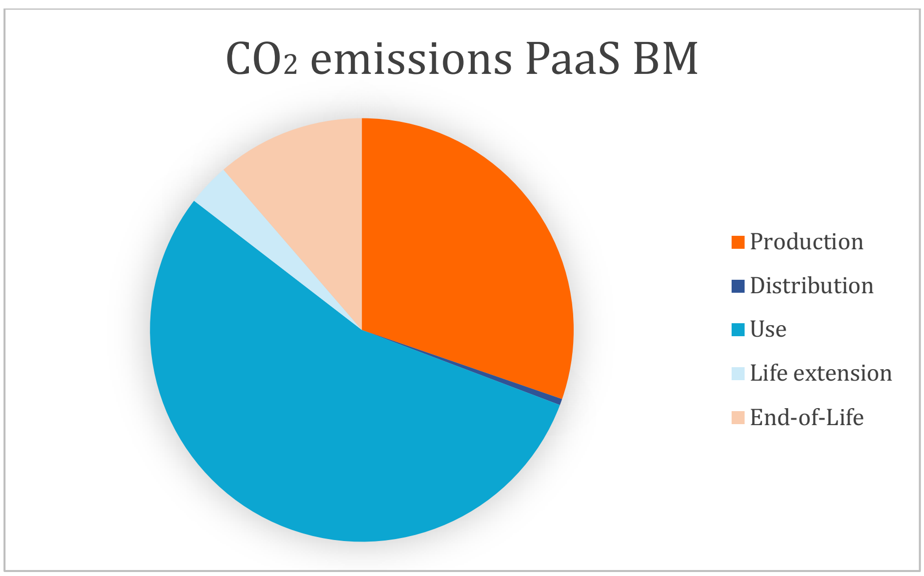


Figure 4.9 Hotspot analysis of WM life cycle in PaaS BM (Source: Author)

4.4 Inspirational cross-cases summary

In this subchapter, three alternative PSS cases in the washing machine industry are analysed, namely BlueMovemenet, Homie and Bundles. Their BMs are evaluated based on an adaption of the SPSS framework and its six elements, explained in chapter 3.3.2. The full analysis of the three companies can be found in appendix Q, R and S. The most interesting results from the interviews are summarised into seven parts. These consist of the organisational structure of the company and the six SPSS framework elements.

4.4.1 Organisational structure

Table 4.5 gives a summary of the key differences within the organisational structure of the three cases.

BlueMovement
BlueMovement was initiated in 2017 by Bosch managers. These direct ties give BlueMovement the advantage of knowing how the WMs are assembled. This can make repairs and refurbishing more efficient. These ties also give them the opportunity to be more active in the design process of new WMs in the future. The BlueMovement team is twice the size of the Bundles and Homie team. Their product portfolio is also the biggest in comparison to Homie and Bundles.

Figure 4.10 BlueMovement logo (Source: BlueMovement website)

Homie
Homie was founded in 2016. The goal was to demonstrate that new BMs can "*contribute to sustainable consumption and a circular economy*" (Homie, n.d.: 3). The product portfolio consists of washing machines, dryers and dishwashers. Homie is a product lease PSS BM where customers pay per wash and vary on the environmental impact generated by the program. The higher the temperature and the higher the rpm, the more expensive the program is. This financial model was chosen because in their eyes it is the only PSS business model where both the manufacturer and user are pushed towards being more environmentally friendly (Bom, 2020). What the total number of subscriptions of Homie are is unknown.

Figure 4.11 Homie logo (Source: Homie website)

Bundles
Out of the three companies Bundles has been on the market the longest. Together with Miele, Bundles created the brand 'WasBundles'. Wasbundles only offers Miele washing machines and has more than 2000 subscriptions (Peters, 2020). Bundles also offers subscriptions in different product categories namely, dryers, dishwashers, coffee machines and beds. WasBundles is a product lease

PSS BM where the user pays a fixed price per month and a fixed cost per wash.
Figure 4.12 Bundels logo (Source: Bundles website)

Table 4.5 Overview key characteristic 'organisational structure' inspirational cases (Source: Author)

Organisational structure	BlueMovement	Homie	Bundles
Established in	2017	2016	2013
Founder	Powered by Bosch	Independent entrepreneur	Independent entrepreneur
PSS BM	Product lease	Product lease	Product lease
Financial model	Fixed monthly fee	Pay-per-wash with tiered prices	Pay-per-wash + fixed monthly fee
Employees	9	4	4
Product portfolio	Washing machines, dryers, refrigerators, freezers, dishwashers, vacuums and food processors	Washing machines, dryers and dishwashers.	Washing machines, dryers, dishwashers, coffee machines and beds.
Manufacturing partnership	Yes, Bosch	No	Yes, Miele
Number of WM users	Unknown	Unknown	2000+

4.4.2 Value proposition

Table 4.6 gives a summary of the key differences within the value proposition element.
The value proposition of the three companies is more or less the same, however they differ slightly. BlueMovement offers a sustainable WM for a fixed price per month. Bundles offers prestiges WMs for a fixed price per month and per wash. Homie offers users a WM where they pay differentiated prices per wash. Each company offers almost the same free services. The differences are that BlueMovement offers free contract transferral and that Homie will collect the WM for free after one year. Homie and Bundles offer a monthly overview and Bundles provides the option of a detergent inventory. BlueMovement has the lowest minimum price per month. This price however only applies to a contract length of at least six years. It seems as if PSS customers would prefer not to choose a six year contract commitment. Its best selling lease is €18.99 per month. Besides this fixed

fee users must pay a deposit, pass a creditworthiness test and pay extra for collection at the EoL. Homie is the only company of the three that takes away all the big upfront investments, does not perform a creditworthiness test and only asks users to pay per wash. This makes the subscription very attractive to people with less financial possibilities. In the WasBundles lease users pay a deposit, a fixed price per month, a fixed price per wash and a collection fee. Assuming that a WasBundles user will wash 15 times per month and chooses the Luxe subscription a total monthly price of €20,95 is calculated. The price difference between Homie and the other two companies is rather large. The value, services and contract requirements of Homie are not regarded as inferior. The last key difference is that only Bundles users can buy the WM from the provider once the contract has ended.

Table 4.6 Overview key characteristic 'value proposition' inspirational cases (Source: Author)

Value proposition	BlueMovement	Homie	Bundles
Value proposition	Sustainable WM lease for a fixed price per month	A WM where the users pays differentiated prices per wash	A prestiges WM where the users pays per wash and a fixed price per month
Free services	Delivery, installation, repairs, user tips, moving, and contract transferral.	Delivery, installation, repairs, user tips, monthly overview and collection.	Delivery, installation, repairs, user tips, monthly overview and detergent inventory.
Minimum contract length	3 months, 1 year or 6 years	6 months	1 month
Price per month (minimum)	€9.99 - €60.99	€12.75 - €19.50	€14,95 - €22.95
Deposit	Yes	No	Yes
Creditworthiness test	Yes	No	Yes
Buy WM at the end of the contract	No	No	Yes

4.4.3 Customer

Table 4.7 gives a summary of the key differences between the customers of the three companies. PSSs can offer flexibility, convenience and take away large upfront investments. This is considered to be attractive to students or young adults. The key customer groups of BlueMovement and Homie confirm this assumption. Bundles mentioned that they have no specific key group. According to Bundles, its user understands that the PSS BM is necessary for a transition towards CE and does not mind paying a little bit extra. Homie customers have been washing 20-25% more efficiently. The average number of wash cycles per household is estimated to be 150 per year. BlueMovement has no data on the washing behaviour of their users. The washing behaviour of Bundles users was also not determined. Bundles mentions that 80% of all their subscriptions have never needed a repair of the WM. Homie and BlueMovement mentioned that most of the WMs come back in a good state. The exact numbers of the repair rate of Homie and BlueMovement are unknown.

Table 4.7 Overview key characteristic 'customer' inspirational cases (Source: Author)

Customer	BlueMovement	Homie	Bundles
Customer key group(s)	Convenience lovers, students and environmentalists	Young adults	None
Motivation	Convenience	Not being able to pay large investments	Understand the BM and are willing to pay a little bit extra for it
Washing behaviour	Unknown	20-25% more efficient and 12-13 cycles per month at 38.1 degrees	Unknown
WM use	Most WMs come back in good state	Most WMs come back in good state	20% Repair rate

4.4.4 Key activities

Table 4.8 summarises the differences between the key activities of the three companies. Homie and Bundles have no direct influence on the production phase of the WM. Because BlueMovement is driven by a manufacturer it knows how the WMs are assembled which can make refurbishing, upgrading and recycling more efficient. During distribution all three companies deliver and install the WM. During installment, Bundles explains how the WM works and mentions washing tips so that customers do not have to read through the entire manual. This can result in less repairs as the WMs are not used incorrectly. It can also have a positive influence on the washing behaviour. During the user phase all three companies repair WMs, first at a distance and second at the users home. If repair is not possible the WM is replaced. All three companies also offer washing tips to the user. The user tips from Homie and Bundles however are personalised as the washing behaviour from their consumer is monitored and summarised in a monthly overview. Homie users can see what their washing behaviour is in comparison to other Homie users and how they can improve their washing behaviour. Bundles users receive personalised tips based on their washing behaviour. Washing patterns were detected and corresponding user tips were generated and sent to users. During the life extension phase all three companies perform the same three activities: reuse the WM, refurbish and recycle valuable components.

Table 4.8 Overview key characteristic 'key activities' inspirational cases (Source: Author)

Key activities	BlueMovement	Homie	Bundles
Production	Knowledge on the WM design	No direct influence	No direct influence
Distribution	Delivery and installation	Delivery and installation	Delivery, installation and explanation of the WM
Use	Repair at a distance, repair at user, replacement and user tips	Repair at a distance, repair at user, replacement monthly overviews and personalised user tips	Repair at a distance, repair at user, replacement, monthly overviews and personalised user tips
Life Extension	Reuse, refurbish and component recycling	Reuse, refurbish and component recycling	Reuse, refurbish and component recycling
End-of-Life	Recycling	Recycling	Recycling

4.4.5 Key resources

Table 4.9 holds a summary of the differences between the key resources of the three companies. Out of the three companies BlueMovement has the least amount of partners to get their PSS BM up and running. This could be due to the fact that BlueMovement has more employees. It could also be due to the fact that the pay-per-wash BMs demands more partners as it is technically more advanced.

It is assumed that the type of WM brand and number of models also impact the environment. This is because less different WM models can make refurbishing and the storage of components more efficient. BlueMovement uses only Bosch WMs and has at least more than two types of models. Homie uses two type of Zanussi WMs in their lease. Bundles provide four different Miele WMs. Miele WMs are considered to be of very high quality and can wash for at least 10000 cycles. Zanussi WMs are categorised in the basic segment and Bosch WMs are categorised to be in the mid-range.

All three companies offer WMs with an energy label of A+++ or higher. The higher the label the more energy friendly the machine is. Currently there are WMs on the market that are more than 30% more energy friendly than the WMs that carry the A+++ label. Therefore WMs with a label of A+++ are considered to be too outdated.
Both Homie and Bundles monitor the washing behaviour with the help of an external tracker. Homie has the tracker built in whereas Bundles has the tracker built onto the WM.

Table 4.9 Overview key characteristic 'key resources' inspirational cases (Source: Author)

Key resources	BlueMovement	Homie	Bundles
Number of partners	5	7	6
WM brand	Bosch	Zanussi	Miele
Build quality	Mid-range	Basic	High-end
WM models	2+	2	4
Energy label	A+++-30%	A+++	A+++ up to A+++-20%
Monitoring	No	Yes, built in device	Yes, built on device

4.4.5 Adoption factors

From the interviews a total of six different drivers and barriers were mentioned that are applicable to the transition to a PSS BM (see table 4.10). BlueMovement and Bundles mentioned that the willingness of customers to choose a WM in a PSS BM is increasing. Also, the awareness on sustainability amongst customers is increasing according to BlueMovement and Homie. Homie mentioned that financial assistance by the government has enabled them to realise a pay-per-wash BM. The revised energy labelling system will encourage manufacturers to improve the impact of their WM designs. Another driver is the ecodesign measures that will promote the repairability of the product.

In the three interviews there were also barriers mentioned that block a PSS BM from fully blooming. All three companies mention that the current conventional household WMs are not suitable for a PSS BM. For example because some components in the WM are difficult to disassemble. WMs suitable for a PSS demand high investments which will only pay off after a long period of time. The fact that investors will only receive the benefits from these designs after eight to ten years, makes this long term perspective another barrier. Another barrier mentioned by BlueMovement is the fact that there is a stigma around refurbished products. Some customers might feel that they are inferior to new products. Homie expressed that the quality of returns can be degraded because owners feel less responsible for maintaining the quality of the WM. Another barrier is the VAT rate on refurbished products. Both of these two barriers do not make the BM financially appealing to providers. Bundles mentions that the stigma that renting is for poor people is a barrier they are facing. Lastly, consumers have less trust in service providers. Bundles says that this barrier occurs because people are becoming more self sufficient.

Table 4.10 Overview of the 'adoption factors' according to the inspirational cases (Source: Author)

Adoption factors	BlueMovement	Homie	Bundles
Drivers			
Social	Change in ownership mentality Increased customer awareness on sustainability	Increased customer awareness on sustainability	Increased consumer willingness for PSS
Financial		Financial assistance by the government	
Institutional		Revised energy labelling system Ecodesign measures	
Barriers			
Social	Many consumers still want to own a product Stigma refurbished products		Less trust in service providers by consumers Stigma on renting
Technological	Conventional WMs are not suitable for PSS BM	Conventional WMs are not suitable for PSS BM Quality degradation of returned products	Conventional WMs are not suitable for PSS BM
Financial	Long term perspective from investors	Long term perspective from investors High taxes	Long term perspective from investors

4.4.6 Life Cycle Impact Assessment

The Life Cycle Impact Assessment element of the adjusted SPSS framework is divided into current and future actions. These actions show ways in which companies are trying to decrease the environmental impact of their PSS BM. The current actions are geared to have an impact on the following elements: organisational structure, financial model, number of WM brands, number of WM models, energy label, brand quality, washing behaviour and life extension actions. Future actions are categorised in the following elements: suitable WM design, distribution optimisation, other PSS BM, innovations, replacement and shifting PSS ownership. Table 4.11 summarises all current and future actions that can decrease the environmental impact of the inspirational cases. Only actions that can decrease the environmental impact were taken into account. Some boxes were intentionally left blank because the actions are similar to those in the product lease BM by Coolblue.

Table 4.11 Overview of the current and future actions to decrease the environmental impact of the inspirational cases (Source: Author)

Life Cycle Impact Assessment	BlueMovement	Homie	Bundles
Current actions			
Organisational structure	Driven by manufacturer		
Financial model		Pay-per-wash Tiered prices	Pay-per-wash
Number of WM brands	1, Bosch	1, Zanussi	1, Miele
Number of WM models	2+		4
Energy label	A+++-30%		A+++-20%
Brand quality			Miele WMs are high-end
Washing behaviour		Personalised tips Monthly overview	Personalised tips Monthly overview Explaining WM at installation
Life extension	Reusing Upfront repairs Refurbishing	Reusing Repairs Refurbishing	Reusing Repairs Refurbishing

	Retrieving valuable components	Retrieving valuable components	Retrieving valuable components
Future actions			
Suitable WM design	Modular building	Modular building	Modular building
Distribution optimisation	More customers in the same area	Decreasing styrofoam during transport More customers in the same area	
Other PSS BM			Sharing WMs amongst users
Innovations		Replace concrete block inside the WM	Silver ion technology
Replacement			Replacing discarded WMs in other areas of the world
Shifting PSS ownership			Ownership to manufacturer

4.5 Design concepts

In this subchapter three new PSS BM concepts are designed in order to improve the environmental impact of the PaaS BM by Coolblue. The subchapter is made up of three parts. The first part consists of constructing sub-functions with possible means for a WM life cycle. Constructing the sub-functions and corresponding means was an iterative process. In the second part the three design concepts are explained and their corresponding impact is estimated. The third part summarises the impact of three design concepts in comparison to the current PaaS BM.

4.5.1 Sub-functions per life cycle phase

The overall function of the PSS in this study is to create the possibility of clean clothing. A distinction is made between the five phases in a WM life cycle: production, distribution, use, life extension and End-of-Life. Coolblue has no direct influence on the design choices in the production and EoL phase. From the hotspot analysis it became clear that the distribution phase has an insignificant influence on the overall environmental impact. Therefore no sub-functions were set up for these three phases (i.e. production, distribution and EoL).
The means found for each sub-function in the user and life extensions phase are mainly based on table 4.11 (paragraph 4.4.4). Table 4.11 summarises all current and future actions that the inspirational cases mentioned to decrease the environmental impact of their PSS BM. The table was also an input for brainstorming other possible means. A total of 21 means were constructed. The means were assessed on their suitability for Coolblue and effectiveness to decrease the environmental impact of a PSS BM (see Appendix T). The suitability was measured by the following five degradations: Excellent, Good, Decent, Limited and Not suitable (see table 4.12).

Table 4.12 Suitability steps (Source: Author)

Excellent	Good	Decent	Limited	Not suitable

Use
From the literature review it became clear that the washing behaviour influences the impact of the user phase tremendously. Therefore the sub-functions in this phase aim to influence the washing behaviour. The sub-fuctions for the user phase are: Educate users, Incentivise sustainable WM behaviour and Monitor WM usage (See table 4.13). In this phase the means '4. Personalised tips', '6. Washing championships', '7. Pay a fixed price per wash' and '8. Pay-per-wash with tiered prices' can only be implemented when mean '10. Built in device' is put into place. There is no other constriction for the combination of means. The explanation behind each mean and its effectiveness can be found in appendix T.

Table 4.13 Possible means in user phase (Source: Author)

Sub-functions	Possible means				
Educate users	1. Campaigns	2. Explanatory stickers	3. Tips on website	4. Personalised tips*	5. Explaining WM at installment
Effectiveness	*8%*	*12%*	*1%*	*20%*	*8%*
Incentivise sustainable washing behaviour	6. Washing championship*	7. Pay a fixed price per wash*	8. Pay-per-wash with tiered prices*	9. Give positive user feedback through email	
Effectiveness	*2%*	*15%*	*23%*	*2%*	
Monitor WM usage	10. Built in device*	11. Survey	12. Sampling after use	13. Sampling during use	
Effectiveness	*95%*	*10%*	*24%*	*32%*	

** Means that are restricted*

Life Extension

The core idea of the CE economy is to contain materials within the loop. In order to extend the life cycle the following sub-functions were constructed: Stimulate careful use and Prolong the material life cycle (See table 4.14). Mean '18. Predictive maintenance' is restricted as it must be combined with mean '10. Built in device'. The explanation behind each mean and its effectiveness can be found in appendix T.

Table 4.14 Possible means in life extension phase (Source: Author)

Sub-functions	Possible means			
Stimulate careful use	Deposit	Rewards for good returns	Email reminders	Strict contractual terms
Effectiveness	*90%*	*29%*	*1%*	*90%*
Prolong the material life cycle	Predictive maintenance*	Planned maintenance	Repair at user	Refurbishment
Effectiveness	*95%*	*80%*	*70%*	*60%*

** Means that are restricted*

4.5.2 3 Alternative PSS concepts

In this paragraph three new design concepts were developed for the WM PSS BM by Coolblue. The three concepts should be seen as a stepping stone towards circularity, from small steps to more extreme ones. All means that were classified as 'not suitable' were not taken into consideration. The combination of means for each concept is explained below. The detailed calculations can be found in the External Excel.

1. ***Concept 1: The Friendly Reminder***

The Friendly Reminder is the first new design concept (see appendix U). The means chosen in this concept are easy to implement by Coolblue as they are not too different from the current PaaS BM. The means are mostly 'friendly reminders' for the customer to change its washing behaviour. The biggest difference is the WM type. The default WM is a horizontal-axis mid-ranged WM with an A+++-40% energy label. With this energy label the average energy consumption for 220 cycles at 40 and 60 degrees in a household is 116 kWh per year. In the user phase four means and in the life extension phase three means were chosen.

In order to educate the user tips can be found on the website and the WM will be explained during installation. These means will also save the user from going through the entire WM manual. In order to incentivise the user to wash more sustainably positive user feedback will be given by email. This feedback is based on average consumer use. The last mean in the user phase is a survey which is sent around to the users asking them about their washing behaviour. It is expected that not all users will fill in the survey and also that not all answers are filled in correctly and true. The effectiveness of the means in the user phase are summed up to 1%.

For the life extension phase the user will be reminded of careful use by email. Not all users will read the email and act upon it. When the machine is not working it will first be repaired at the users home. If this is not possible the machine is collected and refurbished at the warehouse or depot. After refurbishment the WM is sent back to the user. These means are expected to affect the life extension phase by a 16% reduction.

The biggest difference from the current PaaS BM is that the WM will be kept inside the PaaS loop instead of sending it to SecondChance or WeCycle. The means from concept 1 will lead to 71 kilograms of CO_2 emitted per year. This is a 17% CO_2 decrease compared to the current PaaS BM.

2. ***Concept 2: Planned Maintenance***

Planned Maintenance is the second design alternative in which some more innovative means have been implemented that can decrease the environmental impact of the product lease BM (see appendix V). Similar to concept 1, the WM has a A+++-40% and is a mid-range quality which is assumed to last 12 years. The main difference with the current PaaS BM is the different energy label, WM built and the fact that planned maintenance is incorporated. In the user phase five means and in the life extension phase two means were chosen.

The second concept focuses on educating the users even more during the user phase. This is done by introducing explanatory stickers. The stickers are placed on the WM to remind the user which programs are more sustainable. Furthermore the WM usage is monitored more correctly by analysing the state of some WMs after the EoU. This will give Coolblue a more thorough and true

understanding of the WM usage then from the survey. These means will decrease the user phase by 1%.
During the life extension period emails concerning careful use and positive feedback are sent to the customer. Furthermore, planned maintenance is put into place. Planned maintenance will decrease the amount of repairs. These means will decrease the CO_2 emitted in the life extension phase by 23%.
Implementing concept 2 will lead to 70 kgs of CO_2 emitted yearly. This is a 19% CO_2 decrease compared to the current PaaS BM.

3. Concept 3: Pay-per-wash

The third design concept contains more radical measures which are expected to lead to more CO_2 emissions savings then the two previous concepts (see appendix W). The concept is very different from the current PaaS BM which results in a bigger decrease in CO_2 kgs. In the Pay-per-wash concept a high-end WM with the A+++-40% is chosen. The high-end WM is assumed to have a lifespan of 15 years. The biggest difference in this concept compared to the current PaaS BM is the energy label, WM built and pay-per-wash model with tiered prices. The suitability of some of the means chosen in this concept are labeled as 'limited'. This is because the current business model is not equipped to install built in device and a pay-per-wash model. Nevertheless the means were chosen to show the effect these more radical means have on the CO_2 emissions.
In the user phase of concept 3 the means pay-per-wash with tiered prices are implemented. This design choice makes the choice for a built in device mandatory. Because a built in device is in place, personalised tips can also be given. Furthermore the WM is explained during installation. These means are expected to decrease the CO_2 emissions in the user phase by 10%.
During life extension the customer will receive email notifications to remind them of careful use and rewards for good returns (e.g. a Coolblue discount or coupon) are given. Lastly, predictive maintenance will prolong the material life cycle of the WM. These means will lead to a 39% reduction in CO_2 emission in the life extension phase compared to the PaaS BM.
Implementing concept 3 will result in 61 kgs of CO_2 emitted per year. This is a 29% CO_2 decrease compared to the current PaaS BM.

4.5.3 Design concepts compared to the PaaS BM

In the current PaaS BM the WM is a horizontal-axis front loader with an A+++-30% energy label. The WM is a basic built WM which is assumed to have a total lifespan of nine years. After three years of use the WM is sent back to Coolblue. Then it is refurbished and can be used for another six years. The user will wash 220 cycles per year at 40 degrees. This makes the total kilogram CO_2 emitted in the current PaaS BM
$7.8x10^2$in nine years and 86 per year. Table 4.14 summarises the key differences in the 4 cases. Figure 4.13 illustrates the overall CO_2 emissions per phase in the total lifespan. This figure suggests that concept 3 emitted the most kilograms of CO_2. The effect of the lifespan on the CO_2 emissions in the different concepts is not visible (see table 4.14). Therefore the relative share of each of the phases was multiplied by the yearly emitted kilograms of CO_2. Figure 4.14 illustrates the CO_2 emissions for each concept per phase per year. This shows that concept 3 emitted the least amount of CO_2.

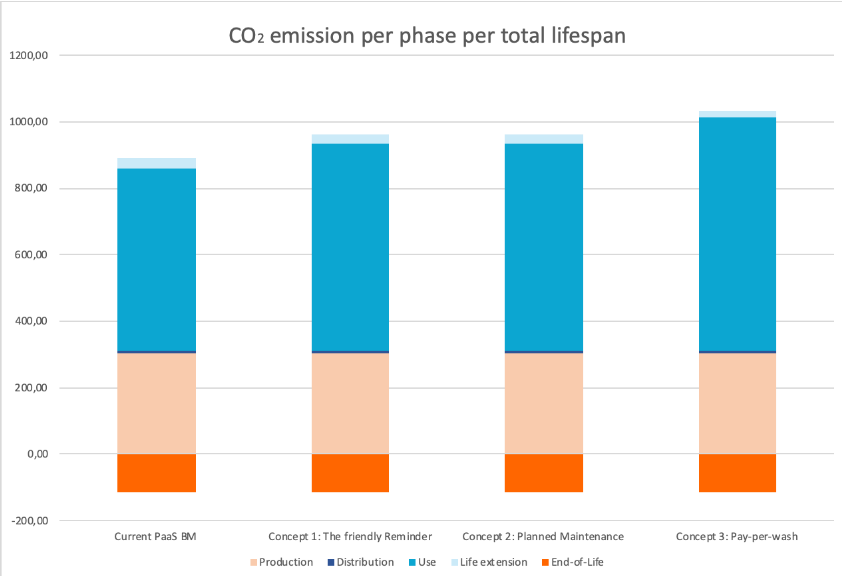


Figure 4.13 CO_2 emissions per life cycle phase per total lifespan (Source: Author)

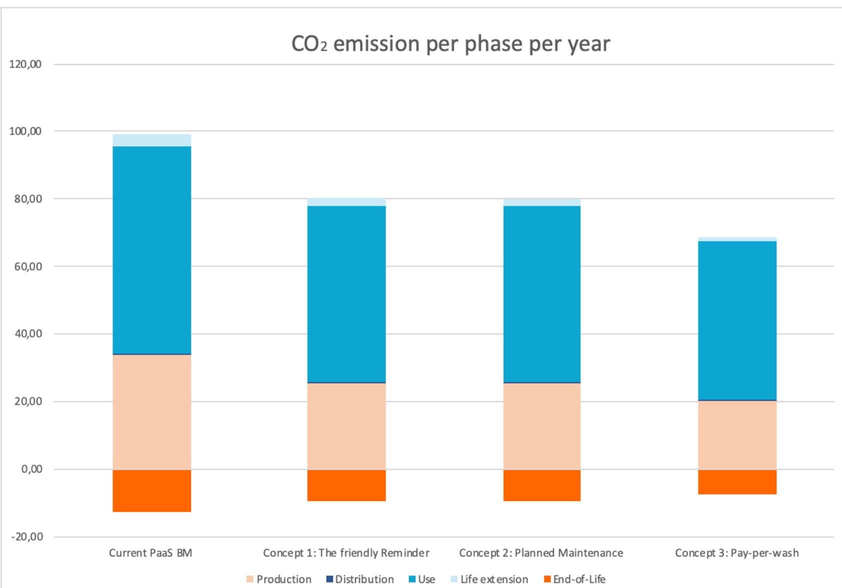


Figure 4.14 CO_2 emissions per phase per year (Source: Author)

Table 4.15 CO_2 emissions impacts of the three alternative designs (Source: Author)

	Current PaaS BM	The friendly reminder	Planned maintenance	Pay-per-wash
Energy label	A+++-30%	A+++-40%	A+++-40%	A+++-40%
WM built	Basic	Mid-range	Mid-range	High-end
Lifespan [year]	9	12	12	15

05.

DISCUSSION

This research was an explanatory and descriptive research on measuring the environmental impact of the Product-as-a-Service business model by Coolblue and exploring ways to improve upon this impact. In this chapter the research process of this study is reflected upon by discussing the limitations concerning the performed literature review, case study, screening LCA and alternative design concepts. Secondly, the scientific contribution and thirdly the broader relevance of this research are mentioned.

5.1 Limitations

5.1.1 Literature review limitations

An extensive literature review was done on the topics of the Circular Economy, Product-Service Systems, the washing machine industry and possible frameworks. However there is such an abundance of literature available on these topics that not everything was assessed. This may have resulted in some sub-functions or means not being considered for the new design concept. By performing multiple interviews and field visits the research has tried to diminish this fact.
The alternative cases Homie and Bundles were categorised as product oriented product-service systems (PSSs). This is because the user receives a WM and has exclusive access to it. Both BMs could also be considered as a result-oriented PSS as the users pay per wash. Nevertheless it is expected that this does not affect the results for this study as the two cases were solely used as inspiration to improve the environmental impact.
Furthermore, the SPSS framework used to analyse the five cases in this research has been constructed by combining two frameworks. Although the construction of this adaptation and interpretations was done as thorough as possible, it could be that the FW was not complete and therefore some functions and means were missed. The social and economic aspects of the business models (BMs) have been barely touched upon. This was not the aim of the research.

5.1.2 Case study limitations

Three companies were interviewed for the inspirational case study analysis. The intention was to interview companies with different PSS BMs in order to incorporate multiple perspectives. Eventually only product lease companies were interviewed for two reasons. These were the only three companies that showed to be active with sustainability. Secondly, there was only one result-oriented company active in the Netherlands. This company seemed to be in a start-up phase and was therefore not examined any further.
Nevertheless the information that was retrieved from the interviews is considered to be valuable for the new design concepts. There are two types of biases that may have influenced the case studies, namely respondent bias and researcher bias.

Respondent bias:
The respondent bias could be present in the way that the interviewee presented their answers in a socially desirable way or have overstated the steps that the company was actually taking. Another

limitation of the inspirational case studies was that only one interviewee from each company was interviewed. This might also have led to more optimistic outcomes of the companies. For the Coolblue cases it was also possible to perform field visits, which decreased this bias in their two case studies. Unfortunately it was not possible to perform field visits at the inspirational cases.
Researcher bias:
Considering the researcher bias, the interpretation of the gathered results may have been influenced unconsciously by the researcher. By using a fixed coding list of six elements the data was collected as structurally as possible. Because this list was fixed some answers might have been lost in transcription.

5.1.3 Screening LCA limitations

It should be highlighted that the environmental impact analysis contains a high degree of uncertainty as it was done on a screening LCA. Although results were validated with findings from the literature, these estimates still involved many assumptions. First it should be mentioned that the main research question aims to improve the environmental impact of the PaaS BM. In an LCA multiple impact categories are analysed in order to measure the complete environmental impact. Examples of these impact categories are eutrophication (aquatic), ozone depletion, human toxicity or ecotoxicity. In the screening LCA however only the impact category Global Warming Potential (GWP) and more specifically the CO_2 emissions were taken into account. GWP consists of multiple greenhouse gasses (GHG) such as CH_4, N_2O, HFCs, CFCs, etc. CO_2 emissions is the primary GHG emitted through human activity. Therefore in this analysis it was assumed to be the most relevant GHG emission.

A parameter that had a major influence on the outcome of the comparative LCA is the energy label and lifespan of the WM. The traditional BM had a A+++-10% energy label and twelve year lifespan. The PaaS BM had a A+++-30% energy label and nine year lifespan. These lifespans were based on the quality of the WM. The impact of consumer behaviour on the lifespan of the WM was not taken into consideration. A sensitivity analysis on the energy label and lifespan might show what the actual influences are.

The CO_2 emissions caused by the production phase are taken from the Ecoinvent v3.6 database. These numbers are based on the paper by Yuan *et al.* (2016). The paper itself also has some limitations. For example some components are outsourced. For these components only material consumption is taken into consideration and not the manufacturing itself. This leads to an underestimation of the production phase.

For measuring the distribution it is assumed that the WM shipped from the port of Shanghai, as it is well-known for shipping consumer goods. Transportation within China was not taken into consideration. The ship in question, MSC Beatrice, is one of the largest container ships in the world. It was not considered that the size would change the route as it may not be able to sail everywhere. Emissions from loading and unloading the containers, construction of the ship and containers and human caused emissions were not included.

The emission factors caused by truck transportation were taken from the TNO report of 2016. Although this report forecasts what the factors in 2020 might be, it is still a prediction based on data from four years ago. A combination of the emission factors is made based on the different road types. Even though the reasoning behind this is explained, it is still highly subjective. Although a lot of assumptions were made during this phase, it is expected that other choices would not have resulted in much higher CO_2 emissions and thus increasing the impact of the distribution phase to a more significant share of the total life cycle.

The impact of the user phase was solely based on the electricity use in kWh of the WM during the life span. The amount of kWh was based on the average yearly energy consumption of an European household who performs 220 wash cycles using only the 40 and 60 degrees eco programs and a load capacity of 8 kgs (Rowan, 2020). (Pakula and Stamminger, 2010) state that on average Dutch people wash 165 times per year. Bocken *et al*. (2018) think that the actual number is higher because people wash more than they report during interviews. It is important to acknowledge these differences as they have a significant impact on the user phase.
The decision to include only the electricity use of the WM in the user phase was based on the paper by Yuan *et al.* (2015). The study shows that electricity consumption takes up 95% of the total Global Warming Potential (GWP) and tap water 5%. When looking at other impact categories, such as Abiotic Depletion elements (ADP elements) or Eutrophication Potential (EP), detergents use up to around 80% of the share and electricity 10% to 20% (Yuan *et al.*, 2016).
CO_2 emissions from detergents, water supply and waste water treatment were not included in the screening LCA. This led to an underestimation of the CO_2 emissions measured in the user phase. For the completeness of a future LCA, these emissions should also be incorporated. It is important however to point out that water supply and detergent usage are interconnected and that emissions should not be calculated twice.

To estimate the impact of the Life Extension phase three activities were taken into consideration. Firstly, the energy use for two wash cycles. Secondly, the emissions from transporting the WM from the WH to the customer. Thirdly, it was estimated that the refurbishing process would need 10% new materials. This was calculated by taking 10% of the total CO_2 emissions in the production phase. The production phase however also includes CO_2 emissions during assembly. The estimation has also assumed that every WM can be refurbished. The 60% success rate from theCoolblue refurbishing pilot was not taken into account. This led to an overestimation of the CO_2 emissions during the life extension phase.

The collection rate at End-of-Life (EoL) was assumed to be 100% in the PaaS BM in order to make a clear distinction between the two Coolblue BMs. A collection rate this high is impossible as there will always be a machine or part of a machine that is not collected. The collection rate is also related to customer willingness. This was not taken into account. Furthermore, the EoL phase was calculated as a recycling credit by taking 10% of the CO_2 emitted in the production phase. It is important to note that for the initial production estimate no recycled materials should be used. This would mean that avoided CO_2 emissions have been accounted for twice. Emissions of the recycling process itself were not taken into consideration. The CO_2 emissions from incinerating parts that could not be recycled are also not accounted for. Therefore the EoL recycling credit is overestimated

5.1.4 Alternative design concepts limitations

A total of three design concepts were constructed using the morphological chart method. The overall function of a PSS BM in the washing machine industry was established and then sub-functions for the phases in a WM life cycle was constructed. It was concluded that Coolblue has no direct influence on the production and EoL phase. Furthermore, the effect of the distribution phase on the overall share of CO_2 emissions was considered insignificant. No sub-functions and means were therefore constructed for these three phases. Nevertheless, from the interviews some actions were established that could reduce the CO_2 emission during these three phases. A function analysis usually precedes a morphological method. In this study however, constructing the sub-functions and corresponding means was an iterative process. This might have resulted in overlooking some sub-functions.

For each of the sub-functions possible means were found. A total of 21 means were found throughout the literature review, interviews and brainstorming. Some of the means that were not chosen due to suitability could still be relevant for Coolblue if they are properly designed. For example a 'washing championship' might be suitable for Coolblue if it is set up on a general level and Coolblue knows what they want to educate the consumers on.
The implementation of some means such as 'a deposit' or 'strict contractual terms' might prevent consumers from choosing the PSS BM. The downsides of means were taken into consideration in the suitability score.
The suitability of a mean was based on the NPS, EBITDA and overall suitability to Coolblue as a company. Although the research has tried to remain as transparent as possible it could be that some subjectivity was present. By implementing five degradations for suitability this subjectivity was minimised.
For Coolblue it would have been interesting to see what the financial costs would have been for each mean. This was however not the scope of this research. It was not possible to assess all the combinations of all means. It should be noted therefore that there are other combinations of means possible for Coolblue to improve their environmental impact. The means can also be implemented independently.

The effectiveness of each mean has been determined. This was done as transparent as possible. Nevertheless, determining the effectiveness remained highly subjective. The concepts are aimed to decrease the CO_2 emissions of the current PaaS BM and should be seen as a stepping stone towards circularity. Complete circularity will not be possible. The energy label in combination with the lifespan of the WMs is the main influence in the emission difference. The lifespan was based on the building quality of the WM. It should be noted that if the energy label improves, the outcome of the design concepts will also change greatly.
Furthermore, the PaaS business case assumes that a user holds on to the WM for three after which it is refurbished. In the estimations for the design concepts of 12 and 15 years, the refurbishment

process was only taken into consideration once. For completeness of the designs the CO_2 emissions of refurbishment or repairs should be considered more often.

The two sub-functions of the life extension phase were meant to 'stimulate careful use' and 'prolong the material life cycle'. The effectiveness of the chosen means was multiplied by the CO_2 emitted during the life extension phase. Perhaps it would have been more appropriate to relate these means to the EoL phase, since the two means have an effect on the quality of the returned product. This would increase the recycling credit as more valuable components or materials are retrieved.

5.2 Scientific contribution

From the literature review it became clear that a lack of assessment methods for evaluating the CE impacts is hindering the implementation of CE (Bocken *et al.*, 2016b; Bresanelli *et al.,* 2019*)*. By performing a screening LCA this study has added more insight on this subject. The effect of services on the environment remains unknown. The assumption was that due to extra logistical steps a PSS BM might have a higher environmental impact during the distribution phase. This study showed that the impact of the distribution phase was insignificant compared to the other phases in a WM life cycle.

The literature stated that in a linear BM the user phase of a WM life cycle was a hotspot (Amasawa *et al*., 2018; Bocken *et al*., 2018; Giagnorio *et al.*, 2017; Laitala *et al*., 2018). From this study it became clear that in a product lease BM the user phase is still responsible for the highest CO_2 emissions. Therefore this research confirms the importance of washing behaviour during the user phase on the environmental impact of a WM.

Literature stated that from the three PSS categories result-oriented PSSs can achieve the highest resource efficiency and circularity (Michelini *et al.,* 2017). Bundles and Homie were considered a product lease PSS with a pay-per-wash financial model. Both companies and especially Homie seem to be able to influence the washing behaviour of their users. Based on this information it could be concluded that the financial model of pay-per-wash can also contribute to the circularity of the PSS BM.

Literature showed some potential benefits of a PSS BMs for the customer. From this study four additional benefits can be mentioned. Firstly, a PSS BM can give elderly people the feeling of independence back. Secondly, a PSS BM can also offer the opportunity of social contact. Thirdly, a PSS BM also gives the customer the option to buy certain 'status'. For example, people who are not able to pay for a Miele WM can now show their friend that they have enough money to use a Miele washing machine. Lastly, the literature mentioned that more jobs can be created. This benefit was confirmed during the interviews. These jobs can also be given to those with a distance to the labour market.

There is a technological barrier for the transition towards a PSS. The literature never mentioned that some conventional household products are not suitable for a PSS type BM. The disassembly and refurbishing of components is very time-consuming. If WMs would be specifically designed for PSS use, the BM would financially be better equipped opposed to the linear BM.

Furthermore, this study has developed a framework which allows for structural analysis of a WM life cycle in a PSS BM and reveals which variables should be considered for an LCA. In the literature a WM life cycle is explained in four phases, namely: production, distribution, utilisation and disposal. From this research it was established that the utilisation phase should be subdivided into a user phase and life extension phase. The user phase holds all the activities that take place when the WM is at the user. The life extension phase focuses on the actions that are taken to prolong the lifetime of a WM at the End-of-Use (EoU). This division was done to make it more clear which activities extend the lifespan of the WM after the EoU.
The screening LCA and morphological chart in this research could have been realised more thoroughly. However, the study shows that both methods work.

5.3 Broader relevance and implications

The literature review shows the importance of the CE and the role that a PSS BM can have towards its transition. This research analysed the environmental impact of a product lease BM for WMs. In particular, the product lease BM by the Product-as-a-Service department of Coolblue was analysed. The screening LCA has given a rough overview of the CO_2 emissions of two WM BMs by Coolblue (i.e. PaaS and traditional BM). It shows that CO_2 emissions in the user phase have a significant share of the total impact in both BMs.
The screening LCA can also be used for further research if Coolblue decides to analyse its impact. This needs to be done by a certified organisation. The aggregation of the variables and emission factors from this study can be used as a starting point.
The literature also showed that a PSS can achieve sustainability gains if it is intentionally designed to do so. As Coolblue has a clear overview of the hotspots in the WM life cycle, it can now start redesigning their product lease towards circularity. The three alternative design concepts can be used as a guideline to achieve this goal. The concepts were designed out of a combination of means that were found throughout this study. These concepts can be implemented by the PaaS team to reduce their environmental impact. Even a single mean can also independently enforce a reduction in the environmental impact of the WM life cycle.

The methods in this study such as the SPSS framework and screening LCA can be used by other PSS providers. Some of the means can also be used by other WM product lease providers, as a WM was the main focus of this research. The design alternatives can also be applied to other consumer goods in a PSS BM, both use-oriented and result-oriented. Some of the means can even be implemented by consumer good providers in the linear economy.

The interviews showed that PSS providers are still having difficulty competing against linear models. This is mainly due to financial issues. One of the companies still exists because of external funding. Lowering taxes or offering subsidies can make the BM more financially attractive. Another obstacle is the fact that conventional WMs are not fit for a PSS BM. Manufacturing a WM that is suitable for PSS requires high investments and a long term perspective from investors.

06.

CONCLUSION & RECOMMENDATIONS

In this final chapter, the conclusion of this thesis is presented. The answers to the four sub-questions are given. These will help to answer the main research question of this research: *How can Coolblue improve the environmental impact of their current and future washing machine product-service system?* This chapter is completed with recommendations for product-service system providers, washing machine producers, policymakers and future research.

6.1 Conclusion

SQ 1: What is the current state of product-service systems within the washing machine industry and their environmental impact?

Product-service systems (PSS) are said to be the pioneering business model (BM) to lead the transition from a linear to a circular economy. In a PSS the user is no longer the owner of the product. Therefore the provider is more interested to control and prolong the material flow. This could lead to a decrease in material consumption. However not all scholars are convinced that PSSs should be called the sustainability panacea.
A washing machine is considered to be a perfect candidate for a PSS BM and there are several companies in the Dutch washing machine industry that opt for a PSS business model. The most common one being a product lease BM. Nevertheless, the result-oriented category seems to be the most promising to achieve circularity and contribute to resource-efficiency. Only one company with a result-oriented PSS BM was found to be active in the Netherlands.
According to the literature, there are various activities in the washing machine (WM) life cycle that have an impact on the environment. Activities that have a significant impact are the frequency of washing, the washing temperature, energy label, the detergent volume, the WM building quality and material supply during production. These studies are based on a linear WM cycle or renting/sharing a WM. The environmental impact of WM in a product lease PSS BM is yet unknown.

SQ 2: What is the environmental impact of Coolblues washing machine business models and how can they be analysed?

There are two BMs which Coolblue use to sell or lease WMs. The first is the traditional selling BM and the second is the product lease BM. The environmental impact was measured by performing a screening LCA in order to estimate the CO_2 emissions of both BMs. These emissions were then compared with each other in a comparative LCA analysis. For the product lease BM also a hotspot analysis was executed to show which of the phases in a WM life cycle had the greatest contribution in the environmental impact. A phase was considered a hotspot if its impact exceeded 10% of the overall life cycle impact.
Before estimating the environmental impact the BMs were first analysed structurally by the Sustainable Product-Service system business model Framework (SPSS FW). The framework consisted of six elements: Value Proposition, Customer, Key Activities, Key Resources, Adoption factors and the Life Cycle Impact Assessment. The framework was filled in with information

retrieved through semi-structured interviews, field visits and desk research. Based on the analysis it became clear which elements needed to be taken into account when measuring the environmental impact.

For the business case of the traditional BM it was assumed that the WM would be used by the customer for twelve years. After these twelve years it is assumed that the WM breaks down and is recycled. The WM in this BM has an energy label of A+++-10%. In the PaaS BM the WM is assumed to be used for three years, after which it is refurbished and used for another additional six years. The energy label of the WM was considered to be A+++-30%. The total CO_2 emissions over the total life cycles were similar, however when dividing the emissions per year a 35% difference was noted in favour of the PaaS BM. This difference is explained by the fact that the WM in the PaaS BM is assumed to have a life span of nine years, whereas the WM lifespan in the traditional BM is assumed to be twelve years. When comparing the CO_2 emitted per year, a difference of 10% is detected in favour of the PaaS BM. This difference is mainly due to the improved energy label in the PaaS BM. From the hotspot analysis it became evident that the user phase is the highest (71%) contributor to the overall CO_2 emissions share. The production phase has the second highest share (39%) of the CO_2 emitted in the ten year WM life cycle in the PaaS BM. Given its explorative character, the results of this study cannot be used for a comparative assertion disclosed to the public.

SQ 3: How do alternative product-service systems in the washing machine industry decrease their environmental impact?

Besides the Coolblue cases, there were three alternative cases in the washing machine industry analysed, namely BlueMovement, Homie and Bundles. These analyses will provide input for new design concepts to decrease the environmental impact of the Coolblue PSS BM. All three companies are categorised as a product lease PSS BM. Homie and Bundles carry out their WM lease with a pay-per-wash model.

From the interviews twelve ways to decrease the environmental impact of a PSS model were recognised. By using high quality WMs with a high energy label, energy, water and detergent consumption can be limited. Using WMs from one brand and a limited number of WM models can allow for more efficient storage and remanufacturing. In addition, all three cases showed the importance of waste hierarchy. First the WM should be reused. Second preventive maintenance should be carried out. A third action is repairing WMs and the fourth would be refurbishment of components. Lastly, the option of component recycling should be considered.

The case of BlueMovement showed that a strong connection with the manufacturer can make disassembly of the components easier. This is because the PSS provider knows exactly how the machine is built and assembled.

The two pay-per-wash cases showed that the BM stimulates the user to decrease the amount of wash cycles. In the case of Homie the price per wash differs based on the temperature and dryness program. Both these incentives have resulted in a 25% water and energy savings for Homie users. The case of Bundles highlighted the importance of explaining the WM during installation. If explained correctly, the user will not have to flip through the entire manual. The company can explain which programs are most environmentally friendly.

For the future there were also changes recommended that have the potential to decrease the environmental impact. All three companies recommended a change in design. Specifically designing a WM more suitable to the PSS BM. For example, by building WMs out of modular components and by omitting excess functions on the machine the life expectancy can improve. Since PSS BMs usually demand more logistic steps than a regular BM, two of the three cases stated that optimising their distribution phase was important.
Bundles mentioned looking into different PSS BMs such as sharing a leased WM and shifting the ownership from provider back to the manufacturer.

SQ 4: What alternative washing machine designs can be developed to improve the environmental impact of the Coolblue washing machine lease?

The last sub questions deals with designing new concepts which can decrease the environmental impact of the PaaS BM by Coolblue. Each concept is made up of a combination of means, aiming to decrease the environmental impact of the current PaaS BM. Coolblue has no direct influence on the design choice in the production and EoL phase. From SQ 3 it became clear that the distribution phase showed to have an insignificant contribution to the overall environmental impact. Therefore, no sub-functions and means were designed for these three phases.
The means were based mostly on information provided by the inspirational cases and brainstorming. Three alternative PSS design concepts were established. Concept 1: The Friendly Reminder, Concept 2: Planned Maintenance and Concept 3: Pay-per-wash. All three concepts included improving the energy label of the WM to A+++-40%.

Concept 1'The Friendly Reminder' contains measures that are easy to implement in the current product lease and can easily be taken up by the PaaS department. Measures such as explaining the WM during installation and reminding the consumer of careful use during the subscription through email. A 17% decrease in CO_2 emissions per year can be realised by releasing this alternative in comparison to the PaaS BM. This is mostly because of the different energy label of the WM.

The second concept 'Planned Maintenance' still opts for a product lease BM in which more boosting means have been implemented. In this design, measures such as planned maintenance and explanatory stickers to educate the users will help to improve the environmental impact of the BM. Also the building quality of the WM is upgraded to mid-range. These measures can result in a 19% decrease in CO_2 emissions per year compared to the current PaaS BM. This decrease is mainly due to the energy label of the WM, planned maintenance and WM quality. The means cause an additional 2% reduction in CO_2 emissions compared to the first concept.

The third concept shows the most radical combination of means. Measures such as, paying-per wash BM with differentiated prices. This design choice requires a built in device which also makes predictive maintenance possible. The suitability of some of the means chosen in this concept are labeled as 'limited'. This is because the current business model is not equipped to install built in device and a pay-per-wash model. Nevertheless the means were chosen to show the effect that these more radical means have on the CO_2 emissions. The WM in the Pay-per-wash concept is of high-end quality. It is therefore assumed to withstand a minimum of 5000 wash cycles. All these means result in the highest decrease, namely a 29% CO_2 emission reduction per year.

Main RQ: How can Coolblue improve the environmental impact of their current and future washing machine product-service system?

The main research question consists of two parts, namely how can Coolblue improve their current WM lease subscription and how can they improve future subscriptions. It is worth mentioning that the current PaaS BM should not be categorised as a product lease until the WMs are sent back into the subscription loop.

Based on this study the production phase has a significant influence on the overall environmental impact. Coolblue however has no direct influence on this phase. Nevertheless there are some choices for the assortment that Coolblue can make. Coolblue is advised to choose horizontal-axis WM. The energy label should be A+++-30% or higher. If financially possible Coolblue should opt for a high-end WM as it can endure more wash cycles than a mid-range or basic built WM. It is also advised to offer less WM brands and less different WM models in the assortment. This can enhance the efficiency of the repairing and refurbishing process. Furthermore, it is recommended for Coolblue to use their relationships with manufacturers to encourage them towards more sustainably built WMs suitable for a PSS BM.
From the hotspot analysis it became clear that the distribution phase causes an insignificant impact on the total amount of CO_2 emissions. Nonetheless, the distribution phase could be more efficient by offering postal code or street discount. This could optimise the driving routes even further, assuming that these discounts will not increase WM sales unnecessarily. Second, by selecting manufacturers closer to the WH less transport emissions will occur. Third, by reducing packaging the impact could even be further reduced. A fourth action could be to transport the WMs by electric vans. This action does not take the emissions caused by the production of new vans into account.
The literature review and hotspot analysis showed that the user phase is the biggest hotspot. This is mainly due to the energy label and lifespan of the WM. The user should be educated to wash more sustainably and use the WM more carefully. Placing stickers on the WM can remind the user of sustainable washing and careful use. During installation the WM and its eco programs should be explained. To extend the lifespan of the WM careful use should be stimulated by offering rewards for returning WMs in good condition (e.g discount coupons). Furthermore it is important to prolong the material life cycle of the WM by repairing the WM at the users home instead of offering a direct swap or by establishing planned maintenance. By offering a service (i.e. planned maintenance) within the PSS subscription some breakdowns can be prevented.
For the EoL phase Coolblue can improve the training of personnel and monitor their performance. This might decrease the number of unnecessarily discarded products sent to the recycler.

In conclusion, based on this research the user phase in a life cycle of a WM shows to have the greatest impact in CO2 emissions, both in a linear and product lease BM. Ways to decrease this impact should be focused on educating the user and stimulate sustainable washing behaviour.

A pay-per-wash model with tiered prices can influence the washing behaviour significantly. It stimulates the customer to wash less using a more environmental friendly program. The model would require a built in device which would make predictive maintenance also possible. PSS providers can influence the emissions of the WM lifecycle by choosing a WM with a high energy label and built with high-end quality.
Furthermore, the production phase is the second greatest contributor to the overall CO_2 emitted in the WM lifecycle of a product lease BM. WM manufacturers can play a major role in designing new washing machines that are more suitable to a PSS BM. This would entail that WMs are modular built. This would make disassembly easier and refurbishing and upgrading more efficient. Which could decrease the need for new raw materials.

6.2 Recommendations

In the following sub paragraph recommendations for PSS providers, WM manufacturers, policymakers and future research are made.

6.2.1 Recommendations for product-service system providers

The first recommendation is that PSS providers must intentionally design their PSS BM towards circularity by looking into the option of all three PSS categories. Some categories may have better results environmentally (i.e. result oriented). The waste hierarchy should be used as a guideline to keep materials in the loop as much as possible. Training personnel and monitoring performance can decrease the number of unnecessarily discarded products sent to the recycler.

Another recommendation for PSS providers would be to decrease their product assortment if possible. By restricting the number of brands and types, the repairing and refurbishing process can be more efficient.

Implementing technological innovation into the PSS can result in decreased material consumption. For example predictive maintenance will decrease product breakdowns. Built in devices can monitor user behaviour and result in enabling a pay-per-wash model and offer more targeted feedback.

Furthermore PSS providers are recommended to stay in touch with the customer as the success of a PSS depends on the relationship. By offering a good service, users are more inclined to look after the product. This is of course very target group dependent. Besides strong bonds with the consumer, PSS providers are advised to strengthen their relationships with manufacturers to encourage them towards more sustainably built WMs.

6.2.2 Recommendations for washing machine producers

Manufacturers are recommended to look into the possibility of new washing machines designed specifically for PSS BMs. This would entail WMs that are modular built, which would make disassembly easier and refurbishing and upgrading more efficient. Also for a PSS BM it is preferred that these WMs should be easier to transport. This can be done by replacing the concrete block inside by a bag of water. The number of unnecessary programs and corresponding materials can also be reduced for these new PSS WMs.

It is important to note that these investments in new PSS products require a long term perspective as the benefits of such designs will take eight to ten years.

Another recommendation for manufacturers would be to think about setting up their own PSS BM. This could eliminate the need for retailers, which could affect the market price. Manufacturers might also be more inclined to improve the quality of the WMs, which could eliminate planned obsolescence.

6.2.3 Recommendations for policymakers

Recommendations for policymakers was not an intended outcome of this research. Through the interviews it became apparent however that policymakers still play a big role in the success of PSS BMs. Policymakers need to revise the financial models of traditional and PSS BMs. Also policies should be put into place to make the PSS BM more attractive.

6.2.4 Recommendations for future research

For future research it is important to look into design possibilities for WMs that are more suitable for PSS BMs. Future research could also look at other ways of influencing washing behaviour, besides the financial incentive. What other incentives can be taken to change the washing behaviour of the consumer?

Furthermore, future research should involve a complete LCA for WM in a product lease BM taking different impact categories into account. It would also be interesting to measure the environmental impact of other PSS BMs and other consumer goods.

Lastly, the customer acceptance of second hand WMs, renting a WM, sharing a WM should be investigated. What are the stigmas around these BMs and how can they be dealt with?

07.

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08.

APPENDICES

Appendix A - Company information

A1. History
CoolBlue is one of the biggest online webshops in the Netherlands, specialised in consumer electronics. The idea to start a company came up when three friends, Pieter Zwart, Paul de Jong and Bart Kuijpers, were brainstorming in a Dutch café in 1999. They were 21 years old and studied business administration at the Erasmus University of Rotterdam. While their initial goal was to become multi miljonairs, after a short discussion they realised that it would be better *to become an example for other companies in the field of customer oriented entrepreneurship*.
They started selling MP3 players from a little dorm room in Rotterdam. They are now specialised in 10 categories from white goods to garden & tools. Within 5 years they had a turnover of 16.4 million euros per year (nieuws.coolblue.nl, 2019). In 2010 this was increased to nearly sixfold with a revenue of 100 million euros per year. In 2018 they had a record year when it came to finances. Mid 2019 Zwart bought de Jong and Kuijpers out with the financial assistance of HAL investment who now owns 49 percent of the company (nieuws.coolblue.nl, 2019).

Coolblue is active in both the Netherlands and Belgium with a turnover of 1.35 billion (nieuws.coolblue.nl, 2019) euros in 2018.. With 12 physical stores in Amsterdam, Arnhem, Den Haag, Eindhoven, Groningen, Haarlem, Utrecht, Rotterdam, Tilburg, Antwerpen (BE), Gent (BE), Wilrijk (BE), and Zaventem (BE), they are one of the biggest e-commerce businesses in the Netherlands and Belgium. Their head office is in Rotterdam and two distribution centres in Capelle aan den Ijssel and Tilburg. Coolblue offers jobs to more than 4500 people (Yearbook, 2018).

A2. Company core values
It is said that the huge success of the company is due to their core company values, *unconventional, friends, go for it, flexible and simply amaze*, illustrated in figure A.1 (Yearbook 2018, 2018). These values were written down in a manifesto in 2011, and they are still practiced today. It is important for CoolBlue to know that everyone understands who they are, what they stand for, what unites them and how they treat one another. Every decision made, big or small, is based on these core values.

CoolBluers are *unconventional*. Everyone should be able to be themselves because people who are true to themselves are hard to copy. They are all doing this for the first time, so the right answer is not always apparent immediately. That is why they need daring people that do things that have not been done before. There are not many companies where so many people are both *friends* and colleagues. This value forms the basis of how CoolBlue was founded, and this is still one of their strengths. Friends are honest, direct and open with each other as are their suppliers and customers. This approachable yet professional way of working is experienced in the office. This is evident in their use of funny names for conference rooms to word jokes on the coffee machine. Just *go for it* is their third value with a no-nonsense entrepreneurial attitude. This idea is useless without a follow up. Don't over analyse in endless discussions but switch over to immediate action. In order for CoolBlue to keep up with the rapid growth they are undergoing it is important to stay flexible. This flexibility can be found in the development of their system that can handle double the expected load. Or perhaps due to the fact that CoolBluers continuously want to improve their own expertise. The last value *simply amaze* sounds contradicting, but that is what makes it CoolBlue; both unconventional and down-to-earth. Exceeding the expectation of the customer through simple yet meaningful gestures. At the end of the day, Zwart classifies his company as just an ordinary retailer that works in a special way. They just 'sell stuff' but are always obsessed with the customer journey.

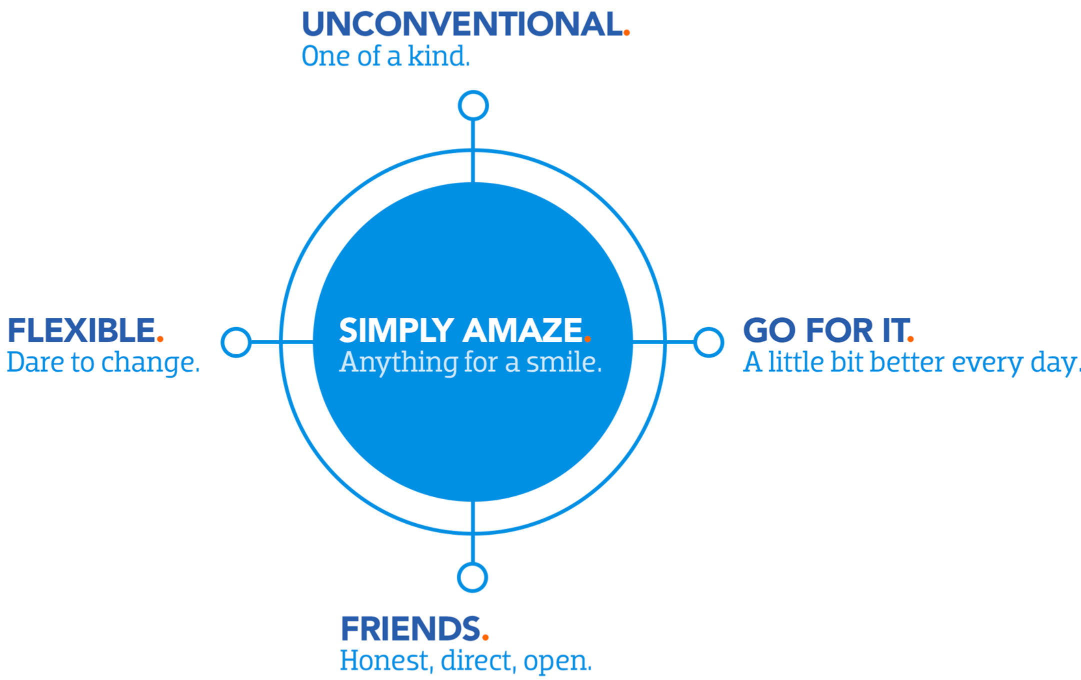


Figure A.1 Company core values (Yearbook 2018, 2018).

A3. Measuring success

Coolblue measures its success in two ways. First its profitability in EBITDA: Earnings Before Interest, Taxes, Depreciation and Amortization. The EBITDA increased 28% from €26.9 million in 2018 to €34.5 million in 2019. Coolblue says this is due to the improved purchase conditions, rationalisation of the product assortment and optimal cross sell opportunities.
Second they measure success by its customer satisfaction using the Net Promoter Score (NPS). The NPS is measured by how likely a customer is to recommend Coolblue's service to a friend. Customers that score Coolblue between a 1 and 6 are called Detractors. Passive customers give a score of 7 or 8. Promoters would definitely recommend Coolblue to a friend as they give a 9 or 10 (see figure A.2). The NPS is calculated as follows: % Promoters - % Detractors. In 2018 Coolblue had a NPS of 68 and in 2019 this number increased to 69.

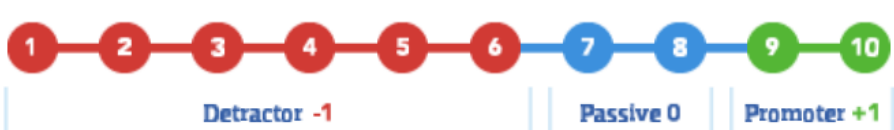


Figure A.2 NPS scoring card (Yearbook 2018, 2018).

A4. Go Green

Coolblue has a Green department that focuses on making Coolblue more sustainable. Three focus areas can be distinguished: assortment, consumption and waste management (Yearbook 2019, 2019).

Assortment

By providing better insights in the product's energy consumption, Coolblue helps its customers to make eco-friendly choices. Also after purchase, advice on how to use their appliance in the most energy-efficient way are given. To further help its customer, Go Green labels are used for the five most energy-consuming products groups. This label indicates which products are the most energy efficient.

The products that are offered on the website is a high-quality range. If customers repeatedly indicate that they are unhappy with a product, the product is removed from the product range and replaced. Also suppliers are asked to create products based on this feedback. This all results in less defect products and product returns.

In 2019 Coolblue started selling and installing solar panels. This way customers can generate their own energy and become more sustainable. They have also installed solar panels on top of their gigantic warehouse.

Consumption

Coolblue is well known for their iconic blue carton box. In 2019 they saved over 20% on the consumption of cardboard. The materials that do go into the cardboard packaging are 75% recycled. Since 2020 many of their products are delivered in a carton bag using bike deliveries. This allowed Coolblue to save up to 80% on the carton used and deliver 10% more packages by bike.

Waste management

Other green initiatives that Coolblue promotes is SecondChance. Whenever a customer returns a product, it is sent to the Warehouse where it is checked for any damages and defects. When possible the product is repaired, cleaned and sold with a fitting discount on their website.

Besides reselling products in SecondChance, some whitegoods are being refurbished. Discarded products are taken in by Coolblue and if possible refurbished. Currently only washing machines, dryers and dishwashers are refurbished. From the waste that is generated in the depots and warehouse, 97% is successfully separated. This includes cardboard, styrofoam, wood and plastics. Also a pilot has been started with the biggest suppliers to send new stock in reusable containers, which has led to a significant decrease of incoming streams of cardboard.

Lastly, Coolblue offers repairs in store and on location for certain types of products. This extends the product's lifespan and decreases the waste flow. It also requires less transport and is more convenient for the customer.

Appendix B - Hierarchical cycles of the Butterfly diagram

Table B.1 Explanation behind the hierarchical cycles

1. Prevention	The most preferred option is to prevent any waste from happening (Lansink, 1979)
2. Minimisation	If prevention is not possible, consumption should be minimised which can then also lead to less waste
3. Maintenance	Maintenance prevents a breakdown or defect from happening, which extends the life time of the product. This is usually performed as a scheduled activity. Cleaning or other esthetic measures are also considered maintenance.
4. Repair	Repair extends the life time of the product after a breakdown of defect has occurred, which restores the product to its original state, or less (Parlikad *et al.*, 2003). Therefore, the warranty is not restored. Cleaning or other esthetic measures are also considered repair.
5. Refurbishing	Refurbishing a product is taking a used product and bringing it back to a satisfactory working state. Components close to breaking are swapped, which makes refurbishing a combination of maintenance and repair (Bakker *et al.*, 2014).
6. Redistribution	Redistribution can also be described as *reuse without treatment*. By redistributing the product to another user who still has a need for the product. A platform such as Marketplace is usually needed to connect users and facilitate this swap.
7. Upgrading	Upgrading means that out-of-date components or modules are swapped with more technologically superior ones (Parlikad *et al.*, 2003).
8. Remanufacturing	Remanufacturing means to repair or replace components, so that an equal or higher performance of the product is reached. Therefore, the warranty of the product stays (Bakker and Hollander, 2013).
9. Recycling	Recycling recovers some base materials from the used product, however the added or embodied value (i.e. energy, labour and costs) is not retrieved.
10. Energy Recovery	Energy recovery retrieves some of the energy content in the form of heat, electricity or fuel.
11. Disposal	Disposal must be seen as the final resort for a material flow. All other loops are recommended above this one.

Appendix C - Building blocks towards a CE

In order to overcome these barriers and transition towards a CE, scholars reckon that there are four fundamental blocks that should be built upon (EMF, 2012; Bresanelli *et al.*, 2017; Planing, 2018).

1. ***Materials and product design***: manufacturers should design their products in such a way that they are easy to reuse, remanufacture or recycle.
2. ***New business models***: a change from the traditional ownership-based model, towards a performance-based payment model is crucial to stimulate manufacturers in design-to-last products. In this service economy, consumers will become users and providers/manufacturers will remain owners of the product (Bresanelli *et al*., 2017). This will increase the durability and use-intensivity of products even more (Mont, 2008), as they are considered an asset, rather than a consumable
3. ***Reverse networks****:* in order to transition towards a CE, a reverse supply chain is needed in order to close the loop. The logistic chain for the collection of products and materials should be developed (Bresanelli *et al*., 2017).
4. ***Enabling conditions***: to enable this transition, some conditions must be met, namely: financial, educational, cross-cycle and cross-sector collaborations, but most importantly digital technologies (Bresanelli *et al*., 2017).

Appendix D - Circular economy principles

Principle 1: Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows (EMF, 2015: 5).

The first principle starts by dematerialising utility (EMF, 2015). This is accomplished when resources are selected wisely and technologies and processes use renewable sources. Michelini *et al*. (2017) state that only result-oriented PSS have contributed to resource efficiency and circularity. This is confirmed by Tukker who says that result-oriented systems offer the highest potential of radical resource-efficiency and thus are most effective when shifting towards a CE (Tukker, 2015). This is because they maximize product utilisation, without high risk of thoughtless product usage by the user(s) (Tukker, 2004). Use-oriented could result in less careful use and although product-oriented PSS are the easiest to implement, the provider is incentivised to sell as many products as possible and thus material use is not necessarily reduced (Michelini et al., 2017; Tukker, 2015). However, as more consumers' needs are met with one product in a use-oriented PSS, the system could still have a positive environmental impact.

Principle 2*:* Optimise resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles *(EMF, 2015: 7)*.

The second principle is focused on designing for remanufacturing, refurbishing and recycling, in order to keep components and materials within a closed loop. Companies that have a more service-oriented PSS type BM, are more likely to retrieve the products back at their highest value. As companies retain ownership in each PSS, they can reuse parts of the product up till the EoL (Michelini *et al*., 2017). Also, by retaining the ownership to the producer, the producer is incentivised to design a system with a higher resource and energy efficiency (Tukker, 2015). However, it should be noted that without ownership, consumers feel less responsible for the product and thus it could be more damaged when returned (Sumter *et al*., 2018).

Principle 3: Foster system effectiveness by revealing and designing out negative externalities *(EMF, 2015: 7)*.

The last principle highlights the importance of reducing damage to systems and areas. Sustainability considerations should be extensively represented in the PSS design, in order for initial potentials of sustainability gains to be uncovered (Tukker and Tischner, 2006). Therefore Michelini *et al.* (2017) state that the Life Cycle Assessment (LCA) tool is important in designing a PSS BM for a circular economy. The assessment will give important insights into how the products including externalities are designed and how they should be designed for continuous recovery and reusing products, components or materials.

Appendix E - Eight types of PSSs

According to Tukker (2004), Product-Service Systems (PSSs) can be split up in three main categories (i.e. product-oriented PSS, use-oriented PSS and result-oriented PSS) and further distinguished into eight types of PSSs, as shown in figure D.1 and explained below.

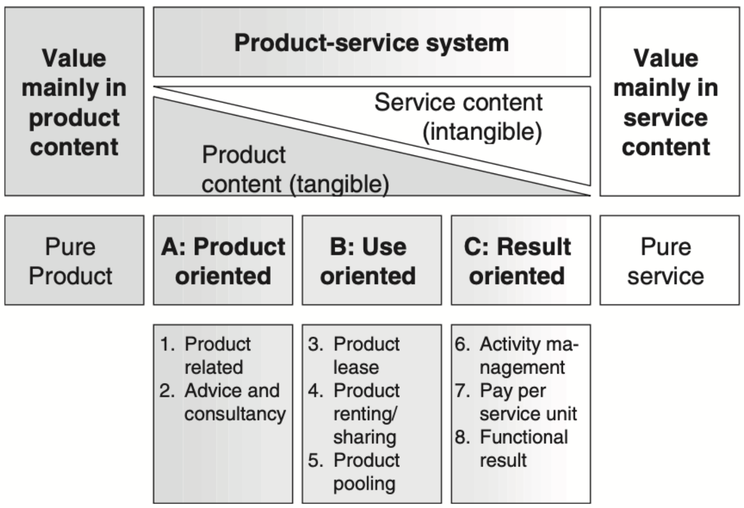


Figure D.1 Main categories and subtypes of PSSs (Tukker, 2004).

Product-oriented PSS

This category focuses on the sales of products but offers some extra services.

1. *Product related service:* Besides a product, the provider also offers a service that is needed when using the product. An example could be a maintenance contract.
2. *Advice and consultancy:* Information on the most efficient way to use the product is given by the provider, next to the product. Advice on optimising the lifetime of the product is an example of this service.

Use-oriented PSS

In the second category, the business model has shifted from traditional ownership to remaining in ownership of the provider and allowing the product to be used by multiple users.

3. *Product lease:* The provider is the owner of the product and for the regular fee, the user gets unlimited access to the leased product and services are offered, such as maintenance, repair, disposal and control. SwapBike is an example of such a lease, where the user pays a monthly fee to use the bike and the provider offers services such as repairs.
4. *Product renting/sharing:* This system is similar to product lease; however, the user does not have unlimited and individual access to the product. An example of this system would be ToolShare, where users can pay an hourly fee to use a certain tool or equipment.
5. *Product pooling:* The last use-oriented system strongly resembles the previous system; however, the product is used simultaneously by multiple users. Carpooling would be a good example of this system.

Result-oriented PSS
The last category does not focus on a product, but a certain result is agreed upon between the provider and customer.

6. *Activity management/outsourcing:* This system is explained by an activity of a company which is outsourced to a third party. The outsourcing of catering would be an example of this system.
7. *Pay-per-service-unit:* Here, the user does not pay for or own a product, only the output of the product is bought. Paying only for prints is a typical example of a pay-per-service-unit.
8. *Functional result:* Although this system is much similar to activity management/outsourcing, the output of the agreement between the two parties is different. Whereas the provider has a concrete result to deliver respectively in the latter system, the provider is freer to deliver the result in the other system. An example would be agreeing on the delivery of 'pleasant lighting' rather than specifying how much lighting or dimming.

Appendix F - Background in the washing machine industry

F.1 Historical background of washing

Since the origin of cloth, human beings have been washing their clothes. With the use of rocks, clubs and animal fat resembling soap, they would rub away the dirt in their local streams (Maxwell, 2003). Going from these rather primitive methods, a big leap is made to the 18th century where the first washing 'machine', a scrub board, was invented. This invention was still hand powered. It wasn't until 1908 when the first electric-powered washing machine was introduced by A.J. Fisher (Maxwell, 2003). The machine *Thor* was powered by an electric motor and gearing system, which empowered a drum to rotate eight times in one direction, before automatically rotating in reverse (figure F.1). From 1937, the first domestic automatic washing machines were introduced, an early adoption of the machines we use today (LIFE, 1950). Electric washing machines became popular from the 1950s onwards, due to the economic impact of the second World War. Over the past few years, washing machines are connected to the internet and updates have mainly been in reducing costs, increasing user friendliness and making the machines more environmentally friendly.

Figure F.1 Thor: First electric washing machine in 1908 (Maxwell, 2003)

F.2 Socio-cultural context of washing

In the frame of the Thor, an inscription was made stating "*SAVE WOMENS LIVES*" (Maxwell, 2003: 17). The imprint confirms that washing in those days was primarily done by women and the washing machine was there to make their lives easier. Washing back then would at times take up an entire day. The arrival of washing machines is said to be a force behind the empowerment of women, as it decreased the time and energy spent on household chores which enabled them to enter the workforce (Rosling, 2010; University of Montreal, 2009).
Whereas it is also stated that the washing machine has led to a type of social isolation, as women would usually come together in wash houses (French-Fuller, 2006).

When looking at the ownership of washing machines around the world (Laitala *et al*., 2017), the west of Europe has 94% of ownership, whilst hand washing is more common in the developing countries. In the Netherlands 98% of the people own a washing machine. In some countries it could even be seen as a status symbol, symbolising "*progress and modernity*" (French-Fuller, 2006: 85).

Amasawa *et al*. (2018) have looked at the behavioural shift between home washing and using a laundromat in Japan. Interesting outcomes from their research was that 68% of the respondents mentioned that being the owner of a washing machine was essential for their lifestyle. If their machine would break down they would use a laundromat, however only temporarily, as they would immediately buy a new machine. 22% Of the respondents did not think owning a washing machine was necessary. However distance to the laundromat, quality and the costs for washing and drying were most often mentioned for a lifestyle without a private washing machine.

Appendix G - Six steps for conducting an interview

1. *Choice of research topic*

Before being able to conduct an interview, the companies must know what the thesis topic is and what the goal of the interview is. The central theme of the thesis is environmental impact of PSS and the goal of the interview is to fill in the Sustainable PSS BMC for each of the companies as much as possible and finding additional information, if possible, on the environmental impact holders of the PSS.

2. *Preparation and planning*

Full disclosure will be given on the thesis. Also a consent form, with research ethics, is sent to the companies, along with the interview questions, all shown respectively in Appendix I and J. For the selection of the interviewee of the company, the following criteria needed to be met: The interviewee must talk Dutch or English fluently; The interviewee must have consent from the company to give the interview and The interviewee must have knowledge on of the company business model.

3. *Interview*

The interview will be held by phone or video call. During the call, the interviewer and interviewee will walk through the questions and discuss the framework components. If other questions pop up that were not written down from the start, the interviewer can decide to ask them if it feels necessary. The interviewer will be recorded, so all answers can be written down after the interview.

4. *Transcription of records*

During this step, all relevant parts of the recording will be transcribed into text.

5. *Analysis and interpretation of data*

After filling in the Sustainable PSS BMC and sorting the additional data on the environmental impact of the PSS, an analysis will be made. This is made possible after grouping the information and going through the data again.

6. *Preparation of report*

This step consists of making sure all the above mentioned steps are included in the report to help answering the sub questions and main question in the report.

Appendix H - Interview question

H.1 Questions for Coolblue traditional BM

Doel van het interview

Meer informatie verkrijgen over de verschillende BMs binnen de wasindustrie en hun mogelijke milieu impact en welk onderdeel van de cyclus levert de grootste impact. Daarnaast, het identificeren van het business model, wat zijn de succesfactoren en waar zit nog ruimte voor verbetering?

A. Introductie

Datum, plaats, tijd		, ,
Interviewer		Katie Froeling
Geïnterviewde	*Naam*	
	Bedrijf	Coolblue
	Functie	
Consent form ondertekend		JA / NEE

1. Introductie voor het interview door Katie (doel van het onderzoek)
2. Wat is uw rol binnen het bedrijf?

B. Business model

1. Hoe zou je circulaire economie beschrijven
2. Met welke circulaire ontwikkelingen zijn jullie bezig binnen het bedrijf?
3. Ken je Product-service systems (PSS) (Katie geeft korte uitleg)? Zoja, Hoe duurzaam denk je dat PSS is? En waarin verschilt het van jullie business model?
4. Hoeveel wasmachines verkopen jullie per jaar?
5. Wie zijn jullie grote concurrenten? Wat is je mening over hun business model?

C. Sustainable PSS BMC framework

Waarde propositie 1. Wat is de waarde die jullie aan je klant geven? 2. Bieden jullie nog extra services?	**Klanten** 3. Klanten charakteristiken? Wie is jullie target group? Samenstelling huishouden? 4. Welke interacties hebben jullie met de klant? 5. Welke informatie wordt er met de klant gedeeld?

	6. Customer behaviour
Essentiële activiteiten** 7. Welke stappen ondernemen jullie in de levenscyclus van de wasmachine?	**Essentiële middelen** 8. Welke menselijke middelen hebben jullie nodig (i.e. essentiële partners? 9. Welke financiële middelen hebben jullie nodig? 10. Welke fysieke middelen hebben jullie nodig? 11. Welke intellectuele middelen hebben jullie nodig? (e.g. copyright, patent, data)
Adoptie factoren 12. Zijn er groeifactoren? 13. Zijn er belemmeringen?	**Milieu impact** 14. Welke wasmachine verkopen jullie het meest? Wat zijn de karakteristieke van deze machine? 15. Hoe leveren jullie de wasmachine bij de klant, welk type vervoer? 16. Wat is de gemiddelde afstand naar de klant 17. Heeft u enig idee welk onderdeel het meest vervuilend is in de levenscyclus van een wasmachine? 18. Zijn er denkt u manieren om de milieu impact te verminderen? / Hoe zorgen jullie ervoor dat de milieu impact zo laag mogelijk is?

23. technische barriers met de wasmachine waar jullie tegenaan lopen?
24. Zou je iets veranderen aan het apparaat?

Heeft u zelf nog verdere vragen of opmerkingen die ik niet gesteld heb?
Bedankt voor uw tijd.

H.2 Questions for Coolblue PaaS

Doel van het interview
Meer informatie verkrijgen over de verschillende PSS types binnen de wasindustrie en hun mogelijke milieu impact en welk onderdeel van de cyclus levert de grootste impact. Daarnaast, het identificeren van het business model, wat zijn de succesfactoren en waar zit nog ruimte voor verbetering?

A. Introductie

Datum, plaats, tijd		, ,
Interviewer		Katie Froeling
Geïnterviewde	*Naam*	
	Bedrijf	Coolblue
	Functie	
Consent form ondertekend		JA / NEE

1. Introductie voor het interview door Katie (doel van het onderzoek)
2. Wat is uw rol binnen het bedrijf?

B. Product-service system

1. Hoe zou je circulaire economie beschrijven
2. Met welke circulaire ontwikkelingen zijn jullie bezig binnen het bedrijf?
3. Hoe duurzaam denk je dat PSS is? Wat is denk je het milieu potentieel ervan?
4. Wat is de naam van het PSS van jullie bedrijf en sinds wanneer is het opgericht?
5. Wat houdt het PSS precies in? Waarin onderscheid het PSS abonnment zich van de traditionele business model?
6. Als je kijkt naar de 8 verschillende PSS types volgens Tukker (2015)*, onder welk type zou je jullie PSS schalen?
7. Hoeveel klanten heeft jullie abonnement/business model per jaar?
8. Wat vind je van andere PSS voorbeelden in de was industrie? En wat vind je van de milieu resultaten die daar behaald worden?

C. Sustainable PSS BMC framework

Waarde propositie	**Klanten** 3. Wie is jullie target group? Samenstelling huishouden?

1. Wat is de waarde die jullie aan je klant geven? 2. Welke services hebben jullie?	4. Welke interacties hebben jullie met de klant? 5. Welke informatie wordt er met de klant gedeeld? 6. Customer behaviour
Essentiële activiteiten** 7. Wat zijn de stappen tijdens het distributie en acquisitieproces? 8. Wat zijn de stappen die jullie als bedrijf ondernemen tijdens de gebruiksfase? 9. Wat gebeurt er als de wasmachine terugkomt? Wat zijn de stappen aan het eind / End of Life proces?	**Essentiële middelen** 10. Welke menselijke middelen hebben jullie nodig (i.e. essentiële partners? 11. Welke financiële middelen hebben jullie nodig? 12. Welke fysieke middelen hebben jullie nodig? 13. Welke intellectuele middelen hebben jullie nodig? (e.g. copyright, patent, data)
Sociale aspecten 14. Zijn er sociale voordelen waar jullie PSS aan bijdraagt? 15. Zijn er sociale belemmeringen waar jullie tegenaan lopen met het PSS?	**Milieu impact** 16. Welke wasmachine verkopen jullie het meest? Wat zijn de karakteristieke van deze machine? 17. Welke gemiddelde temperatuur en frequentie wast jullie klant? 18. Hoeveel was (kg) gaat er gemiddeld in de wasmachine? 19. Hoe leveren jullie de wasmachine bij de klant, welk type vervoer? 20. Wat is de gemiddelde afstand naar de klant 21. Heeft u enig idee wat het elektriciteitsverbruik van de machine is tijdens gebruik? 22. Heeft u enig idee welk onderdeel het meest vervuilend is in de levenscyclus van een wasmachine? 23. Zijn er denkt u manieren om de milieu impact te verminderen? / Hoe zorgen jullie ervoor dat de milieu impact zo laag mogelijk is?

23. technische barriers met de wasmachine waar jullie tegenaan lopen?
24. Zou je iets veranderen aan het apparaat?
25. Wat houdt jullie tegen om de refurbished wasmachines bij de klant neer te zetten?

Appendix I - Interview consent form

- I …………….. voluntarily agree to participate in this research study.
- I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer
  any question without any consequences of any kind.
- I understand that I can withdraw permission to use data from my interview within two weeks after the interview, in which case the material will be deleted.
- I agree to my interview being audio-recorded.
- I understand that all information I provide for this study will be treated confidentially.
- I understand that in any report on the results of this research my identity will remain anonymous if that is requested.
- I understand that disguised extracts from my interview may be quoted in the thesis paper of Katie Froeling.
- I understand that signed consent forms and original audio recordings will be retained until November 2020.
- I understand that under freedom of information legalisation I am entitled to access the information I have provided at any time while it is in storage as specified above.
- I understand that I am free to contact any of the people involved in the research to seek further clarification and information.

Signature of participant	Date
--	---------------------

Signature of researcher	Date
--	---------------------

Appendix J - LCA framework

J.1 LCA framework structure

According to the ISO 14040 and 14044 standards, the LCA framework is made up of the four following phases, illustrated in figure J.1; *goal and scope definition, inventory analysis, impact assessment and interpretation*. The arrows allow for an iterative process to occur, which is often necessary (Klöpffer & Grahl, 2014). The ISO standard stresses that in order for LCA studies to be comparable with each other, their system boundaries essentially have to be the same.

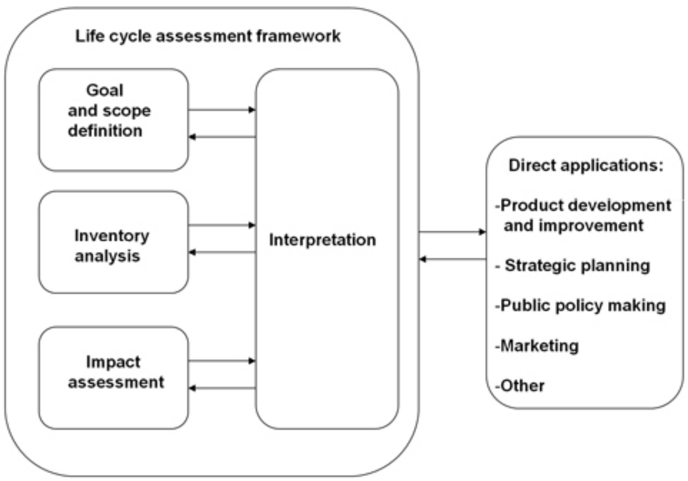


Figure J.1 General LCA framework (Based on ISO 14040, 1997)

J.2 Goal & Scope Definition

The first phase of the framework helps to identify the structure of the LCA. According to the International Standard 14044 (2006) the "goals and scope of an LCA shall be clearly defined and shall be consistent with the intended application. Due to the iterative nature of LCA, the scope may have to be refined during the study". The goal definition should explain the objective of the study (i.e. range of application), why is the study conducted (i.e. interest or realisation), for whom will it be conducted (i.e. target group(s)) and the accessibility of the publication should be explained (Klöpffer & Grahl, 2014).

The scope of the study is described by technological, temporal and geographical coverage within the system boundary. The technical system boundary covers the technologies and process stages. The temporal and geographical system boundaries cover the data gathered with respect to time and area (Heijings & Guinée, 2015). Lastly, a function, suitable functional unit (fU) and reference flow need to be defined. The function is the operation of the system and the fU is a measure of the function which "*provides a reference to which the inputs and outputs can be related*". The fU is a key element for a LCA that needs to be clearly defined. The reference flow represents product flows that measure the outcome of the study (Heijings & Guinée, 2015)

Table J.1 Goal and Scope components adapted from text

Goal	Scope	Extra
Objective	Temporal	Reference flow
Interest	Geographical	Function
Target group(s)	Technological	Functional unit
Publication		

J.3 Life Cycle Inventory (LCI) Analysis

The ISO standard 14040 (1997: 2) defines the Life cycle inventory (LCI) analysis as the "phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its entire life cycle". In other words, LCI is the process for quantifying the resource and energy consumption and generation of emissions, waste and products throughout all process stages in the product system, per functional unit. A system flowchart is a schematic illustration of all the unit processes and the involved dependencies (example figure J.2).

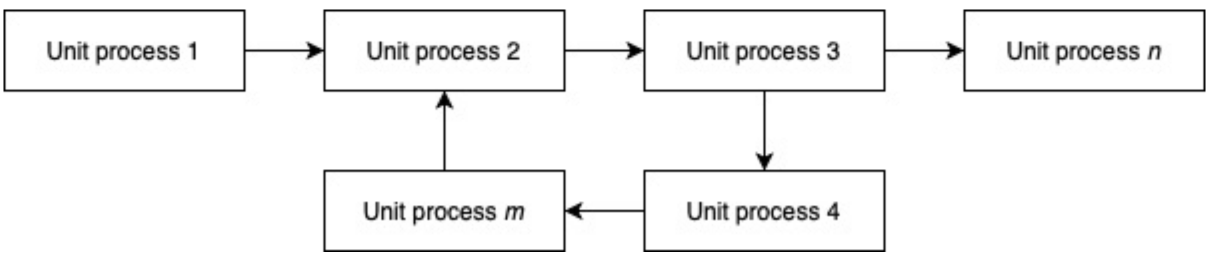


Figure J.2 Example of system flow chart

A unit process resembles a step in the life cycle of a product, for example production or transport of the product. The more specific and accurate the unit process is defined, the better the quality and transparency is of the collected data (Klöpffer & Grahl, 2014). Figure J.3 gives an illustrative representation of a unit process, with all the input and output parameters that are collected and calculated. The following five principles are scientifically proven laws and form a solid framework for the processes within LCI's (Hunt *et al.*, 1992; Hau *et al.*, 2007): Conservation of mass; Conservation of energy; Increase of entropy; Principles of stoichiometry and $E = mc^2$ (Klöpffer & Grahl, 2014). Although the conservation of mass and energy state *input = output*, most LCAs do not conform to a precise balance. For example, oxygen is usually not taken into consideration as an input, as it is an inexhaustible resource and waste heat is basically not measured on the output side. The data that is needed for the LCI is mainly collected from literature, public institutions, organizations or databases included within the software. Generally acquiring the data is one of the most time consuming phases of the assessment. When specific measured data cannot be found, corresponding estimations can also be made by the use of technical handbooks, manuals or other technical information.

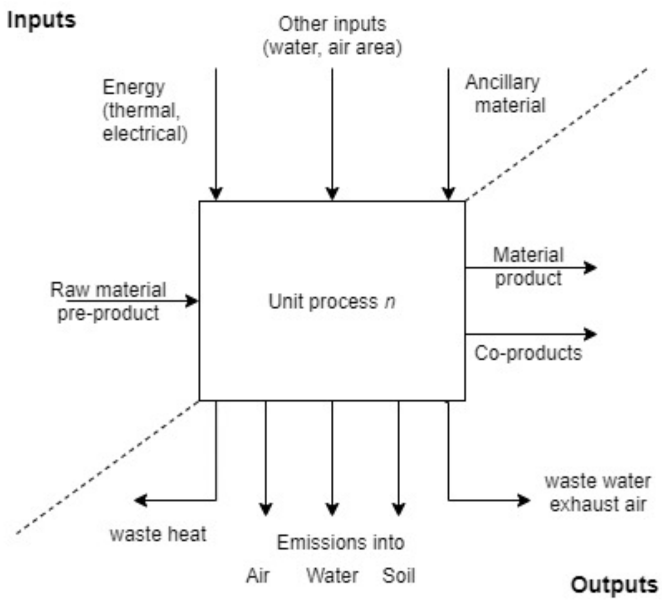


Figure J.3 Example of unit process with input and output parameters (Adapted from Klöpffer & Grahl, 2014: 67)

After collecting the unit process data and a flowchart of the processes is constructed, the data of these processes is quantitatively related to one another, associated to the functional unit. The calculation itself is made up of interconnected and scaled processes, with scales and aggregates environmental interventions.

J.4 Life Cycle Impact Assessment (LCIA)

The Life Cycle Impact Assessment (LCIA) of an LCA is "aimed at understanding and evaluating the magnitude and significance of the potential impacts for a product system throughout the life cycle of the products" (ISO 14040, 1997: 2). In other words, an LCIA interprets the data from the inventory list into environmental impacts. There are three mandatory elements and three optional elements of an LCIA (Klöpffer & Grahl, 2014).

Mandatory elements

1. **Selection**; Selection of the impact categories (e.g. climate change), category indicators (e.g. infrared radiative forcing (Wm^{-2}) and the characterisation model.
   The author(s) of the LCA can chose their own impact categories, however common chosen impact categories are: Human toxicity, Ecotoxicity, Eutrophication (aquatic), Eutrophication (terrestrial), Land use, Ozone formation (near-surface), Resources demand, Ozone depletion (stratospheric) Greenhouse effect, Acidification.
2. **Classification**; assignment of the LCI results, by allocating the flows to the impact categories.
3. **Characterization**; The results are converted to a common indicator by multiplying it with a characterization factor (e.g. global warming potential (GWP) for each GHG (kg CO_2-eq/kg gas).

Optional elements

1. **Normalization**; checking the obtained results on the discrepancies, by comparing it to reference data,
2. **Grouping**; Sorting or ranking the impact categories.
3. **Weighting**; weighting factors are converted with the results, to assess them within the impact categories.

J.5 Interpretation

The last step in an LCA is called Interpretation. This phase entails making an interpretation of the obtained results from the assessment and any assumptions, limitations, uncertainties and choices are analysed on their correctness and robustness. From this an overall conclusion is made (Heijings & Guinée, 2015; Klöpffer & Grahl, 2014).

Appendix K - Cases in the PSS BM washing machine industry

Table K.1 Selection criteria for alternative cases

1	Location	Cases must be operating in the Netherlands
2	Type of CBM	Cases must be a Product-service system, specified to the pay-per-service-unit and product lease archetype
3	Industry	The cases must be active in the washing machine industry with a PSS BM
4	Customer	Every person (over 18 y/o) should be able to sign up for the subscription. Cases must be on domestic washing, so B2C.
5	Business Maturity	Cases must be put into practise or at least be a Small and Medium Enterprise (SME)
6	Sustainable	Cases must be actively busy with reducing the environmental impact of their BM

All cases were active in the washing machine industry and operated a PSS BM in the Netherlands.

Table K.2 Alternative cases in the washing machine industry

#	Company	Type of CBM	Customer	Business maturity	Sustainability	Extra's
1	Coolblue	Product lease - Use oriented	Everyone	Active since 2018	Actively promoting sustainability	-
2	Witgoed verhuur.nl	Product lease - Use oriented	Everyone	Not specified	No active promotion	-
3	Splash	Product lease - Use oriented	Only for student(house)s	Active since 1990	No active promotion	-
4	Skala	Product lease - Use oriented	Everyone	Active since 1980	No active promotion	-
5	Bundles	Product lease - Use oriented	Everyone	Active since 2013	Actively promoting sustainability	Pay-per-wash in combination with a fixed monthly

						fee
6	Blue Moveme nt	Product lease - Use oriented	Everyone	Not specified	Actively promoting sustainability	-
7	Dixons	Product lease - Use oriented	Everyone	Active since 2016	No active promotion	-
8	Meo Lease	Product lease - Use oriented	Everyone	Active since 1975	No active promotion	-
9	Wasgoe d.com	Product lease - Use oriented	Only for student(house)s in 6 cities	Not specified	No active promotion	-
10	Wasauto matenver huur.nl	Product lease - Use oriented	Only for student(house)s	Active since 1990	No active promotion	-
11	Verhuurw itgoed.nl	Product lease - Use oriented	Only for student(house)s	Active since 1990	No active promotion	-
12	Smart Student Deals	Product lease - Use oriented	Only for student(house)s	Active since 2013	Minor promotion	-
13	Homie	Product lease - Use oriented	Everyone	Active since 2017	Actively promoting sustainability	Pay-per-wash with tiered prices
14	Hartland	Product lease - Use oriented	Everyone in Utrecht	Not specified	No active promotion	-
15	De Waslijn	Product lease - Use oriented	Only for student(house)s in Groningen	Not specified	No active promotion	-
16	Laundry BV	Product renting/sharing - use oriented	Industrial size WMs	Active since 1980	No active promotion	Industrial size WMs
17	Wassie	Pay-per-service-unit - Result-oriented	Everyone in Groningen	Not specified	No active promotion	Pay per kilo of washing

Appendix L - Interview questions alternative cases

Goal of the interview
Gaining more knowledge on different types of PSS within the washing machine industry and their environmental impact. Furthermore, identifying the business model and what the success factors are and where there is still room for improvement.

1. **Introduction**

<table>
<tr><td colspan="2">Date, place and time</td><td>XX-XX-2020 , Online , XX:XX</td></tr>
<tr><td colspan="2">Interviewer</td><td>Katie Froeling</td></tr>
<tr><td rowspan="3">Interviewee</td><td>Name</td><td></td></tr>
<tr><td>Company</td><td></td></tr>
<tr><td>Function title</td><td></td></tr>
<tr><td colspan="2">Consent form signed</td><td>YES / NO</td></tr>
</table>

1. Introduction of the interview by Katie (goal of the research)
2. What is your role within the company?

2. Product-service system

1. Which circular developments are you working on within *[company name]*? And what is the circular/sustainability ambition?
2. How does the PSS fit within the circular/sustainability ambition?
3. How sustainable do you think the PSS is and what is the environmental potential?
4. What is the name of the PSS(s) and what does/do it/they entail, when was/were it/they established?
5. How does the PSS subscription distinguish itself from the more 'traditional' selling business model?
6. If you would look at the 8 types by Tukker*, in which archetype would your PSS fall? And what do you think are the biggest differences between the PSS categories?
7. How does *[company name]* try to grow its market share?
8. What are trends within the PSS market and what do you think are future market developments?
9. Do you have a LCA (Life Cycle Assessment) on a part of the life cycle of a washing machine that you are willing to share? Or perhaps an energy analysis?

3. Sustainable PSS framework

Value proposition 1. What is the value delivered to the customer? 2. What services do you offer?	**Customers** 3. Do you have a specific target group? How do they experience the subscription? 4. Customer behaviour: how do you discourage abuse of the product or subscription by the consumer? 5. Is there any knowledge on the washing behaviour of the customers?
Key activities 6. What are the activities that you undertake to get the subscription going? (i.e. Production, distribution, Use and End-of-Life)	**Key resources** 7. Which human resources do you use? 8. Which financial resources do you use? 9. Are there, besides the washing machine, other products needed to get the subscription going?
Adoption factors 10. Which drivers do you encounter? 11. Which barriers do you encounter?	**Environmental impact** 12. Which elements of the washing machine life cycle add to the environmental impact? 13. Are there ways to decrease this impact? How does BlueMovement try to decrease this impact?

Do you have any suggestions or questions that I have not asked? Thank you for your time

* 3 PSS categories:

1. ***Product-oriented PSS***: The provider focuses on the sales of products but offers some extra services, such as maintenance, consultancy, insurance, repair and training.
2. ***Use-oriented PSS:*** In use-oriented PSSs the business model has shifted from traditional ownership to remaining in ownership of the provider and allowing the product to be used by multiple users. Different types being: leasing, renting, sharing and pooling.
3. ***Result-oriented PSS:*** Result-oriented PSS, does not focus on a product, but a certain result is agreed upon between the provider and customer.

Appendix M - Coolblue delivery types

Coolblue has different types of delivery, namely CoolblueBikes; Outsource; 1Man; 2Man and 2Man - Build in; . The choice for each delivery type depends on the weight and size of the product that is being transported. This decision is made in the warehouse whenever a (new) product is ordered. Figure M.1 shows the size and weight class information for the different types of delivery.

Size class information

Gemaakt door Pauline Verbej, laatste wijziging op 23 jan. 2020

Size class	max. sizes in cm	max weight in kg	Propositions: Next day	Propositions: Pick-up	Propositions: Evening delivery	Propositions: Timeslot delivery	Propositions: SameDay delivery
S	21,5 x 14,5 x 2,5	30	YES	YES	YES	NO	YES
M	60 x 40 x 40	30	YES	YES	YES	NO	YES
L1	100 x 70 x 58	30	YES	YES	YES	NO	YES
L2	175 x 78 x 58	30	YES	NO	YES	*NO	YES
XL	225 x 84 x 60	35	YES	NO	YES	YES	NO
XXL	1,1m3	108	YES	NO	YES	YES	NO
XXXL		170	YES	NO	YES	YES	NO

*Except product group televisions, these products can purchased with Coolblue 1M timeslots

Carrier per size class:

See below which size class goes with which carrier. Bold markings indicate the preferred carrier for this size class. Mulitcolli's will always be shipped with the carrier of the largest size class.

	S	M	L1	L2	XL	XXL	XXXL
Coolblue Bike	**X**	**X**					
Bpost (Belgium only)	**X**	**X**	**X**				
PostNL	**X**	**X**	**X**	**X**			
Coolblue 1M	X	X	X	X*	**X**		
Coolblue installeert	X	X	X	X	X	**X**	X
Coolblue 2M	X	X	X	X	X	**X**	**X**

*L2 televisions will be delivered by Coolblue 1M

Size category dimensions:

SIZECATEGORY	MAXIMUM LENGTH (in cm)	MAXIMUM WIDTH (in cm)	MAXIMUM HEIGHT (in cm)	MAXIMUM WEIGHT (in kg)	MAXIMUM VOLUME (in cm^3)	DESCRIPTION
S	31,00	21,50	2,80	1,80		Maximum size that fits into an envelope
M	60,00	40,00	40,00	30,00		
L1	100,00	70,00	58,00	30,00		Maximum dimensions for automated sorting in parcel networks
L2	175,00	78,00	58,00	30,00		Maximum dimensions for manual sorting in parcel networks
XL	400,00	90,00	60,00	35,00	1.080.000	Maximum dimensions for handling products with one person
XXL				108,00	1.100.000	
XXXL				170,00		Maximum dimensions for handling products with two persons

Figure M.1 Delivery size and weight class information (Coolblue Confluence, 2020)

CoolblueBikes

The most recent delivery type, CoolblueBikes, is still relatively new. In 2019, CoolblueBikes has been greatly upscaled. 321.000 packages were delivered in 2019 by bike. These packages are small products (i.e. up to 60 x 40 x 40 cm and 30 kilograms) that can still be transported by bike. In total, 120.000 kilograms of carbon dioxide emissions was saved because of the CoolblueBike.

Outsource

If the product is rather small (i.e. up to 175 x 78 x 58 cm) and not too heavy (i.e. 30 kilograms), which make up the price of shipment, then the shipping of the product is outsourced to. In the Netherlands Post NL is used and in Belgium bpost is the parcel deliverer.

Coolblue 1M

Coolblue 1M trucks deliver products that can be carried by one person, which is up to a certain size (i.e. up to 225 x 84 x 60 cm) and below 30 kilograms. For example: televisions, air conditioners, big printers etc. In 2019 the first electric vans were put into use in Amsterdam and Rotterdam.

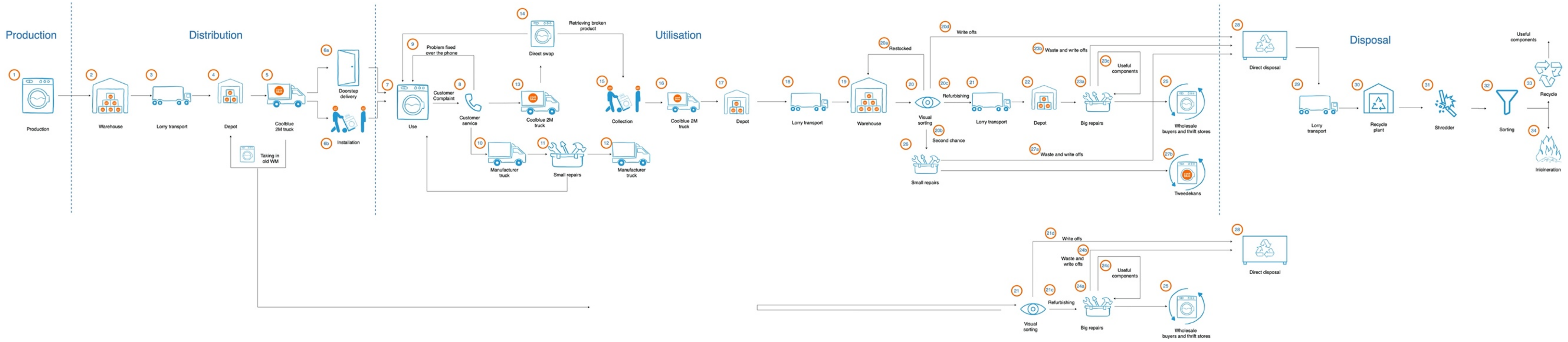
Coolblue 2M

Coolblue 2M trucks deliver everything that is above 30 up to 170 kilograms (kgs). Everything above this weight needs to be carried by two people. Examples of products that are delivered are, fitness apparatus, trampolines, white goods etc. The well-known blue truck weighs around 2750 kilo and 3500 kilo including products.

Coolblue 2M - Built in

Coolblue offers the opportunity to build in fridges, dishwashers and TV's. These types of deliveries take up much more time because for example wall mounts need to be hanged for the TV or water pipes need to be installed for dishwashers. The option for build in is only possible in 2 Man deliveries. Products can be bigger than 1.1 m^3 and heavier than 108 kilograms.

Appendix N - Detailed calculations traditional BM



1. *Production - Producing 1 WM cradle to gate*

The CO_2 emissions of the production phase is based on a study provided by Ecoinvent database v3.6 (EcoInvent v3.6, 2019). The data in the study is based on the paper by Yuan et al. (2015). In the paper the production of a single horizontal-axis washing machine in China was analysed. The system boundary for the production process consists of raw materials extraction, processing, manufacturing and assembly. The WM sold in the traditional BM by Coolblue is assumed to have similar key parameters to those in the paper. Based on the above information, the CO_2 emissions of the production phase are **304.7 kg**.

2. *Distribution - Transporting 1 WM from China to the WH*

The second phase in the life cycle consists of two parts. First, transporting the WM from the manufacturer to the retailer, in this case Coolblue. The assumption is made that the WM is produced in Shanghai (China) and transported by ship to Rotterdam (Netherlands). Second, distributing the machine from Rotterdam to the Coolblue warehouse in Tilburg by truck.
The MSC Beatrice ship is used as the default ship for this calculation. It is one of the largest container ships in the world with a capacity of approximately 14.000 containers of 20 ft (Wikipedia, 2015). One 20ft container weighs 2.230 kgs and has a maximum capacity of 28.250 kgs (TTS-transocean, n.d.). The maximum speed is 24 knots and uses around 210.000 liters of fuel oil per day (Van Dijk and Lalkens, 2017). The assumption is made that the ship will arrive at the Rotterdam port in 25 days, when sailing at an average speed of 20 knots (Ports.com 2020). Multiplying the total fuel use [kgs] in 25 days by the kg of CO_2 emissions caused when burning one ton of Heavy Fuel Oil (HFO)(Jochemsen-Verstraeten *et al.*, 2016), results in 14.291.025 kg CO_2 emissions. Assuming that all containers are completely full, a total load capacity of 395.500.000 kgs can be realised. Assuming that one WM weighs 75 kgs (Yuan *et al.*, 2016), a corresponding load capacity percentage of 1.89*10^-7% is found.
When multiplying this percentage with the CO_2 emissions of the total burned HFO, 2.71 kgs CO_2 are measured for transporting one WM by ship from Shanghai to Rotterdam.
CO_2 emission for producing, transporting and using the fuel used are taken into account. Emissions from manufacturing, repairing and recycling the ship or containers and handling of the containers in the port were seen as out of scope. Also emissions caused by any personnel on the ship were not taken into account.

The second part of this phase is distributing the WM by truck from Rotterdam to Tilburg, which is approximately 100 kilometers (kms) (measured in Google Maps). TNO (Netherlands Organisation for Applied Scientific Research) has assumed CO_2 emissions factors in [g/km] for different classes of vehicles (i.e. light-duty, medium duty, heavy duty and busses) (Ligterink et al., 2016). Figure L.1 in Appendix L shows all emissions factors from 2015-2030. With an average weight of 26.5 ton (i.e. 17.5 lorry weight and 9 tons of products) (External Appendix), the lorry is identified as a heavy duty vehicle (Ligterink et al., 2016). For ease of calculation the weight of the truck was considered to be the same on the way back. It is considered that no congestion will occur as the lorries travel late at night (External Appendix). For heavy duty vehicles on the motorway, the emission value in 2020 is 787 CO2 [g/km]. The weight of one WM (i.e. 75 kilograms), corresponds to less than 1% of the total load capacity weight. By multiplying the CO_2 emissions [g/km]with the traveled distance, back and forth, and then multiplying this number with the less than 1% corresponding WM weight, the CO_2 emissions is considered to be 0.66 kg. This makes the total CO_2 emissions for step 2, **3.4 kilogram**.

3. Distribution - Electricity and gas use of WH for 1 WM

The following step entails investigating the carbon dioxide emissions caused by heating and lighting up the warehouse (WH), which is measured in the average electricity use per month and average gas use per month (see External Appendix). The Whitegoods department takes up 38% of the total WH surface area and around 55.000 washing machines would fit into this space (Lotte, 2018). The lead time of one WM is assumed to be one week. Therefore one WM would take up 1.7*10^-6% of the total electricity and gas use of the WH in one week.
The average electricity and gas usage per washing machine per week (assuming an average lead time of one week) in the WH, respectively are 7.1*2^10-4 kWh and 1.1*10^-3 m3. The CO_2 emissions factor of electricity is 0.45 kg/kWh (CBS, 2017) and one m3 of natural gas emitters 56.4 kg/GJ of CO_2 (Zijlema, 2020).
By multiplying the average electricity use [kWh] and gas use [m3] per month by 1.7*10^-6% and the corresponding CO_2 emissions factors the total CO_2 emissions calculated. The total CO_2 emissions caused by heating and lighting the WH per WM per week are **0.06 kilograms.**
It is assumed that both numbers (i.e. for gas and electricity) are final and account for all activities in the WH (e.g. lighting and heating the WH, instigating the conveyor belts, boxing/bagging station, power the forklifts, etc.). Emissions caused when constructing and repairing the Warehouse are seen as out of scope for this research. Furthermore, emissions caused by Coolbluers when commuting to the warehouse or emissions within the warehouse (i.e. catering, clothing, restrooms etc.) and any extra packaging are also not taken into account.

4. Distribution - Transporting 1 WM from WH to depot

The fourth step calculates the total CO_2 emissions caused by transporting one WM from the WH in Tilburg to the Utrecht depot. The Utrecht depot was chosen as the default depot, because the location is more or less in the middle of the Netherlands and the Utrecht depot is one of the two depots that does inhouse refurbishing. The calculation is similar to the second part of step 2. All parameters are adopted, except for the distance traveled. The distance between the warehouse and the Utrecht depot is approximately 74 kms (measured in Google Maps). Based on the above mentioned information, the CO_2 emissions are considered to be **1.0 kg CO_2**.
Emissions caused when manufacturing and repairing the lorry are not included. Also emissions caused by the lorry drivers (i.e. commute, food, clothing, restrooms etc.) are not taken into account. The CO_2 emissions factors take the road type and fuel use into account. The impact of braking and speeding was also not included.

5. Distribution - Electricity and gas use of depot for 1 WM

The following step contains the carbon dioxide emissions caused by heating and lighting up the Utrecht depot. As mentioned previously, the Utrecht depot is seen as the default depot. The CO_2 emissions are assumed to be similar to those of the Warehouse (i.e. step 3), except for the fact that the Utrecht depot is smaller. The Utrecht depot corresponds to 1.4% of the total surface area of the

WH (External Appendix). Therefore the CO_2 emissions found in step 3 are multiplied by 1.4%, which results in **0.0008 kg CO_2**.

6. Distribution - Transporting 1 WM from depot to customer

The sixth step measures the CO_2 emissions that occur when one WM is transported from the depot to the customer by the Coolblue 2M truck. The average distance from the Utrecht depot to a customer is 8 kilometers (Boven, 2020). It is assumed that the truck is full every time with 750 kilograms of products, which accounts for a total mass of 3500 kgs (Boven, 2020). According to the TNO report (Ligterink *et al.*, 2016) this weight classifies as a light-duty truck.
As products are delivered throughout the day, the road type is considered to be an equal mix of urban congestion, urban normal, urban free flow and motorway average. Respectively, the values of these road types for light-duty trucks in 2020 are respectively 313, 212, 201 and 168 CO_2 [g/km]. The same calculation as in step 4 was used. Based on the above information, the CO_2 emissions caused by delivering one WM to the customer is **0.4 kg CO_2**.
Emissions caused by manufacturing and repairing the truck are not included in the equation. Also emissions caused by the truck drivers (i.e. commute, food, clothing, restrooms etc.) are not taken into account. The impact of braking and speeding were also not included. The stream of ERs was not taken into consideration.

7. Utilisation - Energy usage of 1 WM in 8 years

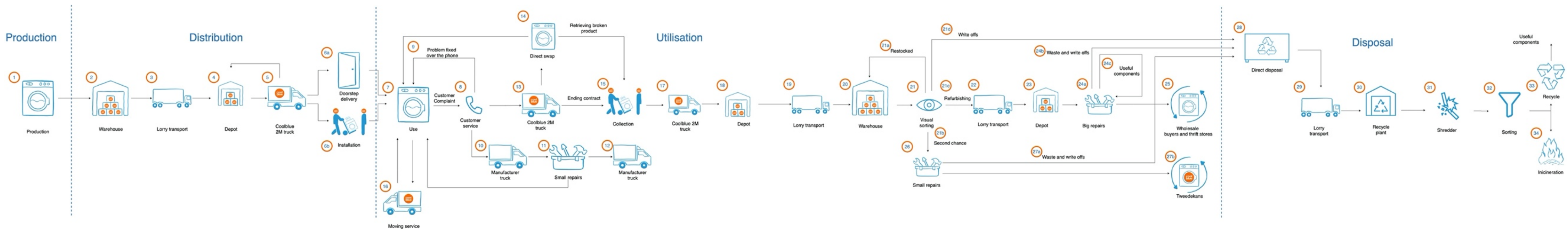
For calculating the energy consumption, a default WM with the energy label of A+++-10% is chosen. The average energy consumption for a WM with the energy label of A+++-10% per year, is 176 kWh (Rowan, 2020). This number is based on a European household who do 220 wash cycles per year, using only the 40 and 60 degrees eco programs and the WM has a load capacity of 8 kgs. This number is calculated by the EU and it includes the power consumption of the appliance when it is in standby mode and when it is turned off.
Multiplying this number by 12 (the assumed lifetime) and the CO2 emissions factor of electricity mentioned in step 3 (i.e. 0.45 kg/kWh) gives a total of **950 kg CO_2** during the time that the WM is used.
Besides energy consumption, it is presumed that there are three other factors that have an impact on the CO_2 emissions generated during use, namely fresh (drinking) water supply, waste water treatment and detergent usage. The CO_2 emissions caused by these factors was not measured, as no CO_2 emissions factors were found. The paper by Yuan *et al.* (2015: figure 4) shows that electricity consumption takes up 95% of the GWP. The other 5% is taken up by tap water. Detergent does not seem to give a significant GWP impact.

8. End-of-Life - Recycling 1 WM unit

The final step in the life cycle is measuring the emissions of recycling one washing machine. As it is assumed that WMs are collected by companies when they deliver a product at the consumer (WEEE, 2015), it is assumed that the emissions caused by distribution are already made for the delivery of other products and thus it is not accounted for in this step. 90% Of all WMs are said to be collected in a traditional BM. The assumption is made that this number corresponds to 90% of one WM being collected.

The study by Yuan *et al.* (2016: figure 3) shows that the two biggest CO_2 emissions contributors in the production phase respectively are plastic parts and electronics. WeCycle (n.d.) mentioned that more than 75% of a WM can be recycled. It is assumed that of these 75% recycled materials, 50% can be returned back into the production process. Based on this information, the emissions of recycling one WM is calculated by multiplying the collection rate of 90%, 75% recycling rate, 50% material return rate by the CO_2 emissions from the production phase. This results in a recycling credit of **102.9 kg CO_2**. This number is a negative number, as this step leads to a recycling credit. Emissions of the recycling process itself were not taken into consideration. The incineration of the parts which could not be recycled are also not accounted for.

Appendix P - Detailed calculations PaaS BM



1. Production - Producing 1 WM cradle to gate

It is presumed that the CO_2 emissions due to production are similar to the traditional BM. Although the WM in the PaaS has a better energy label and higher quality, the impact of these differences were not taken into consideration. The fact that the WM with the

2. Distribution - Transporting 1 WM from China to the WH

It is presumed that the CO_2 emissions due to transport from China to Tilburg are similar to the traditional BM.

1. Distribution - Electricity and gas use of WH for 1 WM

It is presumed that the CO_2 emissions due to lighting and heating the warehouse are similar to the traditional BM.

2. Distribution - Transporting 1 WM from WH to depot

It is presumed that the CO_2 emissions due to transport from the WH to the depot are similar to the traditional BM.

3. Distribution - Electricity and gas use of depot for 1 WM

It is presumed that the CO_2 emissions due to lighting and heating the Utrecht depot are similar to the traditional BM.

4. Distribution - Transporting 1 WM from depot to customer

It is presumed that the CO_2 emissions due to transport from the depot to the customer are similar to the traditional BM.

5. Utilisation - Energy usage of 1 WM for 3 years

To measure the energy consumption of a WM in the PaaS BM, an energy label of A+++-30% was chosen. The average energy consumption for a household of 1 or 2 people, doing 220 cycles at 40 and 60 degrees is 136 kWh per year (Rowan, 2020). This number is multiplied by 3, as it is assumed that the WM is located at the customer for three years (Van der Meer, 2020). The amount of kWh is multiplied by 0.45 kg/kWh (the CO_2 emissions factor of electricity). This makes the total CO_2 emissions emitted due to electricity in the user phase **183.6 kg CO_2**.
Emissions caused by water supply and detergent use have not been taken into account for the same reasons as the traditional BM.

6. Life extension - Refurbishing

The activities performed when refurbishing one WM include cleaning, two test runs at 60 degrees, additional materials/components (Boon, 2020) and transport from the WH to the customer. One wash cycle at 60 degrees of a WM with the energy label of A+++-30% consumes 0.64 kWh. Multiplying this with the electricity emissions factor (i.e. 0.45) results in 0.6 kg CO_2.
The assumption is made that around 10% of the components need to be replaced (Boon, 2020). The total emissions emitted during refurbishment are calculated by adding transport emissions from the WH to the depot and from the depot to the customer. Then 10% of the emissions caused in the

production phase were taken and added to the electricity emissions of two wash cycles. This resulted in **32 kg** CO_2 emitted during refurbishment.
The water usage during refurbishing was not taken into account. Emissions caused by the tools and equipment that is needed for refurbishment were not taken into account, as they can be used indefinitely and thus the emissions were not included. Electricity and gas use in the WH and depot were also not incorporated.

7. Life extension - Energy usage after refurbishment

The assumption is made that WMs after refurbishment will still run for an additional six years (Bijl, 2020). This makes the total lifetime of the machine ten years. This is assumed to be higher than the WM in the traditional BM, as it is mentioned that they have a lower breaking percentage and are of better quality. This makes **367 kg** CO_2 emitted in the additional user phase due to energy.

8. End-of-Life - Recycling 1 WM unit

The CO_2 emissions from the EoL phase are almost similar to the traditional BM, except for the fact that a 100% collection rate is assumed and. This results in a recycling credit of **114.3 kg CO_2**. Emissions of the recycling process itself were not taken into consideration. The incineration of the parts which could not be recycled are also not accounted for.

Appendix Q - BlueMovement

BlueMovement carries out a product lease PSS archetype in the washing machine industry. It is driven by BSH, formerly known as Bosch and Siemens Home appliances, which is now fully owned by Bosch. BlueMovement was initiated in 2017 by Bosch managers. PSS was considered an upcoming trend which they were interested in, because it allowed Bosch to stay owner of the product. By remaining the owner of the product, the return of products can be ensured which allows for a better control on the material flow (Reich, 2020). BlueMovement is still powered by Bosch and only Bosch products are offered in the lease: washing machines, dryers, refrigerators, freezers, dishwashers, vacuums and food processors. Currently, they are in the scale-up phase. The number of customers is unknown and the BlueMovement team consists of nine people.

There is a lot more we can do in how products are designed to be used after usage: designed to be refurbished - Dirk Reich

A semi-structured interview was conducted with Dirk Reich, who is responsible for operations and the financial flows of BlueMovement. He has been working at BSH for over 15 years and has been active in several locations and backgrounds. The transcribed and coded interview can be found in the External Appendix.

Value proposition

A. Value

The value BlueMovement provides is offering a working WM for a fixed monthly fee in a hassle free lease with the assurance of a sustainable WM (Reich, 2020). In order to keep adding value to the lease, it is important to stay close to the customer and find out about their needs (Reich, 2020).

B. Services

The free services included in the product lease are, delivery, installation, moving, user tips, the option to transfer the contract and repairs over the entire rental period. The customer will pay extra for canceling the contract and having BlueMovement collect the WM at the end of use.

C. PSS characteristics

For the subscription, the customer can choose between a new or refurbished WM and between three contract lengths. Every customer pays a deposit, to discourage abuse of the product or subscription. Also in the contract there are some requirements on how the customer should return the product, regular use marks are allowed. Furthermore, an acceptance test is performed to check the creditworthiness of a future customer. Lastly, contractual terms with user obligations make sure that the machine is returned in a proper state.

Customer

A. Key groups(s) and motivation

BlueMovement customers are categorized into three groups, namely convenience lovers, students and environmentalists (Reich, 2020). Reich (2020) mentions that the reason for a consumer to lease at BlueMovement is convenience. This is because the users are looking for ways to be more sustainable, but do not want to make a big effort. BlueMovement markets their BM as a subscription towards a sustainable household (BlueMovement, n.d.).

B. Customer use

Most of the customers treat the appliance well, which makes the subsequent steps more easy (i.e. repair, cleaning, component recycling, refurbishing). Nonetheless, sometimes the product is not cared for well and the deposit is *"by far not enough to cover the costs"* (Reich, 2020: 34).

Key activities

A. Production

The WMs in the BlueMovement lease are the same conventional Bosch WMs sold to retailers. BlueMovement is driven by BSH, however it is not clear what the exact influence is of BSH during the production phase.

B. Distribution

As part of the lease, the WM is delivered and installed. BlueMovement is looking into ways to optimise their distribution flow. For example, refurbishing on the go. This would entail, refurbishing a WM when driving from one customer to the next (Reich, 2020). In the end, the number of subscriptions and the location play a big role in optimisation. If more subscriptions would be in the same area, the distribution process could be optimised.

C. Use

During use, BlueMovement offers tips on how to wash, detergent use and explanatory videos are available to support their customers. However, not all customers take advantage of these services. During use BlueMovement also offers to repair the WM if it is not functioning properly. BlueMovement tries to repair the WM together with the user at a distance. If this does not work BlueMovement will come by within three working days and repair the WM at the users home. The WM will only be replaced if it is beyond repair.

D. Life extension

At the EoU, the WM is collected and a full service check is performed. During this check, components that could break during the next contract term are repaired upfront. The machines are then cleaned and ready to be sent off to the next customer. As BlueMovement has direct ties with the manufacturer, they know exactly how the products are assembled, which makes refurbishing much easier and efficient (Reich, 2020). Reich (2020: 32) thinks that other PSS providers do not "*have the insights in the appliances… and the technical set up to really refurbish appliances".* He describes this knowledge and capabilities as their competitive advantage.

E. End-of-Life

When the WM is beyond repair or refurbishing, valuable and frequently used components are retrieved and stored by BlueMovement before sending it to the recycler.

Key resources

A. Human

There are five key partners that help BlueMovement to make the subscription work. First there is Bosch, who produce and repair the WMs. Second there is the logistic service provider who delivers and installs the machines. The third key partner is Focum, who checks the credit worthiness of a future customer. The fourth partner is the recycler who takes care of the End-of-life phase of the discarded WMs. The fifth partner is the debt collecting agency. BlueMovement also works together with the Excess Material Exchange (EME). The EME is a digital platform that helps BlueMovement to find sales channels for their high-value materials or (waste) products. This partner however is not crucial to make the subscription work.

B. Financial

Besides receiving monthly payments of the customer and the deposit, BlueMovement is actively looking into new markets for reselling (waste) materials components or products. For example, the glass door of a WM is of high quality glass which is suitable for glass perfume bottles (Reich, 2020).

C. Physical & logistics

Only Bosch WMs with the energy label A+++-30% are used in the BlueMovement subscription (Reich, 2020). Furthermore, tools are needed for repairs, refurbishing and cleaning. Trucks, fuel and a handtruck are also needed to deliver the machine.

D. Knowledge

Lastly, there is the IT system behind the website to make the selling process work. BlueMovement has some data on washing behaviour from connected appliances, but this data is not used.

Adoption factors

A. Driver

Reich (2020) has noticed a mentality change among consumers, people do not feel the need to own products as much as they used to. The awareness of environmental topics is also growing (Reich, 2020). This is favourable for the adoption of PSS BMs.

B. Barriers

According to Reich (2020) there are still many customers who want to own a product, because it feels more safe as no one can take the product back. There is also still a stigma concerning the quality of refurbished products which says that their performance is inferior to those of new products (Reich, 2020). A third barrier is the fact that current WMs are not suitable for PSS BMs. This is visible in the fact that they are not designed for refurbishment.

Life Cycle Impact Assessment

A. Current

There are nine ways in which BlueMovement is trying to decrease the environmental impact of their WM lease subscription. First, only the most efficient WMs in terms of water consumption, detergent consumption and electricity consumption are offered in the lease. Second, leasing WMs from one brand makes the storing of components more efficient which consequently makes reusing components easier. Also the fact that BlueMovement is driven by Bosch gives them better insights in how their WMs are manufactured, which makes dismantling easier and more efficient. Offering user tips on the website is a fourth way that BlueMovement is decreasing their environmental impact.

A fifth way to decrease the environmental impact is by first reusing the WMs when they are at the EoU. When a WM is at its End-of-Use (EoU) BlueMovement collects the machine and performs a full service including upfront repairs. This is to prevent any breakdowns or defects from happening in the next leasing term. Repairing WMs when they are not working instead of writing them off directly is a seventh way. The eight action to decrease the impact is by refurbishing the WM if repairing is not an option. The last action is retrieving valuable components and reselling them on the market.

B. Future

In the future, BlueMovement is still looking at ways to optimise their delivery system Reich (2020). Reich also has some thoughts on the production process of WMs. According to him the innovation steps in producing WMs are more or less done (Reich, 2020). In order for manufacturers to be more circular the focus should be transferred from energy and water consumption to the possibility of separating WM components and materials. Currently, products are not yet designed to be recycled or refurbished. This new way of designing products asks for a long term perspective from producers, as the benefits will arise after eight to ten years (Reich, 2020). BlueMovement is also looking at optimising their distribution phase. For example by delivering products to customers in the same area.

Appendix R - Homie

The second inspirational case which is observed, is Homie. The company was founded in 2016 by Colin Bom, Hidde-Jan Lemstra and Nancy Bocken. The goal was to demonstrate that new BMs can "*contribute to sustainable consumption and a circular economy*" (Homie, n.d.: 3). The product portfolio consists of washing machines, dryers and dishwashers.

Homie is a product lease PSS BM where customers pay per wash and vary on the environmental impact generated by the program. The higher the temperature and the higher the rpm, the more expensive the program is. No additional costs such as deposit are implemented. Homie chose a pay-per-wash model because in their eyes it is the only PSS business model where both the manufacturer and user are pushed towards being more environmentally friendly (Bom, 2020). The business model is envisioned to be made up of two phases. The first one is proving that the model can make an impact, by focusing on the user phase and steering the consumer to more conscious washing. The second phase consists of developing products that are suitable for a PSS BM. These machines will be too expensive for sales, but not for a PSS BM as the machine will last longer. Bom (2020) believes that because of this, eventually washing with a PSS BM will be cheaper than the traditional BM. However, this second phase can only be reached if Homie generates more capacity. Currently, Homie is still in the first phase. What the total number of subscriptions of Homie are is unknown.

The pay-per-use business model is the only PSS model where both the manufacturer and user are pushed towards being more environmentally friendly - Colin Bom

Currently the operating team of Homie consists of four employees. One of them is Colin Bom, who is the managing director of the company and one of the co-founder. A semi-structured interview was performed with Bom. The coded transcripts can be found in the External Appendix.

Value proposition

A. Value

The PSS subscription by Homie offers the possibility of creating clean laundry at a low price and at the same time offering convenience, flexibility and unburdening the customer of unexpected costs. At the same time Homie is actively steering its consumers towards more sustainable washing behaviour.

B. Services

There are six free services included in the Homie subscription, namely: delivery, installation, repair, a monthly overview of the washing behaviour, user tips and collection at the end of use after one year. In case of a cancelation within the minimum contract duration the user will be charged. Moving the WM to another location is also charged.

C. PSS characteristics

A Homie customer only pays for the number of washes that are done at differentiated temperatures. Washing programs that are less environmentally friendly, according to Homie, have a higher price (ranging from €0.60 to €1.75). A deliberate choice was made to not ask for a deposit, because this goes against the concept of taking away the large investments at the beginning (Bom, 2020). Customers do not need to pass a creditworthiness test. The only additional costs that occur are a collection fee if the contract is terminated within one year. To ensure the viability of the Homie pay-per-wash model, the user pays a minimum monthly fee (Bom, 2020). Furthermore, a free maintenance wash at 90 degrees is offered every quarter to prevent an accumulation of detergents in the pipes of the machine (2020). Contractual terms with user obligations make sure that the machine is returned in a proper state. Lastly, when the contract ends the customer cannot buy the WM from Homie.

Customer

A. Key group(s) and motivation

According to Bom (2020) their key group is between the age of 35 to 40, also referred to as young adults. Their motivation for them to choose for a Homie subscription is because they are not able to pay large investments and they no longer need to own everything. A sum of the Homie customers are already sustainability conscious. Although sustainability is not their determining factor to choose a lease, they like knowing that the option is more sustainable than another.

B. Customer use

From the interview it seems as if Homie has a good relationship with its customers and a high customer satisfaction. This can be seen in the fact that a lot of new customers are friends, family or colleagues from current customers. Also when surveys are sent by the company, many customers respond without needing any incentives. The trust that Homie puts in its customers, is mutually returned. This can be seen in the fact that most customers pay on time and the WMs come back in a good state. The amount of repairs is unknown. Homies does however see an increase in repairs for households that share a WM.

Key activities

A. Production

Homie receives the WMs after the production phase. Currently, Homie only gives feedback to its manufacturing partners. In the future, the idea is to (help) design WMs specifically made for PSSs. The purchase costs of these machines will most likely be too expensive for customers, but not for a PSS BM as the machine will have a long lifespan (Bom, 2020).

B. Distribution

During the distribution phase, the WM is delivered and installed at the customers house.

C. Use

The user phase has the main focus point of the Homie subscription (Bom, 2020). By sending a monthly overview the user is made aware of their washing behaviour. This awareness is made visible into two ways. First, by using tiered prices for sustainable options, the consumer is steered to choose lower program temperatures and lower dryness levels where possible. Second, as the consumer pays per wash, he or she is incentivised to wash less. This is confirmed by data (Homie, n.d.) which shows that Homie users on average wash at 38.1 degrees versus the European average which is 43 degrees. The BM also shows that a Homie user washes 12 to 13 times a month, in comparison to the European average of 13.5 times a month. The monthly overview shows users what their washing behaviour is in comparison to other Homie users and how they can improve their washing behaviour.
Furthermore, Homie repairs the washing machine if needed. Repairs are preferably executed at a distance. If this does not work Homie goes to the user and repairs the WM there. The WM will only be replaced if it is beyond repair.

D. Life extension

There are three types of life extension present in the Homie PSS BM after End-of-Use, namely: reuse, refurbish and component recycling. The preferred option is to reuse the machine for another customer, after some minor actions. The second way the life of the machine is extended after EoU, is by refurbishing. Most WMs can be reused two or three times after refurbishing (Bom, 2020). If the two previous ways are not feasible, valuable components are retrieved from the machine which can be used for refusbishment.

E. End-of-Life

If the product is beyond life extension, the WM is sent to a recycler.

Key resources

A. Human

Homie has seven key partners that help to set up the pay per wash BM. The washing machine manufacturer is responsible for production and repairs. Homie also works together with logistic service providers on the other side of the Netherlands because this is out of their logistics zone. The government and ABN Amro are investors whom without the BM would financially not be possible (partner three and four). The fifth partner is the debt collecting agency. WeCycle is a sixth key partner that is responsible for recycling the WMs at the EoL. And the seventh (silent) partner is the TU Delft who were very important in the start-up phase of the company.
Homie is responsible for setting up the subscription, the entire IT system, minor repairs, distribution and retrieving valuable components from written off products.

B. Financial

To get the BM off the ground, large investments were needed. These costs are regained with the monthly payments from the users.

C. Physical & Logistics

Two types of Zanussi WMs models are used in the lease. Bom (2020) says that the appliances have a good price-quality ratio and not too many extras. The products are conventional WMs within the lower price range and an A+++ energy label. The quality is usually basic built. Furthermore, a built in device tracks the number of times the machine is used and which washing programs (Bom, 2020). For the distribution phase, a truck, fuel and handtruck is needed.

D. Knowledge

One of the most important resources is the technological platform behind the subscription (Bom, 2020). All payments are based on the data provided by the tracker. Homie also has much knowledge on which components most frequently need to be replaced. This makes storing and recycling more efficient.

Adoption factors

A. Driver

According to Bom (2020) customers are more conscious in terms of sustainability. A second driver mentioned by Bom (2020) is the financial assistance by the government. A third driver is the fact that the energy labeling system is being revised. This will stimulate manufacturers to produce WMs with a high energy label. A fourth driver is the new ecodesign measures by the European Commission that promote the repairabilty. One measure for example states that spare parts of household WMs must be available for a minimum of 10 years after the purchase date (European Commission, 2019b)

B. Barriers

One of the bigger conceptions on a PSS BM is that users do not look after the product well and that the quality is degraded when it is returned. Bom (2020) confirms that this does occur however this barrier is more visible in a PSS BM then in a traditional BM because the product is returned. A second barrier mentioned by Bom (2020) is the fact that PSS providers are still highly taxed for refurbished products. He believes that policymakers can show more support by lowering these taxes. A third barrier is the fact that current WMs are not suitable for PSS BMs. This is visible in the fact that they are very heavy to lift during transport.

Life Cycle Impact Assessment

A. Current

Homie tries to decrease the environmental impact of their BM in nine ways. First, by incentivising their customers to wash less frequently. A second way is by implementing tiered prices for different wash programs. This has shown its effectiveness, as customers have been washing 20-25% more efficiently (Bom, 2020). Because Homie is leasing WMs from one brand the storing and reuse of valuable components is made more efficiently. The monthly overview and user tips are the fourth and fifth way to decrease the environmental impact. Other ways to decrease the impact is by reusing WMs, repairing broken WMs and refurbishment. The ninth action is retrieving components that can be used in refurbishment.

B. Future

Bom (2020) has mentioned many ideas for the future that can decrease the environmental impact of Homie even further. One idea is developing WMs that are suited for a PSS BM. Currently they are working on a project to help design the first pay-per-use washing machine. For example, designing the WMs into different components. Or by replacing the concrete block inside by a bag of water the WM is lighter to transport. This will make refurbishing or transportation more efficient. Furthermore, there are also steps that can be taken to optimise the distribution phase. For example by diminishing the amount of styrofoam or if more customers would live in the same area.

Appendix S - Bundles

Bundles was founded by Marcel Peters in 2013. At the time he was working at an energy provider company and was familiar with the circular economy and its opportunities. One of his projects meant working together with Miele and improving the impact of the CE. This project gave him more energy as he also believed that linear consumer-good providers were taking advantage of the take-make-dispose economy with planned obsolescence. In his eyes a PSS BM can offer quality goods for a fair price and keep the material.

Together with Miele, Bundles created the brand 'WasBundles'. Wasbundles only offers Miele washing machines and has more than 2000 subscriptions (Peters, 2020). The Miele WMs are said to last 10000 wash cycles (Peters, 2020). Bundles also offers subscriptions in different product categories namely, dryers, dishwashers, coffee machines and beds. WasBundles is a product lease PSS BM where the user pays a fixed price per month and a fixed cost per wash. Bundles consciously chose for a fixed price per wash instead of differentiated prices, due to the complexity of differentiated prices.

> *In the current market, the lifetime of washing machine is artificially limited: planned obsolescence* - Marcel Peters

The Bundles team consists of four employees and Marcel Peters is one of the founders. A semi-structured interview was performed with Peters. The coded transcripts can be found in the External Appendix.

Value proposition

A. *Value*

Bundles offers the possibility of leasing a WM in a hassle free subscription. Furthermore the prestige status of washing with a Miele WM is guaranteed (Peters, 2020).

B. *Services*

Bundles offers six free services in the subscription. (Peters, 2020). First, the WM is delivered and second installed by the company. Third, the WM is repaired if needed and a fourth service is receiving a monthly overview on the users energy use. This overview also contains tips that are based on certain washing patterns that are detected. A fifth optional service is the inventory management of the detergents. Lastly, users have the opportunity to call with the customer service and ask for some washing tips. The WM is collected at the EoL and can be moved for an additional fee.

C. *PSS characteristics*

The minimal contract length is one month and the user pays a fixed monthly price and the costs per wash. WasBundles offers three washing machine subscriptions, ranging from a 'classic', to 'luxe' to a ‘all-in’ subscription. The monthly payment (i.e. €14.95 to €22,95) and energy labels (i.e. A+++ to A+++-20%) increase respectively. The user has to pay a deposit and be financially accepted before the contract is final. The installation step is very important for educating the customer, as the ins and outs of the WM are explained (Peters, 2020). Therefore he or she does not need to go through the manual and Bundles is assured that the customer knows how to treat the machine well. Contractual terms with user obligations make sure that the machine is returned in a proper state. Lastly, the customer has the opportunity to buy the WM of Bundles when the contract ends.

Customer

A. Key group(s) and motivation

Bundles has no specific key group, however there are two main reasons for customers to choose for Bundles according to Peters (2020). First, most users understand that PSS are needed to transition towards the CE and they do not mind paying extra for their laundry. Second, customers do not feel the need to own a WM anymore and prefer the extra services that are included. Bundles mission is to convince the average Dutch household to choose a PSS BM.

B. Customer use

Bundles detected washing patterns which enables them to target customers that need certain washing tips. Furthermore, the user is held accountable for its responsibility and the sustainability aspects of the BM are explained. All these strategies have resulted in higher product quality returns and only 20% of the machines are repaired (Peters, 2020). This low repair rate is also due to the fact Miele machines are of high quality.

Key activities

A. Production

Bundles does not produce any of the products in its subscription. The only influence they have on the production phase is providing Miele with their user data. For example, this data points out which functions in the WM are unnecessary.

B. Distribution

During the distribution phase the WM is delivered and installed. Furthermore, the user will receive information on how to use the machine.

C. Use

During the user phase, there are four activities that can occur. First, the user receives a monthly overview concerning the energy consumption. Furthermore, user tips (e.g. program choice, load capacity, detergent use, etc.) are made available and detergents are delivered to the consumer's house. The fourth activity entails repairing the machine whenever it is not working. Repairs are preferably executed at a distance. If this does not work Bundles will go to the user and repair the WM there. In collaboration with Miele a maintenance program was set up in which the user also plays a role. This allows them to repair most WMs themselves and outsource only the more advanced actions.

D. Life Extension

Besides repair, Bundles also refurbishes the WMs. In general a returned WM can be refurbished up to two or three times (Peters, 2020).

E. End-of-Life

According to Peters (2020) the End-of-Life phase should be postponed at all costs. If the WM is beyond repair it will be collected and sent back to Miele. Miele will take out any valuable components and remanufacture the WMs and recycle them as a last resort.

Key resources

A. Human

Bundles works together with six key partners in their BM. First of all their partner Miele produces the WMs and is also responsible for repairing and taking in the machines at the EoL phase for remanufacturing. The second partner is the detergent manufacturer. Both products (i.e. WM and detergent) are delivered to the customer by a logistics service provider, the third partner. A fourth partner is the payment service provider who takes care of collecting the invoices and the debt collection agency if a subscriber is failing to pay its invoices. The sixth partner is responsible for the creditworthiness checks.

Bundles is responsible for processing the data, the corresponding administration actions (e.g. detergent management, monthly overview, etc.) and small maintenance actions.

B. Financial

The financial resources needed to make the pay-per-wash BM possible are large investments. Bundles regains these costs by the deposit, monthly payments, the costs per wash and the mandatory distribution fee.

C. Physical & Logistics

There are four types of conventional Miele WMs available in the subscription. Depending on the washing machine A tracker is built onto the machine that is able to record the washing behaviour of the user. Furthermore, tools for the maintenance step are needed and resources such as a truck, fuel, etc. are needed to transport the WM to the user.

D. Knowledge

The software resource is the core of controlling all the work processes (e.g. transport, maintenance, customer service, etc.).

Adoption factors

A. Driver

A driver that Bundles has experienced is the fact that consumers are more willing to choose a PSS BM. This is because it can give elderly the feeling of independence back, the opportunity of personal contact and allow consumers to use products with high prestige.

B. Barriers

Peters (2020) mentioned three barriers that prevent PSSs from flourishing. The first barrier is that people have less trust in service providers because they are becoming more self-sufficient. This is also expressed in the fact that people will not call the customer service for help which sometimes results in unnecessary repairs. The second barrier is that people are not accepting of PSSs because they see renting as an option for the poor. A third barrier is the fact that current WMs are not suitable for PSS BMs. This is visible in the fact that disassembly is sometimes difficult due to glued together components.

Life Cycle Impact Assessment

A. Current

There are twelve ways in which Bundles is trying to decrease the environmental impact created by their BM. First by using WMs from one manufacturer and second by only four different models, storing additional WM components is easier. This makes the refurbishing process more efficient. Because the WMs are of high quality the products can withstand more wash cycles. This can result in serving more users with the same product. Furthermore, by explaining the machine when delivered and holding them accountable for the product, the product quality return is relatively high. Also making users pay-per-wash, will incentivise them to decrease their number of washes. A sixth action is the monthly overview that incorporates personalised tips. Choosing WMs with a high energy label (i.e. A+++-20) is an eight way that Bundles is decreasing their environmental impact. A ninth action is reusing the WM after the maintenance program and a tenth is repairing the machine when it is not working properly. If repairing is not possible, the machine is remanufactured (eleventh way) or a twelfth way is retrieving valuable components.

B. Future

Peters (2020) mentions five actions that can decrease the environmental impact of washing in the future. One is by sharing the WM amongst multiple users (i.e. product sharing/renting archetype). For example by placing a WM in a common washing area in an apartment building. A second action would be to look into the silver ion technology. This technology incorporates silver-based ions which can protect certain materials from bacteria growth. This might make the use of WMs unnecessary. Peters (2020) mentions that customer acceptance is still difficult. A third way is to look at ways to place the WMs in laundromats in slums. Peters (2020) states that a WM could be running there for an additional ten years. A fourth action is by letting the WM producers take over the PSS BM and utilise the tools offered by Bundles. This will eliminate the extra provider costs and incentivise the producer to design machines with a longer lifespan. A fifth action is that Bundles would like to design their own WMs with the tracker built inside, without unnecessary programs and easy to upgrade or take apart.

Appendix T - Means explanation

Suitability

Excellent	Good	Decent	Limited	Not suitable

T1. Use

Mean	What	Effectiveness [%]	Explanation effectiveness	Suitability
Educate				
1. Campaigns	By setting up campaigns on the radio or TV, washing machine users can be educated on sustainable washing.	8	The campaign is assumed to reach 40% of PSS users and 20% of them are convinced.	Coolblue has TV and radio commercials. However, these are based on promoting products or services. Educating consumers is not their field of expertise. Therefore this means is found not suitable.
2. Explanatory stickers	Stickers could be placed on the washing machine to remind the user of the environmental impact of certain wash programs.	12	The assumption is made that placing stickers on all WMs will affect 100% of the users and the impact of this mean depends on how many users are convinced and how many will act upon it. The assumption is made that 20% of the users are convinced and 60% of them will act upon it as they are reminded of the impact everytime they see the WM.	This mean is very suitable. Coolblue can design stickers that can engage and stimulate users in a unique and fun way. It can increase the NPS. The stickers will need to be esthetically pleasing and not too expensive. This however is not perceived as a problem for Coolblue.

3. Tips on website	On the websites features of the WM can be clarified and explain the environmental impact of certain wash programs.	1	This type of educating variable is passive, as the user chooses if he or she looks up more information on the website. Therefore it is assumed that only 10% of the users will see the tips and 10% will change their washing behaviour.	This mean is very suitable. Coolblue can engage and stimulate users in a unique and fun way which can increase the NPS.
4. Personalised tips	By monitoring the washing behaviour, a use pattern can be defined and personalised tips can be sent. A built in device is necessary for this mean to work.	20	As the tips are more targeted, it is assumed that the user is more likely to act upon the tips then the general tips on the website. 100% Of the users will receive the tips and 20% will act upon these tips, as they are more targeted.	This mean is considered suitable as Coolbue can target its users better which can increase the NPS.
5. Explaining WM at installment	When installing the WM, the provider can explain how the WM works. This will save the user from going through the entire manual, prevent misuse of the machine and educate them on the most environmentally friendly programs and detergents.	8	This variable affects 100% of the users and offers more convenience for the user. The impact of this mean depends on how convincing the installer is and whether the customer is willing to act upon it. The assumption is made that 20% of the users are convinced and 40% of them will act upon it.	This mean is considered very suitable because Coolblue can engage and stimulate its users to wash more sustainable in a unique and fun way. This can increase the NPS and decrease returns which could increase EBITDA.
Incentivise sustainable washing behaviour				
6. Washing championships	By organising a washing championship, PSS providers could stimulate the most sustainable washing behaviour. In order for the championship to be transparent, a built in device is needed.	2	The championship is assumed to reach 10% of the users and from this amount it is expected that 20% of the washing behaviour is changed permanently after the championship.	Coolblue does like a 'stunt' one in a while to increase NPS. This mean could suffice for that. However, the stunt is perhaps too product specific.

7. Pay a fixed price per wash	A fixed price per wash system can incentivise the user to wash less frequently. This type of incentive demands a built in device to monitor the usage.	15	The effect of this variable is assumed to be rather high as the user will pay extra for each wash.	Coolblue likes to make the customer journey as pleasant as possible. Making the customer pay per wash with tiered prices may surprise them at the end of the month. This could decrease NPS and is therefore not a great fit for Coolblue.
8. Pay-per-wash with tiered prices	By offering differentiated prices for different washing programs, the user can be incentivized to wash more sustainable washing programs. This type of incentive only works together with the pay-per-wash variable and demands a built in monitoring device.	23	Homie mentioned that a pay-per-wash system with differentiated prices made their customer wash 20-25% more sustainable. (Bom, 2020).	Coolblue likes to make the customer journey as pleasant as possible. Making the customer pay per wash with tiered prices may surprise them at the end of the month. This could decrease NPS and is therefore not a great fit for Coolblue.
9. Give positive user feedback through email	During the lease period, the customer can receive positive user feedback each couple of months through emails. The feedback is general and based on average consumer use.	2	Based on the survey, the assumption is made that 12% will read the emails (Smetsers, 2020) and 20% will be incentivised to act upon the positive reminders. If the feedback is based on true washing behaviour the effectiveness is assumed to be higher. However, this would mean a built in device is needed.	Coolblue does send out emails to their customers, but too frequently sent emails could be seen as spam.
Monitor WM usage				
10. Built in device	Built in devices are trackers that can digitally monitor the washing behaviour of a user. This type of monitoring is very accurate as the	95	The effectiveness of a built in device is assumed to 95% as 5% of the time it might not work correctly.	This mean would require Coolblue to invest in new type of WMs where the device is built in. this would require a lot of investments. WMs

	user cannot interfere with the outcome.			are not their only product group. Therefore the mean is considered to be not that suitable.
11. Survey	Through a filled in survey the WM providers can get an idea of what the washing machine usage is. For example: How often do you wash per week? At what temperature do you wash?	10	Not all users will fill in the questionnaire or answer it truly, this can make the results less accurate. The previous PaaS survey had a response rate of 12% (Smetsers, 2020). The assumption is made that 85% of this information was filled in correctly and true.	Coolblue does send out surveys to their customers, but too frequently sent emails could be seen as spam.
12. Sampling after use	This type of monitoring would mean analysing the WM after usage together with the type of user. This could, for example, reveal user patterns for certain households.	24	It is considered to be too time consuming to analyse all WMs that are brought back. However after a long while it is assumed that 60% of the WMs are analysed and 40% of the analysis are correct and can be generalised for all users.	Coolblue is already testing returned white goods to see if they can be sold again (e.g. SecondChance). By analysing the WM a bit more on its ware and tare user patterns can be established. This will be a bit more time consuming.
13. Sampling during use	This way of monitoring is by going to different users and analysing the state of the WM after a certain amount of time.	32	Going by the houses is assumed to be more time consuming and thus 40% of the WMs will be analysed. As this sampling is done during use it is assumed to be more correctly, resulting in 80%.	This mean not that suitable to Coolblue as it will take a lot of time which they could spent in increasing NPS or EBITDA. It is not Coolblue's field of expertise.

T2. Life extension

Mean	What	Effectiveness [%]	Explanation effectiveness	Suitability
Stimulate careful use				
14. Deposit	A deposit means that users will have to pay a sum at the beginning of the contract and will receive it back if the product is returned in acceptable state.	90	A higher deposit resembles a higher recycling rate (Linderhof *et al.*, 2019), which is assumed to correlate to careful use. A deposit of €75 per washing machine is assumed. This is based on the deposit of Bundles. This amount is considered to be rather high for consumers in a PSS BM and therefore the effectiveness for careful use is assumed to be also very high.	A deposit can scare off some customers and be seen as a barrier. Therefore it can decrease sales and is thus not very suitable.
15. Rewards for good returns	When the WM is returned in good condition the user can receive rewards in the form of discounts or coupons.	29	The rewards are supplementary, which means that if the user does not comply, he or she will not 'lose' anything. Also to make the variable possible, the discounts or coupons will probably not be that high. Based on the survey, 57% of the PaaS users say that financial reasons is the main motivation for choosing a PSS BM (Smetsers, 2020). The assumption is that 50% of them will actually act upon this variable.	This mean is suitable for Coolblue as it can increase both EBITDA and NPS. The two ways Coolblue measures its success.
16. Email reminders	By sending emails to the customer, they can be reminded to use the WM carefully.	12	Based on the survey, the assumption is made that 12% will read the emails (Smetsers, 2020) act upon the reminders.	Coolblue does send out surveys to their customers, but too frequently sent emails could be seen as spam.

17. Strict contractual terms	The contract contains strict measures that can be taken if the user does not comply with the rules of the contract. For example a late payment results in €20 fine.	90	Similar to the deposit variable, consumers might be more inclined to comply with careful use, as they will lose money.	Strict contractual terms are not suitable to Coolblue as it is assumed to decrease NPS and sales.
Prolong the material life cycle				
18. Predictive maintenance	Predictive maintenance means that any maintenance on the WM will be predicted and eliminate unnecessary incidents, whilst reducing downtime. This variable would need a built in device.	95	The effectiveness of this variable is assumed to be almost 100%, however the assumption is made that not every maintenance will be done correctly or on time due to human error.	Offering predictive maintenance to the user can be seen as a beneficial service as the customer does not have to worry about anything and Coolblue will only stop by if necessary.
19. Planned maintenance	Planned maintenance is planned, documented and scheduled maintenance. Downtime of the WM can be reduced.	80	The effectiveness of planned maintenance is assumed to be lower than predictive maintenance, as some components might be repaired when they are still in good condition. Taking human error also into account the effectiveness is assumed to be 80%	Offering planned maintenance at the user can be seen as a beneficial service. This can be experienced as positive by the user. As Coolblue measures its success in NPS this is very suitable. It is important that the maintenance service fits the Coolblue service standards.
20. Repair at user	This type of repairs are done during the user phase at the house of the user. It is assumed that only small repairs can be performed at the users home.	70	Repairing at the user means that there is already something broken in the WM. This can affect other components inside the machine. This effectiveness is assumed to be between planned maintenance and refurbishment which is 70%.	Repairing the WM at the user can be a moment where Coolblue is in contact with the user and 'promote' itself positively. Therefore this means is suitable.

				It is important that the repair service fits the Coolblue service standards.
21. Refurbishmen t	Repairing the WM when the machine is sent back.	60	This means that the machine is collected and sent to the WH or depot where repair(wo)men have all tools, components and time to repair the machine. The effectiveness is assumed to be 60%. This is based on the recovery numbers by Coolblue.	Coolblue already has a refurbish stations at two of their depots. Showing customers that they are actively working on sustainability could increase NPS. Also offering refurbished WMs in the lease can decrease the monthly price for customers.

Appendix U - Concept 1: The Friendly Reminder

Table U.1 Chosen means in the user phase for concept 1 (Source: Author)

Sub-functions	Possible means				
Educate users	1. Campaigns	2. Explanatory stickers	3. Tips on website	4. Personalised tips	5. Explaining WM at installment
Effectiveness	*8%*	*12%*	*1%*	*20%*	*8%*
Incentivise sustainable washing behaviour	6. Washing championship	7. Pay a fixed price per wash	8. Pay-per-wash with tiered prices	9. Give positive user feedback through email	
Effectiveness	*2%*	*15%*	*23%*	*2%*	
Monitor WM usage	10. Built in deice	11. Survey	12. Sampling after use	13. Sampling during use	
Effectiveness	*95%*	*10%*	*24%*	*32%*	

Table U.2 Chosen means in the life extension phase for concept 1 (Source: Author)

Sub-functions	Possible means			
Stimulate careful use	14. Deposit	15. Rewards for good returns	16. Email reminders	17. Strict contractual terms
Effectiveness	*90%*	*29%*	*12%*	*90%*
Prolong the material life cycle	18. Predictive maintenance	19. Planned maintenance	20. Repair at user	21. Refurbishment
Effectiveness	*95%*	*80%*	*70%*	*60%*

Appendix V - Concept 2: Planned maintenance

Table V.1 Chosen means in the user phase for concept 2 (Source: Author)

Sub-functions	Possible means				
Educate users	1. Campaigns	2. Explanatory stickers	3. Tips on website	4. Personalised tips	5. Explaining WM at installment
Effectiveness	*8%*	*12%*	*1%*	*20%*	*8%*
Incentivise sustainable washing behaviour	6. Washing championship	7. Pay a fixed price per wash	8. Pay-per-wash with tiered prices	9. Give positive user feedback through email	
Effectiveness	*2%*	*15%*	*23%*	*2%*	
Monitor WM usage	10. Built in device	11. Survey	12. Sampling after use	13. Sampling during use	
Effectiveness	*95%*	*10%*	*24%*	*32%*	

Table V.2 Chosen means in the life extension phase for concept 2 (Source: Author)

Sub-functions	Possible means			
Stimulate careful use	14. Deposit	15. Rewards for good returns	16. Email reminders	17. Contractual terms
Effectiveness	*90%*	*29%*	*12%*	*90%*
Prolong the material life cycle	18. Predictive maintenance	19. Planned maintenance	20. Repair at user	21. Refurbishment
Effectiveness	*95%*	*80%*	*70%*	*60%*

Appendix W - Concept 3: Pay-per-wash

Table W.1 Chosen means in the user phase for concept 3 (Source: Author)

Sub-functions	Possible means				
Educate users	1. Campaigns	2. Explanatory stickers	3. Tips on website	4. Personalised tips	5. Explaining WM at installment
Effectiveness	*8%*	*12%*	*1%*	*20%*	*8%*
Incentivise sustainable washing behaviour	6. Washing championshi p	7. Pay a fixed price per wash	8. Pay-per-wash with tiered prices	9. Give positive user feedback through email	
Effectiveness	*2%*	*15%*	*23%*	*2%*	
Monitor WM usage	10. Built in device	11. Survey	12. Sampling after use	13. Sampling during use	
Effectiveness	*95%*	*10%*	*24%*	*32%*	

Table W.2 Chosen means in the life extension phase for concept 3 (Source: Author)

Sub-functions	Possible means			
Stimulate careful use	14. Deposit	15. Rewards for good returns	16. Email reminders	17. Strict contractual terms
Effectiveness	*90%*	*29%*	*12%*	*90%*
Prolong the material life cycle	18. Predictive maintenance	19. Planned maintenance	20. Repair at user	21. Refurbishment
Effectiveness	*95%*	*80%*	*70%*	*60%*