

The effect of Product service systems (PSS) on the ecological sustainability of manufacturing firms

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ABSTRACT,

Over the past years, the importance of ecological sustainability linked to inter alia the manufacturing industry increased substantially. In addition to that the development of products and services, contributing to a decrease in the aforementioned ecological issues is from high importance in the manufacturing industry. For this, the implementation of environmental degradation prevention practices such as product service systems (PSS) can be used as a starting point. To identify what effects the introduction of PSS has on the environmental sustainability of manufacturing firms, a case by case analysis including interviews is conducted amongst three medium sized manufacturing firms. In order to do so, a pilot project approach is applied. The aim of this approach is to analyze PSS business opportunities, explore new PSS design and development processes and ultimately find a fitting PSS solution. It was found that the overall energy consumption of manufacturing firms is too high and bears great potential of change in order to act more ecologically sustainable. Therefore, the use of solar energy presented itself most feasible. In order to successfully implement a PSS, a shift from special machine construction towards series production was found as a prerequisite. In order to generate up to high impact reductions manufacturing firms bear great potential of adopting product- as well as use-oriented services.

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Keywords

Environmental sustainability, environmental impact, Product- Service- Systems (PSS), PSS characteristics, case study, manufacturing firms

1. INTRODUCTION

Over the past years, the importance of ecological sustainability linked to inter alia the manufacturing industry increased substantially. It is seen as a global issue as well as great challenge for society (Pathak, Singh, Sharma, 2017). A denoting part of the world's resource consumption and waste production originates in the manufacturing industry. (IEA, 2007). In order to operate more ecologically sustainable, the design and implementation of integrated sustainable practices became crucial for manufacturing firms. Moreover, the development of products and services, contributing to a decrease in the aforementioned ecological issues is from high importance in the manufacturing industry (Pathak, Singh, Sharma, 2017). For this, the implementation of environmental degradation prevention practices such as product service systems (PSS) can be used as a starting point (Pathak, Singh, Sharma, 2017). Nowadays, with the increasing demands of enhancing business competitiveness and reducing material consumption and carbon footprint, there has been ascending importance attached to product service systems. However, for many manufacturing firms shifting to product service systems bears some difficulties due to a lack of understanding the changes coming with it (Xing, Ness, 2016).

The case companies are medium sized businesses, manufacturing both standard and custom-built packaging machines. The provision of efficient solutions in the areas of packaging and palletizing technology, serving the food- as well as non- food industry displays their core activity. As leading players in the sector, supplying companies across the globe, these manufacturing firms increasingly face the demand for reduction in material consumption and carbon footprint. Especially with the recent discussions and demands on the reduction of packaging waste in Germany (Junginger, 2019) as well as globally, the need for adopting environmental degradation prevention practices to tackle arising ecological issues is higher than ever. Therefore, in order to provide guidance to manufacturing firms on what to encounter when shifting to product service systems (PSS), this thesis will focus on the effects of product service systems (PSS) on ecological sustainability.

This thesis intends to fill the research gap of the missing solutions on how to fulfill user demands in a sustainable way. The following research question "How does a shift to Product service systems (PSS) affect the ecological sustainability of manufacturing firms?" should help address this issue.

This research question serves as the main aspect of analysis. However, in order to fully answer the research question, a number of sub questions have been formulated. These are included to further delve into the topic of Product service systems as well as ecological sustainability and therefore give more rise to what the research goal encounters.

- What are Product service systems?
- What is the environmental dimension of sustainability?
- What motivates manufacturing firms to consider Product service systems?
- What are potential barriers for manufacturing firms to adopt Product service systems?

The chosen topic is academically relevant as there is an continuous increase in importance of environmental sustainability in manufacturing firms. Therefore the shift to product service systems has formed the need for further research. Product service systems are seen as a driver for enhancing a firm's competitiveness and fostering sustainability

simultaneously. To determine the sustainability of a product service system, it has to be looked at whether the system operates less material intensive and whether the actors included on the production process feel the incentive to further decrease material intensity. However, there is a lack of understanding what factors determine whether a product service system encourages sustainable behavior (Tukker 2004). Although many papers refer to the topic of product service systems related to sustainability, there is little guidance about its practical implementation and impact towards firm's performance provided (M. Roni, J. Jabar, M.R. Mohamad, M. Yusof 2014). Existing literature so far often only analyses the effect of product service systems on sustainability but do not provide methods to improve sustainable performance accordingly (Huer, Hagen, Thomas and Pfisterer 2018). Furthermore, it can be said that generally positive and negative influences of product service systems on sustainability will be given high importance to but researches still fail to propose sustainable solutions. This lack of solutions poses a grand challenge of product service system research. Only by tackling this issue, sustainable behavior of manufacturing firms can be ensured (Huer, Hagen, Thomas and Pfisterer 2018). Especially when it comes to the shift from traditional business models to product service systems effective decision support have to be provided (Xing, Ness 2016). An overlap between the academic and practical relevance can therefore be observed. A connection between environmental sustainability and product service systems is shown and ultimately poses the need for further research.

The following section explains the theoretical background of the topic. In order to then answer the research question in a structured way, further sections are arranged consecutively. Starting with the analysis of existing literature and theory regarding different PSS as well as sustainability dimensions and more specifically the relationship between PSS and the environmental dimension of sustainability in section two. Section three entails the explanation of methods, used for the data collection. Afterwards, in section four actual case studies are conducted to gain insights on what effects the introduction of PSS has on environmental sustainability of each company in question. Finally, the findings of the thesis will be summarized and guidance is provided on how to successfully implement a PSS in a manufacturing company (section five).

2. EXISTING LITERATURE & THEORY

Traditionally, the main focus of manufacturing companies lays on product design, -development, -production to then ultimately sell the product on the market. However, with the change of global competition in recent years, manufacturing companies have to adapt. Great responsibility for the offered products throughout the entire lifecycle on the companies behalf is demanded. Therefore, more and more manufacturing companies overcome the barrier to shift their business focus from solely selling product to providing (add on) services, from product-oriented to service-oriented. This shift is known as the Product service system approach. Product service systems (hereinafter PSS) can be defined as "the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands." (Manzini & Vezzoli 2002). This means that the company focuses on (add on) immaterial services rather than solely material products. Customer value is rather provided by service provision than product sales. Value creation from the support of customer's activities related to the use of the product rather than creating value embedded in the physical product can be described as an underlying principle of PSS. With the shift to PSS, greater

responsibility for operating and using the products on the company's behalf arises. This includes for example maintenance and disposal. PSS are seen as an motivator as well as enabler for companies to enhance and reuse their products and service throughout the entire life cycle. This can be done by more efficiently using (natural) resources. Conclusively, material consumption is reduced and material efficiency increases as the company's and customer's motivation to do so positively correlates with the shift to PSS. This enables a company to enhance competitiveness and foster sustainability simultaneously. Moreover, it can be said that PSS creates new sources of added value, as customer loyalty is embellished and innovation is boosted (Tukker 2004). This is due to the fact that with PSS, client needs can better be accomplished in an integrated and customized way.

2.1 Product Service Systems

There are three main categories of PSS namely product-oriented, user-oriented, and result-oriented. When talking about product-oriented services, it can be said that the main business focus still lays on selling products (Tukker 2004). However additional basic add on services are already provided. In addition to that, the provision of relevant services ensures product functionality as well as supports product sales (Gebauer, Joncourt and Saul 2016). Compared to traditional business models, here the focus already lays on inexpensively and efficiently meeting customer needs rather than abundantly producing products. For this, constant reinvention resulting from constantly keeping pace with the changing customer needs is from high importance.

The second category is use-oriented services. Compared to product-oriented services, here the main business focus does not solely lay on the product sales anymore (Tukker 2004). The ownership structure changes as the product ownership remains with the provider. Product usage is made available for customers in different forms (Gebauer, Joncourt and Saul 2016). Sometimes, users even share the product. Nevertheless, the traditional product itself still plays an important role (Tukker 2004).

Lastly, there are result-oriented services. This category largely differs from the prior mentioned categories, as with result-oriented services there is no pre-determined product involved anymore (Tukker 2004). Customers and providers only agree on a result and/ or performance. Here, value proposition derives from the promise of achieving a certain customer performance (Gebauer, Joncourt and Saul 2016).

To gain further insight about what the different categories of PSS encounter, more specific PSS types can be described. In the following, the main focus will be on further elaborating on product- and use-oriented services only. This is due to the fact that these categories can be considered most relevant to practice regarding manufacturing firms. As the companies in question are well established and currently follow a traditional business model, it can be said that they are in the early stages of exploring new territory, potentially shifting to PSS. Therefore, result-oriented services are out of question. Figure 1 graphically displays the aforementioned different categories of PSS as well as the following specific types thereof.

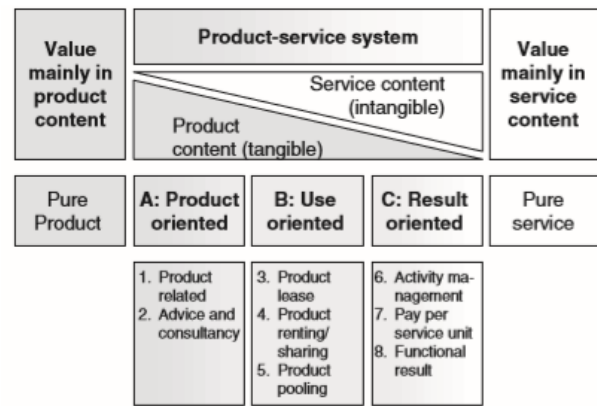


Figure 1. Main PSS categories and specific PSS types

When looking more specifically at product-oriented services, two different types can be described. Firstly, product-related services where not only the product is sold by the provider but additional services are offered as well. The need for these services arises during the product's use phase (Tukker 2004). Examples hereof can be maintenance, a financing scheme or take-back agreements at the end of a product's life cycle.

Another specification of product-oriented services entails advice and consultancy. Here the focus lays on giving advice on the most efficient use of the sold product. Meaning that, the provider for example gives advice on how to optimize logistics in a factory where the product is used (Tukker 2004). Moreover, advice can also be given on the organizational structure of the team which works with the product.

A closer look at use-oriented services gives rise to the following specifications. With product leasing the traditional ownership structure changes as the product does not shift in ownership. This encompasses ownership as well as responsibility for maintenance, control and repair on the providers behalf. In order to unlimitedly and individually using the leased product a regular fee is paid by the lessee (Tukker 2004). Product renting and sharing is closely related to product leasing. The product is owned by the provider, who also takes on responsibility for maintenance, control and repair. Moreover, the user also pays for the use of the product rather than the product itself. However, a great difference between these two specifications is the type of access the user has to the product. With product renting or sharing the user does not have unlimited and individual access to the product. It is sequentially used by different users (Tukker 2004).

Characterizing product pooling in itself does not much deviate from the prior description of product renting and sharing. Here the provider also owns the product, is responsible for maintenance, control and repair and gets paid for the use of the product. With product pooling however, the user is restricted in the access of the product as it is simultaneously used by different users (Tukker 2004).

In general it can be said that within all specifications of PSS categories, the product's purpose of being the core component decreases. In addition to that, it becomes obvious that the customer's needs are formulated more abstract.

2.2 Merits & Drawbacks of PSS

In the following, merits in drawbacks of PSS will be elaborated on. Some companies still face great barriers to shift to PSS as it is rather new territory to be explored. With the introduction of PSS the company has to think about a cultural shift. Incentives

have to be changed from wanting to own a product to rather feeling the need to operate in a sustainable way. The therefore required changes in the corporate culture and organization imply a great challenge for companies (Tischner and Vezzoli). Moreover, barriers in the design-, development-, and delivery process of a PSS deter companies from adopting this new type of business model. Not only the required corporate changes to be made but also the lack of knowledge and experience with a new system have to be overcome. In addition to that companies fear that the new system conflicts with their existing internal processes, offers on the market, tools and business as usual (Tischner and Vezzoli). Moreover, the thought of changing the focus from selling a tangible product to then offering the product with (add on) services and maybe in later stages solely services, currently hinders companies to adapt. However, with the introduction of PSS great benefits arise. As companies more and more face global changes, PSS offers the opportunity to survive in a mature industry as well as enter a new sector (Tischner and Vezzoli). Generally speaking, with the introduction of PSS economic, environmental and social characteristics can better be promoted than within a traditional system. In addition to that, economic as well as environmental efficiency largely increases when adopting a PSS dimension (Tischner and Vezzoli). With regard to recent developments and the future, a shift to PSS will someday become indispensable.

2.3 Sustainability – Triple Bottom Line

With the change of global competition in recent years, inter alia manufacturing companies learned that social and environmental performance correlates with economic achievement. Sustainability is seen as the sum of economic activities corresponding with ecological life support systems. (Gray and Milne 2017). Although traditionally the concept of sustainability is associated with environmental production only, due to the impact of the global changes over time, sustainability nowadays refers to economic, environmental and social dimensions (Arslan and Kisacik 2017). As the importance of these dimensions increased, the concept of triple bottom line (hereinafter TBL) was introduced. The TBL concept by John Elkington “was designed to cover environmental and social dimensions by going beyond the calculations of classical profit, investment income and shareholder value”. This means that social and environmental factors should also be included when making crucial decisions rather than only focusing on profit maximization (Arslan and Kisacik 2017). Therefore TBL is presented as tridimensional.

In that respect, the company’s success is not only measured by the financial bottom line anymore, but social and environmental performance is also considered (Norman and MacDonald 2003). Profit has not become less important, however, the importance given to the environment which enables the profit and the people living in the environment largely increased (Arslan and Kisacik 2017).

Therefore, it can be said that TBL is the joint evaluation of economic, social and environmental sustainability which are the basis of sustainability as well as efficient use of the sources (Elkington, 1997). As TBL not only includes economic- but also deals with environmental and social measures it is often referred to as an accounting framework which widely differs from traditional reporting frameworks. (Slaper and Hall 2011) Companies can measure their sustainability by using the TBL concept. This may help identifying the economic, social and environmental impact a newly introduced project or policy has. Generally, there is no universal standard method for measuring sustainability by using the concept of TBL. However, in order to compare units, sustainability in respect of the TBL concept can

be measured by using indexes. A prerequisite thereof is however, that a universally accepted accounting method is in place.

2.4 Environmental dimension of sustainability

In the below Figure 2, the three dimensions underlying the TBL concept are visually displayed. These dimensions will be described in the following paragraph. However, as the focus of my research lays on the environmental dimension of sustainability, the remaining dimensions will only be shortly commented on.



Figure 2. Three dimensions of the TBL concept

The economic dimension of the TBL concept entails the impact of the company’s operations on the economic system (Arslan and Kisacik 2017).

The social dimension refers to a company’s required applications which are beneficial and fair to society, labor and human capital (Arslan and Kisacik 2017).

The environmental dimension of sustainability includes sustainable environmental practices. It addresses companies to operate in a way that environmental resources are not endangered and their environmental impact is minimized. Great emphasis lays on the efficient use of energy sources and careful management of nonrenewable resources. Furthermore, the protection of natural resources is also from high importance when talking about the environmental dimension of sustainability. In order to operate environmental sustainable, high attention should be given to the use of recyclable materials, secure waste disposal (Schroeder and DeNoble 2014) and the reduction of manufacturing waste in general. Dematerialization and resource efficiency can therefore be described as key drivers for environmental sustainability (Huer, Hagen, Thomas and Pfisterer 2018).

2.5 PSS in relation to environmental sustainability

Tukker suggests, that “sustainability is about fulfilling needs with minimal material use and emissions” (Tukker 2004). Therefore, it can be said that the effect of PSS on environmental sustainability depends on whether or not less material is used in the process. Additionally, it is dependent on the involved actor’s incentives to lower material usage even more. With PSS, a company’s product design should positively contribute to a lower environmental impact. In this way energy demand can be decreased and an increase of durability as well as high levels of asset utilization can be reached (Huer, Hagen, Thomas and Pfisterer 2018).

In the following paragraph, the effects of the aforementioned specified PSS types on environmental sustainability are discussed.

As earlier mentioned, product related services do not consider any change in the existing technological system, neither do they imply any change of how the user operates the system. In addition to that, it can be said that with product related services, the provider does not feel a strong incentive to incorporate life cycle costs in the design process (Tukker 2004). Based on the characteristics of this PSS type, it becomes obvious that some incremental efficiency improvements due to take back provisions or better maintenance can be achieved but are not guaranteed. Therefore, it can be said that product- related services can generate impact reductions. However, they are considered incremental at best (Tukker 2004).

The effects of advice and consultancy on environmental sustainability show some similarities with the effects of product-related services. As already discussed, here the main value is created by providing optimization suggestions to the user. With regard to additional characteristics of this PSS type, it can be said that the application of advice and consultancy enables incremental reductions in environmental impacts.

With regard to the earlier mentioned PSS types and therefore product- oriented PSS in general, it becomes obvious that only incremental environmental improvements will at best be achieved. Expectations for radical changes are rather abstract, as with this PSS dimension the technological system itself does not change. However, to some extent it is operating more effectively. Moreover, as product- related services encounter better maintenance, capital goods can be used more intensively and energy use decreases (Tukker 2004). Nevertheless, all improvements are considered less radical.

For the next PSS type, product leasing, it cannot clearly be distinguished whether or not there will be impact reductions. On the one hand the provider takes responsibility for maintenance, control and repair. This in principle results in the more efficient use of energy and consumables. In addition to that, the product might even have a longer life span. With regard to this, incremental efficiency improvements are achieved. This is enabled by the fact that the product provider has the incentive to extend the product life cycle and adapts it's product design accordingly (Tukker 2004). However, with product leasing the customer in question often is displayed as a leasing company which then further leases the products to third parties. In this case, the incentive of extending the product life span is not passed on and often ultimately reaches a dead end. Another general potential setback to keep in mind is the fact that arising costs during the use phase are generally not covered when leasing a product (Tukker 2004). As a result neither the lessee not the product provider feel the need to reduce energy and material consumption. These setback may arise due to the fact that the user does not own the product anymore resulting in careless behavior, reducing the product life span.

When renting or sharing a product, a more intensive use of the same product by different users is implied. This positively correlates with high environmental impact reductions. Contrary to the aforementioned PSS types, with product renting and sharing integrated costs for the use of the product are paid by the user. From this, an additional environmental benefit arises. The fact that numerous users share the product makes it's use more complicated, resulting in dispirited users to access the product (Tukker 2004). With exclusive regard to the environmental effects thereof, it can be said that positive effects may arise. Under the condition that the renting and sharing situation leads to for example less product use.

The effects of product pooling on environmental sustainability resemble the effects of product sharing and renting. However,

there is one major difference as a characteristic of product pooling is the simultaneous use of the product by different users. As a result, even more environmental impact reductions compared to product renting and sharing can be achieved.

With regard to the aforementioned PSS types, generally use-oriented services, the following can be concluded. High environmental gains can be achieved, due to the introduction of these PSS types. Reasons for this are for example when pooling a product, more people can simultaneously benefit from consumables in the use phase. Therefore, less energy is used and material consumption decreases. Another reason implies that generally with use- oriented services, the use of capital goods is more intensive compared to the traditional system. However, it also has to be kept in mind, that users potentially have to make great tangible as well as intangible sacrifices (Tukker 2004). From this, a decrease in the market value towards competing products results. Nevertheless it becomes obvious that from an environmental sustainability viewpoint, product renting, sharing and pooling, generally use- oriented services are the most promising PSS types.

Although most of the aforementioned PSS will lead to at best marginal environmental improvements, probably all PSS dimensions have some positive effects on environmental impact reductions. At least, environmental performance will not be worst due to the introduction of PSS (Tukker 2004). Deriving from this, all PSS dimensions somehow lead to potential environmental gains with generally not too much risk to take on. However, when looking at the big picture, it can be said that although there are great positive effects on environmental sustainability deriving from PSS use, it is not always an economic- environmental win- win situation (Tukker 2004). A good example of this can be potential economic sacrifices that have to be made when introducing use- oriented services. With PSS, economic aims sometimes contradict with environmental desires. This may lead to companies hesitating to apply PSS. However this barrier can already be overcome by taking small steps in the right direction from an environmental sustainability point of view.

2.6 Merits & Drawbacks of PSS on environmental sustainability

To conclude, merits and drawbacks of PSS on environmental sustainability will be described. With the introduction of for example use- oriented services a provider does not sell the product to it's customer anymore but remains the owner of the product. From this, the benefit of improved utilization of resources arises due to the fact that the product can be reused and ultimately recycled (Huer, Hagen, Thomas and Pfisterer 2018). Although the change of ownership structure leads to environmental benefits, it also may have negative effects on the environmental sustainability. As the user is not the owner anymore, careless behavior might lead to shortened durability of the product (Huer, Hagen, Thomas and Pfisterer 2018). However, the arising benefits outweigh the negative effects on environmental performance as with the introduction of PSS environmental efficiency, - performance and cost savings increase. Nowadays, many companies still cannot overcome the barrier to introduce PSS even though they want to increase their environmental sustainability as they lack concrete solutions how to improve their environmental sustainability. However, the trend develops towards the introduction of PSS as it can be crucial for survival in mature industries or displays an opportunity for entering a new sector (Huer, Hagen, Thomas and Pfisterer 2018).

2.7 Case based analysis – concept

With the introduction of PSS economic, environmental and social characteristics are said to be better promoted than within a traditional system (Tischner and Vezzoli). As the success of a PSS depends on many individual factors, there is not one perfect solution for every company. Therefore, a case by case analysis will be conducted in later chapters to identify what effects the introduction of PSS has on environmental sustainability of each company in question and what should be done in order to successfully implement a PSS. In order to do so, a pilot project approach is applied. The aim of this approach is to analyze PSS business opportunities, explore new PSS design and development processes and ultimately find a fitting PSS solution for the company (Tischner and Vezzoli). The main challenge will be to explore and develop business strategies in order to fulfill user demands in a sustainable way while creating more value simultaneously. Following this approach, qualitative tools are used to analyze each company.

In order to in the end come up with the best solutions for the company in question to move it's traditional system towards PSS and therefore, towards greater environmental sustainability, firstly the existing system has to be analyzed (Tischner and Vezzoli). This can be done in the following steps. In the beginning the focus lays on identifying the company's existing reference system. Here, the general questions to be thought of, are for example what happens internally, within the company or externally, in relation to customers and suppliers. The definition of a satisfaction unit helps identifying important elements of the reference system. In addition to that, fulfilled as well as remaining customer demands are explored in order to identify possible boundaries of the existing system. A list of the most relevant actors of the existing system is created.

With the help of the blueprinting tool and the aforementioned information, a better overview of an existing add on service can be identified. The blueprinting tool displays the existing service with all important activities of the process. Most attention is given to the customer when modeling the process. Resulting from this, a chronological order of activities is made. As earlier mentioned, customer interaction is the key focus of the blueprinting tool.

In order to then understand where problems as well as opportunities in the existing system lie or may arise, a SWOT analysis is conducted. Strengths, Weaknesses, Opportunities and Threats are identified. The SWOT analysis gives inter alia rise to what motivates manufacturing firms to consider PSS and what potential barriers are to adopt it. The focus of the conducted SWOT analysis lies on the environmental dimension of sustainability.

After successfully mapping the existing system and identifying it's Strengths, Weaknesses, Opportunities and Threats, concrete PSS ideas can be developed. The aim here is to improve the existing system. This can be done by solving identified problems, fulfilling remaining customer demands and taking identified opportunities. The goal of developing as sustainable ideas as possible is considered at all times (Tischner and Vezzoli). In order to formulate concrete, new and sustainable PSS ideas, sustainability guidelines are used as assistance. Here, the focus also lays on the environmental sustainability dimension. Resource reduction, waste minimization and conservation/ bio compatibility are factors to be analyzed (Tischner and Vezzoli). Analyzing these factors in depth, ultimately helps develop new PSS ideas to move towards greater environmental sustainability.

3. METHODOLOGY

This thesis follows an empirical research approach. A case study is conducted in which multiple companies are analyzed on the basis of their current business system. Moreover, comparing the companies to the chosen theory is part of the analysis. The reason for conducting this research is to gain greater insights of the phenomenon of PSS and the companies as the units of analysis of the case study.

Data for this research was gathered by conducting in- depth interviews with upper level employees in three medium sized manufacturing businesses serving the food industry as well as non- food industry (see Table 1). The companies all have their sites in Germany and manufacture both standard and custom-built packaging machines. A requirement for gathering useful data was that the employee has extensive knowledge of the company's internal as well as external processes and system. Generally, it was chosen to conduct interviews as this approach enables comparing the original idea of how PSS affect environmental sustainability to the current situation of the companies in question.

Table 1. Companies in the sample

Company	Industrial sector	Market served	Size	Position of interviewee
Company A	Manufacturing	Packaging for Non-food & food industry (agricultural sector)	Medium sized	Sales manager
Company B	Manufacturing	Packaging for Non-food industry	Medium sized	Partner
Company C	Manufacturing	Packaging for Food industry	Medium sized	Software developer

During direct visits to the companies, open- ended interviews were held. Open ended questions were chosen as they not solely provide the direct answer to the question but also provide the possibility that the interviewee additionally explores subjects the interviewer did not think about yet (Andres 2012). Questions were asked considering the current reference system of the company including internal and external process and most important actors and necessary products and services of the system. To get more insight on where possible opportunities and boundaries of the existing system lie, questions regarding the company's strengths, weaknesses, opportunities and threats are asked. To ultimately be able to address the right environmental problems and develop solutions accordingly, questions focusing on resource reduction, waste minimization and conservation/ bio compatibility are asked.

In order to prevent miscommunication and misunderstanding of the interview questions and the topic in question, clarifications were sought through previous email contact and phone calls. In order to comprehensively cover the research issue and intensively ask questions, the conducted interviews lasted one hour. After the interview, transcription follows as well as an intensive analysis of the gathered data. As all case companies are based in Germany, it could not be expected that all interviewees have sufficient knowledge of the English language. Therefore, the interviews were conducted in German. To later assure accurate and consistent data, the interviews were translated into English. Data has to be analyzed in the correct way for generating accurate and valuable outcomes. It was agreed upon that all interviews may be recorded. In that way, the provided content became more reliable and accurate. This is due to the fact that recordings can be reheard, tackling the possible issue of insufficiently taking notes. However, by taking notes during the interview and the latter transcription thereof, useful outcomes can be generated. In order to better link the theoretical framework and the research question of the thesis to the collected data, coding was applied. The pilot project approach as well as sustainability guidelines serve as basis for coding the data. Appendix 2 summarizes the key findings of the outcomes of the collected data. By creating this overview, assessing and

analyzing the data becomes easier. Differences and similarities amongst the companies in question can thus be realized. Therefore, the later analysis and results can be presented. In order to strengthen the data gathered during the interviews, other sources of information were consulted. For this, information was taken from company brochures as well as the company's website. With these additional general sources, the validity of the research can be assured by using a variety of sources to collect data on the same topic. Therefore, the purpose of data triangulation is served.

4. CASE BASED ANALYSIS – FINDINGS

In the findings section, the companies' existing reference systems will be identified. Additionally combining the information, drawn from the existing reference system with the service blueprinting approach, enables identifying the already existing (add on) services the companies provide. Here, the focus lays on maintenance services as they are provided by every case company and therefore serve as a great basis for analysis. Lastly, strengths and weaknesses of each company are identified keeping in mind underlying sustainability guidelines. All information is taken from the conducted interviews.

4.1 Company A

4.1.1 Existing reference system

Company A started off as a village smithy. Over the years they developed towards the well-established medium sized company, they are today. Their product offer ranges from conveyer belt technology and weighing units to packaging machines for the non- food as well as food industry. Here special emphasis is given to the agricultural sector. Company A's products are for example used for weighing, counting and packaging charcoal and cat litter as well as potatoes and dough pieces.

The existing reference system involves the following relevant internal and external actors. The internal product developer is highly important as he develops the machine operations. It is crucial to adopt the machine operation and construction to the offered kinds of packaging. Company A does not employ special product designers. Engineers are working on the standardized design of the machines. The company's interest is paramount for these actors. Internal and external sales representatives try to pass on and sell the product to the customer in close consultation with the management. Both parties follow the company's interest of product performance, economic gain and establishing a competitive advantage. Relevant external actors are customers, suppliers and even sometimes competitors. Outside the company these actors spread the word about Company A and its products which can have positive effects on the company itself. Although it positively affects the company, all actors have their own interests. Customers are interested in high quality and high performance products offered for little money as well as high product reliability referring to an warranted supply of spare parts. For needed serial parts the company mostly relies on engine- and clutch technology as well as cylinder- and valve unit suppliers. Competitors and suppliers do not only spread the word in the company's interest. Basically, they all follow their own interest at first as they want to sell their offers and resources to the customers themselves. However, with some competitors, Company A follows a so called "gentleman agreement". It is nearly unavoidable and common to interact with each other. Business relations are from high importance and displaying a negative example when it comes to for example paying the bills can be defamatory.

4.1.2 Company A - Existing add on service

A detailed graphical display of the provided maintenance service can be found in Appendix 3. Maintenance services are offered in every sector the company serves, the food- as well as non- food

industry. Not only the mechanical and electrical functioning of the machine but also the programmable control system and the weighing units of the machines have to be maintained. This depicts a competitive advantage for Company A. Their programmable control system and weighing units contain in house developed programs which makes them the only possible maintainer. In order to globally provide this add on service, each foreign representative firm has its own service employees to serve the customers abroad. Electrical and mechanical experts like constructors and technicians are from high importance when it comes to maintenance. However, not only the service personal which is directly employed by Company A, but also external service personal employed by foreign representative firms are crucial for the company. Primarily the general interest of the company is served by these actors. When it comes to external service employees, it can be said that they work in close cooperation with Company A and therefore share a common interest. Especially when it comes to maintenance abroad, close cooperation with the representative firms is essential.

4.1.3 Company A – Strengths and weaknesses

With the help of sustainability guidelines, strengths and weaknesses of the company will be identified in the following paragraph.

Company A attaches great importance to resource reduction. In recent years the introduction of standardized resources led to great reduction of material consumption. To make this possible Company A closely works together with their suppliers. All suppliers work with laser technology, which enables tailoring of resources. This prevents the company from wasting material. Additionally, all materials build into the finished product can somehow be reused. An exception would be batteries of defective monitors. It can also be said that the packaging material use is relatively low. Company A's products will normally only be loaded on trucks as the machines, made of steel and stainless steel do not need extra packaging. If however the product has to be plump protected, few material as possible is used.

Company A also focuses on great waste minimization as it inter alia leads to cost savings. Their products will often be overhauled after the end of the life cycle. These overhauled machines can still be sold for 75% of the original price even after a life cycle of 20 years. This makes overhauling products more appealing which leads to the fact that machines are rarely disposed in the end. However, in case a machines is actually disposed, steel and iron still have a decent scrap value. As 90% of the product is recyclable, it can be said that no landfill waste is produced. In case polyamide plates were used, they are specially disposed. Obviously, Company A produces no toxic waste. When it comes to packaging materials like carton, it can be said that these are reused for the company's own spare parts supply.

Energy consumption depicts a great weakness of the company. As Company A's core focus still lays on special machine construction, too much energy is used while manufacturing the products. A shift to series production could possible save more energy. When looking at the energy use of a product itself, again high energy use is observed. Included air pressure systems and the continuous functioning of the product cause somehow indispensable high consumption. Moreover, it can be said that all energy which is used comes from fossil fuels. The company uses no source of renewable energy.

4.1.4 Company B

4.1.5 Existing reference system

Company B offers contract manufacturing, special machine construction, storage- and transport systems for the printing industry and packaging machines for processing (endless) carton.

The products will be developed, constructed and put into operation in house.

The sales department, product developer as well as the constructor- and production department are considered relevant internal actors of the process. They all follow the company's interest of product performance, economic gain and establishing a competitive advantage. Additionally, customers, who give feedback and consultation from the used products and spread the word about the company's products as well as external sales partner can be considered relevant external actors in the process. In addition to that, there might also be an external product designer involved. Both, external sales partners as well as product designers, firstly follow their own interest of marketing their services. However, usually a cooperative partnership is strived for by following a giving and taking approach. Customers however, strive for close business relationships, honest consultation and quick service. Another important external actor involved in the process are competitors. Company B focuses on closely monitoring competitors. They normally do not work together with their competition as competitive pressure in the industry is always present. Therefore it can be said that competitors solely follow their own interests but are crucial for the Company B's success.

4.1.6 Existing add on service

Company B offers maintenance services for each product. A detailed graphical display of the service can be found in Appendix 3. As soon as the products are delivered, the customer has specific contact personal as well as the possibility of getting help through the on call service. The specific contact person has expertise in the software and the electrical and mechanical field of the product's functioning. The products are provided with internet access which enables the in house service engineers to hook up the system via remote maintenance. Therefore, the external service engineers and the in house service engineers can solve an potentially arising problem. In general maintenance is regularly provided. Even during vacation periods. Although this is often seen in countries like Germany, it is not common beyond the alps. As Company B operates globally, providing maintenance services during common vacation periods depicts a competitive advantage. In addition to regular maintenance services, on call service is offered due to an open hotline from six to 22 o'clock. Important actors involved in the maintenance of products are internal as well as external service engineers. As both work in close cooperation, both follow the overall interest of the company.

4.1.7 Strengths and weaknesses

With the help of sustainability guidelines, strengths and weaknesses of the company will be identified in the following paragraph.

Company B already pays great attention to resource reduction. Overall it can be said that their resource use is considered normal within the industry. Resources like steel and raw materials are ordered from local distributors and used for further processing. Consumables are used, however the company is planning to shift towards digital data use in order to reduce the use of consumables. Mostly wooden pallets serve as packaging material. This leads to the fact that Company B does not produce a large amount of landfill waste. The wooden pallets can be reused by customers of the company. In case the product has to be shrink wrapped, the used foil will be recycled. There is no packaging material which is not renewable and the use of polystyrene has already been reduced to a large extent. Company B's products contain steel, plastic, light metals, depending on the product. Nearly everything of the material is used when

producing the product. It is cut to size and therefore, no material is wasted.

Which leads to the next strength of the company, waste minimization. Although there is residual waste and steel scrap, it can be said that this waste is recycled by business partners of the company. When it comes to waste separation, Company B follows a strict system. All waste is separated and it is even further silvered in specific types. As the product reaches the end of it's lifecycle it can be demounted. The product consists by 80% of steel and can therefore be almost completely recycled. Not recyclable parts of the products as oil and lipids from the geared motors are separately disposed. This gives rise to the fact that there is no toxic waste.

Company B does not score well underlying all sustainability guidelines. Their energy consumption is relatively high and bears great potential for reduction. A first step towards reducing energy consumption was made by shifting to LED light technology on the company's construction site. Nevertheless, the used compressed air system and other systems like CAC machines or plotter still consume a lot of energy, water and causes emissions. The company makes no use of renewable energies at all. When it comes to Company B's customers, it cannot be verified for each customer but some use solar energy to some extent. However, that depicts the minority of customers as mostly fossil fuels are used for energy consumption.

4.2 Company C

Company C offers packaging machines in the food as well as non- food industry. The company is strongly represented in special machine construction, developing special solutions for their clients. As the focus lays on special machine construction, standardized programs are not used. There is no series production.

Company C produces customized machines only. The customer sets specifications on what products should be packaged and therefore Company C suggests solutions underlying some standard components which were used before. In order to produce a new product, different components from earlier produced products are gathered and compounded customer specific. If special expertise is needed for the product development, extra meetings are organized to exchange information. Depending on what specific requirements the customer has, different employees are involved. Mechanics, electricians as well as sales representatives and even sometimes technicians attend the convened meeting. There is one employee working for the marketing department who dabbles in designing the machine to some extent. At Company C there is no in house single item production. All parts used for putting together a new machine are bought in addition. Suppliers adjust to a certain extent to the requirements of the company. Cooperation is based on good business relations. Company C employs internal as well as external sales employees. The sales department is broken down into Europe, Germany and oversees. In each region, external sales representatives are deployed. The majority of products are sold through customer contact and. Customers are mainly recruited at fairs. However, new customers are also recruited by long term customers who bring them into the boat when working together on a bigger project.

For these internal actors involved, it is highly important to operate cost effective within each department but in general the overall interest of the firm is focused on. Machines have to be sold in order to make money, as there is no potential for making money by offering services. It can be said that the aforementioned external actors operate in the interest of the company. Sales representatives work on commission and therefore individually benefit from meeting the company's

interest as well. In general, great importance is attached to maintaining good business and customer relations. This is essential for having a chance of becoming a preferred supplier amongst globally large customers.

4.2.1 Existing add on service

At Company C, the launch of new machines into operation as well as pimping old machines is considered a service. In addition to that, half- yearly to yearly maintenance services are offered but not largely obtained by customers. A detailed graphical display of this maintenance service can be found in Appendix 3. For ad hoc maintenance issues, customers are offered a telephone service from which arising issues are forwarded to a corresponding technician.

4.2.2 Strengths and weaknesses

Company C successfully focuses on minimizing their material in the best possible way.

The product itself is not packaged except when it has to be shipped overseas. Therefore, large wooden pallets, sacks which absorb moisture and shrink- film are used to make the product air- and waterproof. The wooden pallets for example are often reused by the customers. However, because of special machine construction, single items are often overlooked resulting in rejects. These rejects are then scrapped.

When it comes to waste minimization it can be said that Company C gives high importance to waste separation. There are different containers for glass, paper and steel. Produced waste is therefore exemplary separated and specially disposed. In the end of it's lifecycle, most customers scrap the machine as it mostly consists of steel and iron. The company cannot control what later happens to the machines after being sold to the customer. Some machines are taken back for redesigning. Company C does not produce any kind of toxic waste. As the machine was lacquered the lacquering is disposed by the furnace.

During the production of the machines, waste production is relatively low. If waste is produced, it can either be properly disposed or recycled.

Company C consume a lot of energy especially during the production of products, using shrink tunnels. At Company C, only fossil fuels are used for energy consumption. It is considered almost impossible to grant the needed energy input to ensure machinery performance. It is known that some customers use solar energy. However, this is customer specific which cannot be controlled by the manufacturer.

5. RESULTS

In this section, opportunities and threats will further be elaborated on. With the help of the aforementioned factors, new PSS ideas to move towards greater environmental sustainability are developed for each company.

5.1 Company A

On the basis of arising issues the following possibilities present themselves to enhance the functioning of the existing reference system.

A large issue to be considered is the company's focus on special machine construction. The market requirements change towards more simplified and standardized processes. Therefore, Company A should consider orienting more towards series production and slowly ceasing special machine construction.

Customer demands move towards fully recyclables and cost effective packaging materials. This gap of customer requirements can be closed by additionally offering specially selected or even in house produced packaging materials. In that way, shortages of potentially needed packaging material can be

overcome and an competitive advantage can be established by serving a unique selling point in the sector. However, it has to be kept in mind that a new market is entered.

In the findings section, it became obvious that the company has one clear weakness when it comes to ecologically sustainable behavior. The overall energy consumption of the company is too high and bears great potential of change in order to act more ecologically sustainable. For Company A it is nearly indispensable to reduce the energy consumption itself to a large extent, as the production of machines, especially special machines consume a lot of energy. However, the issue can be tackled by changing the source of energy used. As the company's construction site is not suitable for using wind energy, solar panels would be a great start towards using renewable energy. Solar energy would be ecological beneficial as well as more cost effective as the company generates it's own energy. This also positively influences the product sales, as more products could be offered less expensive.

On the basis of the aforementioned analysis, shifting their business model towards use oriented services can be recommended. The company already focuses on and offers well established maintenance services which indicates that product related services are already in place. Therefore, Company A's business model can currently be categorized in product- oriented services. This indicates, that at the moment some impact reductions are present but they are likely to be incremental at best. The following specific use oriented service types best fit the company.

Product lease is already offered to some degree in form of lease purchases. In general, at the moment no disadvantages arise through the lease purchases as the contracts bound customers to take utmost care of the product. However when it comes to product leasing, it is not clear whether there will be any impact reductions or not. Most of the time when leasing a product there are lease companies involved. Therefore, ecological sustainable incentives of the company will not be passed on to the customers and get lost along the way as another party is involved. Moreover, the agricultural sector, a large sector served by Company A, currently lives from provincial as well as EU funding. As an agriculturist leases a product, he is no longer eligible for support. Although, not every agriculturist is eligible for support, the majority that are eligible would not choose to lease a product as funding is a great source of finance at the moment. To solely focus on the introduction of product lease in other sectors, is not worth it.

As there are already agricultural contracting businesses that form a cooperative society to use the product sequentially, this thought can further be worked out by introducing product renting and sharing. At the moment the product is sold to a cooperation society and is used by many agriculturists. Utilization periods are organized by the cooperation societies. Introducing product renting and sharing means that the same product is more intensively used. This can lead to high impact reductions. Moreover it can be said that the barrier for new clients to use the renting and sharing opportunity is relatively low, as initial costs attached to it are low.

In conclusion it can therefore be said that Company A should consider the category of use oriented services, specifically concentrating on product renting and sharing. As a prerequisite for that, the company firstly has to shift their focus from special machine construction more towards series production.

Great potential is seen in the company to shift towards a PSS business model and therefore improve their ecologically sustainable behavior. The company already worked towards being more ecological sustainable. Adapting the business culture

accordingly is not seen as a problem. At Company A, the thought of adapting to the ecological requirements already crosses people's minds as the environment suffers a lot at the moment. It is expected that adapting to ecological requirements becomes crucial for survival within the next years anyways. Why not be one of the first to adapt and therefore potentially create competitive advantages.

5.2 Company B

The following paragraph deals with possibilities to enhance the functioning of the existing reference system.

With special regard to the packaging machines, sales practices should be adjusted. A shift from broadly offering products to anyone to addressing a specific field of the industry which is served is necessary. Therefore, sales practices are more concentrated and customers can more intensely be served. In order to solve the issue of lacking maintenance experts, Company B could better work out their approach of remote maintenance and close cooperation with external service engineers. In that way, few in house maintenance experts are sufficient to globally solve potential problems. In addition to that, the overall maintenance service can be improved by anticipatory behavior. This entails regularly building contact with the customers to ask how they are doing with the product and if there are any problems. This active and courteous approach may improve the overall maintenance service.

With special regard to energy consumption, Company B shows a great weakness. Although it is hard to reduce the energy consumption itself in the machine manufacturing industry, Company B can positively contribute to energy reductions by changing the source of their energy. Shifting from only using fossil fuels for energy use to using renewable energy enables greater environmentally sustainable behavior. Not only ecological benefits but also economic benefits arise. Resources are spared, cost savings may arise and more products can potentially be produced. Additionally, products can be offered increasingly competitive.

On the basis of the aforementioned analysis, a shift to use oriented services can be recommended to the company. Company B already offers maintenance services which indicates that product related services are already in place. Therefore, Company B can currently be categorized by product- oriented services. This indicates, that at the moment some impact reductions are present but they are likely to be incremental at best.

The following specific use oriented service types best fit the company. The company already offers the possibility of leasing the product in cooperation with partners and banks. As no disadvantages arise from the already existing product leasing, it is recommended to maintain and maybe even push this use oriented service forward. However, it has to be kept in mind that the incentive of operating more ecologically sustainable felt by Company B, is possibly not passed on. Therefore, it is not guaranteed that there will be impact reductions at all. However, Company B somewhat already applies another use oriented service type. There currently is a kind of product sharing in place when it comes to the offered packaging machines. One machine provides surrounding firms with the packaging they need. However, this is not arranged by the company itself but the customers regulate it amongst each other. Here lays great potential for Company B to further develop this thought. As the provided product is more intensively used by different users, high impact reductions can be achieved. The product sharing and renting approach could firstly be mainly introduced for packaging machines. In later stages, after the shift is more

established within the company, other sectors can be involved as well.

Company B sees no economic disadvantage through this shift entailing the improvement of ecologically sustainable behavior. Although the company has to first invest in improving the ecological performance, the investment is expected to be amortized within a few years. Therefore, the company can only benefit from the shift towards PSS, with special focus on product renting and sharing. Additionally it can be said that, the potential cultural shift coming with the shift to PSS is no barrier for the company. As the new way of thinking and performing is fully and understandably introduced to the employees, it is expected that everyone is keen to work towards it and further educate oneself. Therefore, the potential lack of expertise of the new business model will also be no barrier to the company. Employees are keen to learn new expertise as long as they see the deep thought behind the action.

However, the day to day business is seen as a great barrier for adopting PSS. It leaves no time to intensively deal with this shift. The company would need detailed guidelines on what to exactly do to save time and implement a PSS. At Company B, an implementation of PSS is theoretically possible. Due to the fact that the practical implementation anyways has to be thought of at least within the next few years if the company wants to survive in the industry, the company depicts great potential for implementing PSS.

5.3 Company C

Company C already took a step towards more ecological sustainable behavior by shifting their construction site lighting system to LED luminaries. Moreover, on request, special engines with higher efficiency can be included. In addition to that, the used shrinking tunnels were better isolated already in order to reduce energy consumption. Material use is said to be as ecological as possible.

Nevertheless, energy use reduction still depicts a great weakness of the company. It becomes obvious that improvement is theoretically needed, however, it cannot be that easily implemented. It is indispensable for the company to commission the machine where a lot of energy is used. Here it is focused on perfectly running the machine instead of increasing energy efficiency. In general, Company C pays attention to for example not unnecessarily using much energy. However, it becomes obvious that their main focus still lays on finalizing and selling the products.

The company does not yet feel enough pressure to shift to a more ecological sustainable operations. Moreover, time problems are seen as a barrier for the shift to PSS as the focus lays on complete production and sell the product.

As the company's business focus still mainly lays on selling products and only providing basic add on services, Company C can be categorized as solely product oriented. Maintenance services are present but not well established and used yet. This opens up the possibility of further establishing maintenance services. Meaning that it is recommended to the company to implement product related services where not only the product is sold but additional services are offered as well. In that way product functionality is ensured and product sales are supported. Some incremental efficiency improvements due to better maintenance can be achieved. As the company is considered to be in the early stages of adopting ecological sustainable behavior, it can be said that although product- related services are considered incremental at best by generating some impact reductions, it still is a great start for Company C. It has to be kept in mind that due to their business focus on special machine

construction it is anyhow difficult to apply impact reducing practices. So due to the fact that the company will not change this business focus, introducing product related services are a great option to accommodate this business focus and ecological sustainable behavior simultaneously.

As time goes by and market requirements for ecological suitable operations further increase, it is expected that Company C also adapts to it. However, within the next 5 years there will probably be no initiative taken by the company itself to implement such business models. Due to the special machine construction, the focus just lays on solely selling customized products.

6. CONCLUSION

On the basis of the aforementioned case by case analysis the following findings regarding the research question “How does a shift to Product service systems (PSS) affect the ecological sustainability of manufacturing firms?” are encountered.

Similar effects of the introduction of PSS on environmental sustainability amongst the manufacturing firms in question could be observed. With the help of answering the first two sub question namely “What are Product service systems?” and “What is the environmental dimension of sustainability?”, all companies could be classified in terms of current PSS- and ecological sustainability orientation. The companies were identified as well-established medium sized companies. Based on their current ecological sustainable performance it can be said that all companies generate some impact reductions but they are likely to be incremental at best. By answering the third sub question namely “What motivates manufacturing firms to consider Product service systems?” the following could be identified. A common issue for the current impact reductions was found to be the overall energy consumption of the company. However with regard to the fourth sub question “What are potential barriers for manufacturing firms to adopt Product service systems?”, a great difference in the possibility of implementing PSS amongst manufacturing firms presented itself. On the basis of that, it can be said that generally manufacturing firms bear great potential of adopting product- as well as use-oriented services. Especially product related services as well as within more standardized companies product lease and renting and sharing are realistic PSS types to implement. In that way up to high impact reductions can be generated in order to increase ecological sustainability amongst manufacturing firms.

7. DISCUSSION

The aim of this research was to investigate the effect of a shift to Product service systems (PSS) on the ecological sustainability of manufacturing firms. The findings showed interesting results. The gathered data showed opinions that were widely spread amongst manufacturing firms when it comes to benefitting from and implementing PSS. It became obvious that series production can be seen as a prerequisite for shifting to PSS, as here standardization is a key factor to success. This could however somehow be expected as in general more effort has to be put into special machine construction. This counts for economic as well as ecological performance. The findings of the research should be handled with caution, as only three manufacturing firms were interviewed. The response rate of interview requests led to the assumption that not many companies see the need for exploring the field of PSS as well as ecological sustainability yet. This was surprising as company’s already face great ecological developments coming with expected social changes. Moreover, it became obvious that depending on the position of the employee, different information was given. However, respondent-specific results can be considered valid as communication engaging questions were posed.

8. IMPLICATIONS & LIMITATIONS

8.1 Theoretical implications

Although many papers refer to the topic of product service systems related to sustainability, there is little guidance about its practical implementation and impact towards firm’s performance provided (Roni, Jabar, Mohamad, Yusof 2014). Existing literature so far often only analyses the effect of product service systems on sustainability but do not provide methods to improve sustainable performance accordingly (Huer, Hagen, Thomas and Pfisterer 2018). Furthermore, it can be said that generally positive and negative influences of product service systems on sustainability will be given high importance to but researches still fail to propose sustainable solutions. This lack of solutions poses a grand challenge of product service system research. Only by tackling this issue, sustainable behavior of manufacturing firms can be ensured (Huer, Hagen, Thomas and Pfisterer 2018). Especially when it comes to the shift from traditional business models to product service systems effective decision support have to be provided (Xing, Ness 2016). A connection between environmental sustainability and product service systems is shown and ultimately poses the need for further research.

8.2 Managerial implications

A common issue for the current impact reductions was found to be the overall energy consumption of the company. It is too high and bears great potential of change in order to act more ecologically sustainable. For all companies it is nearly indispensable to reduce the energy consumption itself to a large extent, as the production of machines, especially special machines consume a lot of energy. However, the issue can be tackled by changing the source of energy used. It became obvious that using solar energy would be a potential start towards using renewable energy. However a great difference in the possibility of implementing PSS amongst manufacturing firms presented itself. It was found that a prerequisite for successfully implementing a PSS is previously shifting the focus from special machine construction more towards series production. For companies who already offer series production to some extent, no barrier for the implementation of PSS was depicted. However, for companies focusing on special machine construction only, it is difficult to adapt especially advanced PSS types.

8.3 Limitations & Further research

The goal of this research was attained. However, it is important to weigh the limitations when considering the outcomes of this research. Firstly, it can be said that this research has only been conducted in the region of North Rhine Westphalia. In order to gain more knowledge about the research problem, other parts of Germany should at least be additionally focused on. In addition to that, this research was only conducted with three medium sized businesses. This sample size depicts another limitation of this research. It becomes difficult to draw significant relationships from the data if the sample size is too small. Although the data did not propose any serious implications, it can be questioned whether or not it is representative for manufacturing firms in general. This is due to the fact that the used sample shows unique characteristics. Furthermore, the research was limited in time and extent, which lead to the fact that not every possibly important aspect could be discussed in depth. Lastly, although the amount of literature and theory on ecological sustainability is quite large, PSS can be considered a proportionally unexplored field. The amount of literature and theory is relatively low. Besides the existing theory on PSS, more importantly the successful implementation of PSS can further be explored. Therefore, this thesis has the ability to open up a new field of research.

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10. APPENDIX

10.1 Appendix 1: Interview guidelines

The following questions were used as a guideline whilst generally encouraging an open conversation.

1. For what specific field does the company in question have extensive knowledge and optimal organization? (product development, service development,...) If field is specified; to what extent? (none, little, some, much, very much)
2. What products with (add on) services/ services does the company in sample offer?
3. Describe the underlying process a product goes through during its life span (eg product development, product design, product offer, product sale, product maintenance).
4. Product development:
 - What important actors are involved (externally/ internally) in this phase? (internal product developer, external experts, customers..)
 - What is their interest in the process (economic gain, company development,...)?
 - How should these actors ideally interact with each other to deliver the required product/ service from the viewpoint of the customer?
 - How do they actually interact? Are there remaining requirements that are currently not completely fulfilled?
 - What are (material) products and (immaterial) services necessary in this phase (prototype, product testing, knowledge, consultancy on comparison, customer feedback)
5. Product design:
 - What important actors are involved (externally/ internally) in this phase? (internal product designer, product manufacturers, supplier for needed resources,...)
 - What is their interest in the process (economic gain, business relationship, company development,...)?
 - What are (material) products and (immaterial) services necessary in this phase (manufacturing resources, extensive knowledge, external consultancy)
6. Product offer:
 - What important actors are involved (externally/ internally) in this phase? (sales manager, customers, competitors, technical experts)
 - What is their interest in the process (economic gain, product performance, customer/ business relationship, company development, reputation, competitive advantage,...)?
 - How should these actors ideally interact with each other to deliver the required product/ service from the viewpoint of the customer?
 - How do they actually interact? Are there remaining requirements that are currently not completely fulfilled?
 - What are (material) products and (immaterial) services necessary in this phase (product itself, marketing practices, sales practices, extensive knowledge)
7. Product sale:
 - What important actors are involved (externally/ internally) in this phase? (sales manager, customers, competitors)
 - What is their interest in the process (economic gain, product performance, customer/ business relationship, company development, reputation, competitive advantage,...)?

- How should these actors ideally interact with each other to deliver the required product/ service from the viewpoint of the customer?
 - How do they actually interact? Are there remaining requirements that are currently not completely fulfilled?
 - What are (material) products and (immaterial) services necessary in this phase (product itself, marketing practices, sales practices, extensive knowledge, expertise)
8. Product maintenance/ aftercare:
 - What important actors are involved (externally/ internally) in this phase? (technical experts, contact person, customers, competitors)
 - What is their interest in the process (economic gain, product performance, customer/ business relationship, company development, reputation, competitive advantage,...)?
 - How should these actors ideally interact with each other to deliver the required product/ service from the viewpoint of the customer?
 - How do they actually interact? Are there remaining requirements that are currently not completely fulfilled?
 - What are (material) products and (immaterial) services necessary in this phase (product itself, extensive knowledge, technical expertise, spare parts)
 9. Where do current problems related to environmental sustainability arise? (completely absent existing environmental sustainability reduction practices, energy consumption, material use, waste disposal,...)
 10. What future opportunities arise from this? (competitive advantage through energy use reduction, less material use,...)
 11. What future threats may arise when focusing on operating environmental friendly? (economic gain decreases, shift in corporate culture fails, lack of knowledge,...)
 12. Resource reduction
 - Is the system consuming a quantity of energy when using it? (throughout whole process, from product development to product maintenance; not only the use of the product itself)
 - Is the system consuming a high quantity of natural resources? (suppliers, when manufacturing the product,...)
 - Is the system consuming a high quantity of consumables?
 - Are products, packaging or support products of high materials intensity? (much material used for the development/ production/ maintenance of the product)
 13. Waste minimization
 - Is every waste going to landfill?
 - Is the system at the end of its life producing a high quantity of waste landfill? (easy to recycle, toxic waste,...)
 - Is the production of the used products, packaging and support products producing a high quantity of waste landfill?
 14. Conservation
 - Is all energy in use from fossil fuels? (energy use of product, energy use while manufacturing,...)
 - Is all energy from exhausting resources?
 - Are most materials for products, packaging, support products exhausting and/ or non-renewable?
 15. Would you think it is possible to apply use oriented services in the company in sample? (product pooling, -sharing, -renting)
 16. What barriers do you think, prevent the company in sample from adapting PSS?
 17. Do you see potential in the company in sample to adapt PSS somewhere in the near future?

10.2 Appendix 2: Key findings of the data collection

	Company A	Company B	Company C
Important internal actors involved in existing reference system	Product developer, engineers, sales department	Product developer, sales department, product designer, constructor and production department, engineers	Mechanics, electricians, representative, technicians, marketing employee,
Important external actors involved in existing reference system	Suppliers, customers, competitors, external sales representatives	Sales partners, customers, product designer, competitors, external service engineers	Suppliers, external sales employees, long term customers

Important material products involved in existing reference system	Prototype, website and YouTube channel, product itself	Previously produced production machinery, prototype, website and YouTube channel, spare parts	Already existing machines as prototype, product itself
Important immaterial services involved in existing reference system	Mechanical and electrical expertise, functioning commercial part, marketing practices, customer service	Sales practices, special expertise	Expertise, sales practices
Existing add on service	Maintenance services	Maintenance services	half- yearly to yearly maintenance services
Current problems related to environmental sustainability	Energy consumption is too high	A high amount of energy is used	energy use too high
Resource reduction practices	Due to standardization of resources, material consumption is reduced	Resource use is normal	Well established
Waste minimization practices	Special focus on waste minimization	Well established	Well established
Energy consumption reduction practices	Too much used energy	Too much energy is used	Bears potential for improvement
Barriers to adapt PSS	-	The day to day business	Time problems
Possibility of PSS implementation	Yes	Yes	Only if market requirements for ecological suitable operations further increase

10.3 Appendix 3: Service Blueprint: maintenance service of company A, B and C

Step 1-6: Process undergone with Ad hoc maintenance services

Step 4-6: Process undergone with fixed maintenance services

Physical evidence	Phone records	Purchase and/ or maintenance contract	Phone records	Calendar/ Email	Appearance of employee Product itself	Receipt
User action	Call contact person	Personal identification	Ask for help Report and description of malfunction/ problem	Schedule date and time of service	Visit of contact person/ engineer Reports malfunction/ problem	Approves completed maintenance service
Frontstage actions	Phone call Customer contact	Customer information	Analysis of needed service	Provide date and time options	On the job malfunction/ problem analysis Provide assistance	Prompt for user feedback Follow up service required?
Backstage actions	Provide phone number	Record customer information	Past malfunction records	Generate visit	Respond to potential back up calling	Record user response

	Enable customer/supplier contact	Check contract content		Send email reminder to customer Planning of the required service Obtain potentially required spare parts	Determine who solves the problem	Plan potential follow up service Invoice/warranty issuing
Support processes	Detailed and updated customer information	Maintenance of customer database and underlying contracts	Expertise training Detailed record keeping	Customer information Availability of spare parts (in house, supplier cooperation)	Record keeping on customer/contact person link Training for contact person/engineer expertise level	Record Invoice/warranty documents