Product-Service Systems: Added Value for Productivity and Raw Material Efficiency at one Blow? Status Quo and Potentials in Resource-Intensive Production Processes

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Abstract

Germany is a country with limited resources and thus its industries are highly dependent on an intelligent and efficient use of raw materials and resources. In order to stay competitive, the management has to seize and implement strategic solutions which focus on efficiency and contribute to global sustainability. Hence, the use of product-service systems (PSS) could have a valuable impact on this development, e. g. by intensifying the usage of products or because the provider possesses a deeper know-how for a more efficient use of the product. The hereby induced changes in the relationship between supplier and customer can also lead to a decoupling of resource consumption and profit generation and thus reduce the environmental impact.

Until now, the concept of PSS has been well known within the context of total cost of ownership concepts and productivity. There are few sources of management literature which refer to their potential to reduce the environmental impact of industrial production. However, the effects of PSS on cost and resource efficiency as well as on increasing productivity have not been explored thoroughly.

Hence, we identify opportunities for PSS along the production processes within resource-dependent industries with a high use of raw materials, such as e. g. the chemical, metal and steel making industries. Afterwards, we will assess the potential economic impact as well as the potential environmental benefit and try to crosslink them for PSS with the focus on improvements regarding energy and material efficiency, recycling processes as well as closed loop systems.

We derive hypotheses from a comprehensive literature review and from empirical data from a large scale survey of the German manufacturing industry conducted in 2009 to analyse the current situation of PSS in resource-intensive industries focusing on raw material efficiency. Moreover, a qualitative assessment of these hypotheses based on 14 interviews with different customer and provider companies for PSS in the steel making, chemical and recycling industries is given.

Key words: Product-service systems, PSS, raw material efficiency, raw material intensive production systems, resource efficiency

1 Introduction

Nowadays services are the primary source of income in industrialized countries, not least due to the significant growth and innovation potential inherent in this sector. Its contribution – from the supplier as well as the customer perspective – to increase productivity, competitive differentiation and customer retention is non-controversial in the industrial sector.[1] Thus, in the manufacturing industry, the trend towards offering solutions, such as service-oriented business models, instead of products is observable. Service-oriented business models create the conditions to improve the profitability situation of the companies involved not only by the products as such, but in addition, largely or even entirely, through certain services or functions assumed by the provider.

The field of research on service-oriented business models is characterized by many different terms i. e. servitization[2], functional sales[3], performance-based contracting[4] or high value integrated solutions[5]. The business concepts outlined hereunder aim to describe a customer-specific stand-alone solution, which is ready for the market and contains a combination of one product and one service at the minimum.[6] Within the research area dedicated to sustainability issues, these service-business-relations between suppliers and their customers are predominantly referred to by the term product-service systems (PSS).[7] It stresses the opportunity of decoupling volume (producing a large number of goods) from profitability and focuses on functionality, not on material content, and by these means reduce the environmental impact in production systems.[8]

A representative large scale survey of the German manufacturing industries conducted in 2009[9], which provides a sample of 1,484 companies, shows the diffusion of different PSS concepts according to non-resource-intensive and resource-intensive industries (cf. Figure 1). The latter are industries with a high affinity to raw materials. The analysis indicates that PSS in form of availability guarantees (16 % vs. 18 %) and contracts for continuous optimization (9 % vs. 9 %)

1 Lay et al., 2010
2 Vandermerwe and Rada, 1988
3 Stremersch et al., 2001
4 Kim and Cohen, 2007
5 Davies, 2004
6 Becker et al., 2009
7 Goedkoop et al., 1999
8 Maxwell and van der Vorst, 2003, Reiskin et al., 2000
9 Jäger and Maloca, 2009

are established in the German manufacturing industries. However, concepts such as pay on production (4 % vs. 3 %), guaranteed life cycle costs (4 % vs. 2 %) and chemical leasing (3 % vs. 2 %) are rarely implemented.

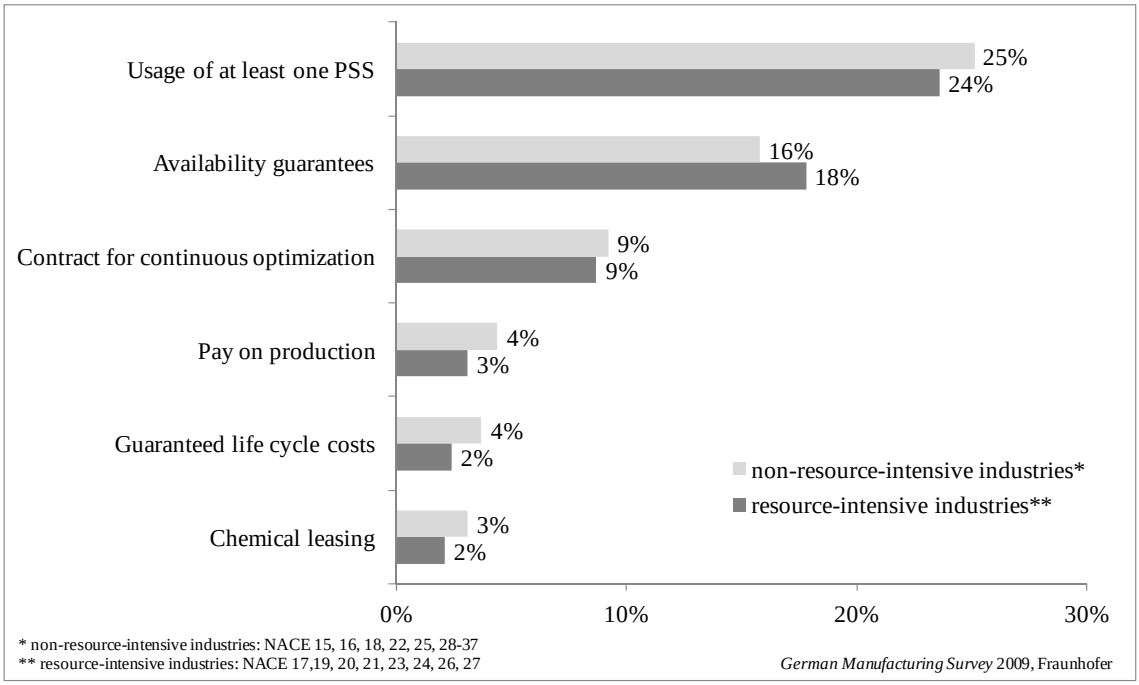

Figure 1: Diffusion of PSS concepts according to resource-intensive and non resource-intensive industries

The motivation for offering and using PSS is varied: Besides the ever-present aspect of cost-effectiveness even ecological aspects of sustainability – i. e. in the case of energy-contracting – become crucial.[10] The state of use of different PSS concepts connected with the aim of reducing material and energy consumption is plotted in Figure 2. Especially concepts such as chemical leasing (58 %), contract for continuous optimization (36 %), pay on production and guaranteed life cycle costs (31 % each) seem to have an impact on the reduction of energy and material consumption.

[10] Ostertag, 2003

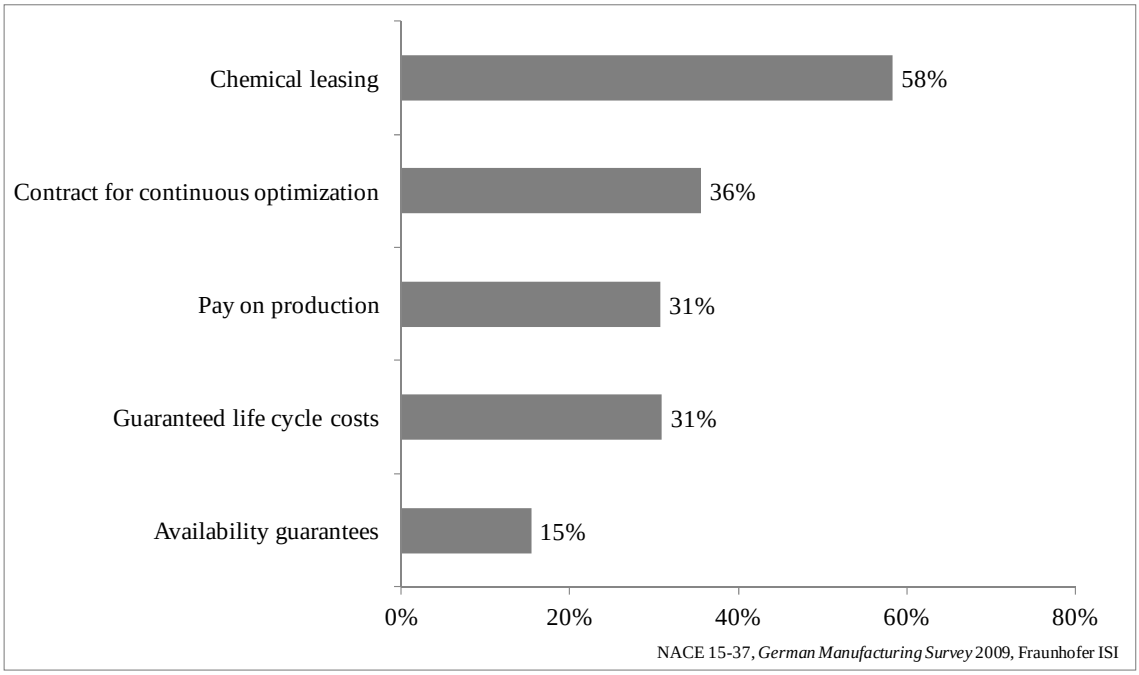

Figure 2: Usage of different PSS concepts to reduce energy and material consumption

Even though PSS are already, but still rarely, used in order to reduce resource consumption, there has not yet been a study on possible effects of PSS on the raw material efficiency in the value creation process in raw material intensive production systems in Germany. Therefore, the aim of this paper is to examine the current usage and the effects of PSS on raw material intensive production systems in Germany. Based on Tukker's definition "sustainability is about fulfilling needs with minimal material use and emissions"[11], this paper focuses on raw material efficiency as one element of resource efficiency. Raw materials are the basis for value creation in Germany's industrial society. Currently there is a yearly need for 1.4 bn tons of abiotic raw materials in Germany.[12] This has not been a problem for decades but is becoming of great interest today as international buyers compete for raw materials.[13] According to this, resource and especially raw material efficiency is the subject of multiple scientific projects to optimize processes or to develop resource efficient production processes for industrial use. Within this context, strategic goals like material- and energy efficiency, climate protection and security of energy supplies are cited by different authors.[14]

11 Tukker, 2004
12 Statistisches Bundesamt, 2008
13 Albrecht et al., 2012
14 Albrecht et al., 2012

Quantitative approaches have shown the diffusion of PSS and the potential to reduce resource consumption by using PSS (cf. Figure 1, Figure 2), but could not identify conditions, chances and risks of using PSS by both customers and suppliers in detail. Therefore a qualitative design has been chosen for this paper and the general research question has been defined as:

RQ: Are PSS able to decrease raw material consumption within current raw material intensive production systems in Germany?

The paper is structured as follows: Section two is based on a literature review, giving an introduction to and an overview of different types of PSS. Moreover, we will derive our hypotheses which will be tested in our paper. Section three describes the data applied. We use a qualitative approach based on expert interviews to identify potentials for raw material efficiency through PSS. This includes the development of interview guidelines and the selection of experts as well as the qualitative content analysis. Section four presents the results carried out separately for three chosen sectors “Steel and metal production”, “Coating / chemical industries” as well as “Recycling”. The last section contains the conclusion

2 Framework of Research Hypotheses

For the purpose of deriving hypotheses on the effects of PSS on industrial raw material, we used a comprehensive literature review with a focus on previous studies and publications on PSS and sustainability. Nowadays companies from different sectors are testing innovative services as a first step towards PSS. It is key to these concepts to support the customer in the daily use of the products (e. g. plant and machinery) by a complementing service offer or – one step further – by taking over the risk for the production process (e. g. build-own-operate-model) and to be paid for the production results. In this way, the customer is released from tasks which are not related to his core business. The business model itself changes from a transaction-based to a relationship-based concept.[15]

PSS is defined as a combination of tangible products and intangible services with the aim of fulfiling specific customer needs.[16] It is also possible to enrich the product by specified not stand-alone services,which are directly connected to product and solution. Thus, PSS concepts can be structured and designed in multiple manners.[17] Regarding the service-related terms and their added value in comparison to the traditional business concept, Toffel[18] refers to “servicizing” that “involves suppliers providing functionality rather than products”. Hockerts[19] refers

[15] Oliva and Kallenberg, 2003
[16] Tischner et al., 2002
[17] Baader et al., 2006
[18] Toffel, 2002
[19] Hockerts, 2008

directly to the term PSS and claims that they are superior market solutions in relation to the traditional selling of products.

Different forms of PSS are described in the literature. However, they are not linked to an explicit definition. Consequently, different typologies for classification can be found.[20] Tukker[21] introduced a widely used segmentation scheme for PSS, which is applied in this paper when referring to PSS. This scheme divides PSS into three subgroups:

- *Product-oriented services*: Services are added to the traditional business model „sale of products“, e. g. contracts for maintenance.
- *Use-oriented services*: The ownership of the products stays with the provider and is placed at the disposal of the customer, sometimes shared by a number of users. The provider takes over the customer's processes like maintenance or service and guarantees the machine's performance for a certain time, e. g. leasing concepts.
- *Result-oriented services*: Customer and provider agree on a certain result (e. g. amount of parts produced) but not necessarily on certain products, technologies or methods. The provider assumes complete responsibility and risk for the production process. In this concept the product is replaced by the service.

From product- to result-oriented PSS, the product content decreases in favour of the service content. Product-oriented services have been successfully integrated into value chains for a long time. However, use-oriented or result-oriented services require re-engineering of the classical business models.[22] They nevertheless give the provider of the PSS the possibility to have a higher influence on the value creation due to the increase in service content. As a result, different benefits of the latter two PSS models can be observed such as higher margins[23] and higher customer loyalty[24]. Moreover, different authors have pointed out that these PSS positively influence the environment and sustainable development[25] through the shift of incentives which may lead to dematerialization. In contrast to traditional business concepts, in which the supplier wants to increase the volume of sold material, whereas the customer wants to decrease the volume of material, PSS offer the possibility to increase the value of the service for both parties involved.[26] Reiskin et al.[27] call this phenomenon “decoupling volume from profitability”. Another advantage of PSS is that the provider possesses a more specialized knowledge, e. g. spe-

20 Lay et al., 2009, Molinari-Tosatti et al., 2002, Oliva and Kallenberg, 2003
21 Tukker, 2004
22 Lay et al., 2009
23 Oliva and Kallenberg, 2003
24 Hypko et al., 2009
25 Baines et al., 2007
26 Reiskin et al., 2000
27 Reiskin et al., 2000

cial engineering competencies, capabilities for process design or even access to special customer groups. By using these competencies, the provider is able to perform better than his customers and thus an added value can be achieved by offering the PSS for both parties involved.[28] Hence, the latter two models and their linkage towards sustainability, especially to raw material efficiency in production processes, are of special interest to our work.

Even though PSS offer possibilities for saving resources as described in the paragraph above, the presented results of the quantitative analysis in the previous chapter have shown that the usage of PSS in resource-intensive industries is low. To assess this phenomenon based on the planned expert interviews in the three sectors, the following hypothesis has been formulated:

H1: PSS are not yet widely diffused within the chosen sectors.

Based on the quantitative analysis, it can be derived that the market for PSS does not seem to be ready yet, especially for chemical leasing and contracts for continuous optimization, which have a high impact on the resource saving potential. In contrast, the implementation of result-oriented PSS in order to achieve a reduction of environmental pollution as well as of emissions seems to be successful in other areas as e. g. in the field of compressed air, in which the implementation rate is rather high.[29] This leads to the following hypothesis:

H2: There is no or low awareness of reduction potentials of raw materials by industrial services or PSS within the chosen sectors yet.

The low implementation rate of PSS as shown by the quantitative analysis in the previous chapter, the low or non-existing awareness regarding the assumed saving potentials by using PSS and thus the lack of experience with PSS may indicate that perceived barriers and risks impede the use of PSS. Regarding the offering and the use of PSS Lay et al.[30] and Hypko et al.[31] identified several risks. Hence, new suppliers of PSS may be reluctant to enter the market as they do not possess information about the life cycle costs and the different parameter of the equipment's operational phase, especially if the products provided are customized solutions. Another barrier is the rather hesitant transfer of experiences and information from the customer to the provider, especially as customers fear the loss of their technological core competencies and – as a consequence – the loss of their competitive advantage. This holds especially true if PSS focus on harnessing the potential of process optimization.[32] These observable risks and barriers in the literature review lead to the following hypothesis:

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28 Schröter et al., 2010
29 Schuh et al., 2006
30 Lay et al., 2007
31 Hypko et al., 2009
32 Lay et al., 2007

H3: Potential risks and barriers are dominant in decision processes for / against PSS.

The three hypotheses presented above were tested by the interviews conducted. The results of the qualitative content analysis according to the three sectors “Steel and metal production”, “Coating / chemical industries” as well as “Recycling” are outlined in the fourth chapter.

3 Methodology

The aim of this paper is to determine and evaluate the effects of PSS on raw material intensive production systems in Germany. Quantitative approaches have shown the potentials (see Figure 1, Figure 2) but could not identify conditions, chances and risks for PSS in detail. Thus, to address the research question and the proposed hypotheses outlined in the previous chapters, a qualitative approach has been chosen.

To focus on resource-intensive industries, the investigation was limited to three sectors “Steel and metal production”, “Coating / chemical industries” as well as “Recycling” in Germany. Hence, experts employed in customer or supplier companies from these sectors have been chosen as interviewees (see Figure 3). The experts were identified on the basis of the related research projects of the funding priority “r² - Innovative Technologies for Resource Efficiency - Resource-Intensive Production Processes”[33]. In total, 14 interviews were conducted. As the recycling sector can partly be seen as an intersection of the other two sectors and some interviewed companies can be added to the supplier as well as to the customer side according to their activities in the value chain, the conducted interviews can partly be added to several categories.

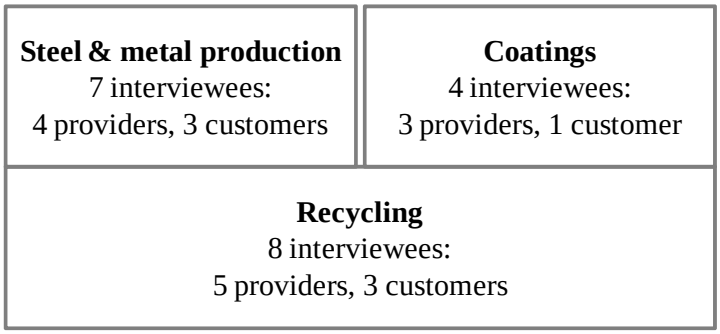

Figure 3: Interviewees

Next, an interview guideline was elaborated to achieve comparability between interview results. The guideline contained several blocks of questions to cover the above presented hypotheses

[33] http://www.r-zwei-innovation.de/en/index.php (accessed on 2012-07-27)

and to capture most of the experts' knowledge, experience and thoughts on the effects of PSS. Hence, they dealt with the risks and chances of using PSS and services, the critical success factors for offering PSS and services, PSS and their economical and ecological effects as well as their influence on raw material efficiency. Moreover, this interview guideline served as an orientation for the interviewers to keep all aspects in mind, but allowed going into detail in case the interviewee offered special expertise.[34]

For the steel and metal production sector seven experts (four suppliers, three customers) of PSS for raw material intensive production systems were interviewed. Additionally, four interviews from the coating industry (three suppliers, one customer) and eight interviews from the recycling sector (five suppliers, three customers) were conducted. The analysis based on the above presented hypotheses according to the different industries can be found in section 4.

The expert interviews were conducted by telephone from April to May 2012. Two researchers took part in every interview, which lasted between forty and ninety minutes, one to lead the interview and to ask the questions and one to take written notes of the interview. Additionally, most of the interviews were recorded with the consent of the interviewee. Afterwards, the transcripts of the interviews were sent back to the interviewees for revision.

To structure the results and the statements given by the experts as well as to identify linkages, a qualitative content analysis was chosen. This method is preferable because it allows working independently from the written interview text and tries to systematically reduce the volume of information as well as to structure information according to the pursued interview question.[35] It was a big advantage to have the interview guideline structured into operational questions and to get support by the software tool atlas.ti, which is designed specially for qualitative content analysis. Two or three researchers analyzed the protocols independently to guarantee profound results. Supported by the software, the complex hypotheses were divided into small fragments and connected to the answers from the expert interviews. If there was a deflation concerning the interpretation of certain information, this issue was discussed within the project team. The results of the interviews are presented in the following chapter.

To answer traditional criteria of reliability of the results, the analyses of the answers were carried out by multiple researchers. Furthermore, addressing newly established quality criteria of qualitative research, the procedural manner was carefully documented and the evaluation of the hypotheses has been embedded into a written argumentation. Contributing to the traditional criteria of validity, the questions included in the guided interview are based on the hypotheses derived from the theory outlined in chapter 2.[36]

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[34] Perry, 1988
[35] Perry, 1988
[36] Mayring, 2003, De Ruyer and Scholl, 1998

4 Results from Expert interviews

In the following sub-sections, the results of the tested hypotheses will be presented. Due to the small amount of interviewees, these results will only be divided into the investigated sectors steel / metal production, coatings / chemical industries and recycling, but not on the provider or customer level.

Whilst basic services like maintenance, training and spare-part-management, referred to in the literature as „product-oriented services“, are widespread in all sectors, use- or even result-oriented services such as chemical leasing, renting, pay-on-production etc. are rarely found. This correlates to other German industries: The above mentioned large scale study on German manufacturing industries in 2003 showed that only 4 % of the German machine tool builders offered pay on production concepts to their customers[37], although these business models have been promoted in the literature as a key to higher margins[38] and to foster ecological benefits[39]. A similar picture can be found on the customer-side: only 3 % respectively 2 % of the companies in resource-intensive sectors are using pay on production or chemical leasing today (cf. Figure 1). The interviews investigated the reasons along the hypotheses.

To come to the point: Hypothesis 1, PSS are not yet widely diffused within the chosen sectors, seems to be completely true for all three sectors. Only two of the fourteen interviewees have to date been involved in planning or running a PSS, either as a service provider or as a customer. Therefore, it does not make sense to granulate this result by dividing it into the three sectors. However, this will be done for the specified reasons, risks and chances of PSS for the different sectors.

Hypothesis 2 will be analysed by sectors in detail. According to common opinion the following reasons for and against PSS seem to be irrelevant:

- transfer of risk
- financing aspects
- improvements of technological solution
- improvements regarding upgrading

This is surprising because of the claims of risk transfer and technological improvements due to growing competitiveness[40] and pressure of international markets. However, it is far too early for interpretations based on this limited scope of information. Thus, the analysis concentrates on chances and risks that were discussed intensively and in detail with the interviewees.

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37 Copani et al., 2007
38 Wise and Baumgartner, 1999
39 Mont, 2002
40 Neely, 2007

4.1 Steel / Metal production

Germany has the biggest steel industry in Europe and is in sixth place worldwide.[41] Since the global economic crisis in 1973 there have been only minimal changes in production output which is currently about 40-45 million tons of steel. Increased productivity (up to 4 times) has been the key to success – modernisation and concentration on core competencies have been the main factors.[42] The cost structure of the steel production is as follows: 76 % material costs, 14 % energy consumption, 9 % labour costs and 1 % capital consumption.

When analysing the defined hypotheses, **hypothesis 1** seems to be completely true as indicated above. The customers of the steel / metal production sector, who were asked for the reasons for a (possible) use of PSS, specified the following (sorted by relevance):

- chance to **focus on core business**: to reduce number of employees, to reduce costs and to be more flexible;
- **reduction of qualification measures**: service providers possess special equipment and technological core competencies, reduction of number of employees
- **cost savings**: reduction of lifecycle costs
- service providers have **better competencies**: specialised companies possess a better / more adequate know-how;
- **increase of availability**: less downtime, longer life time of material and an increase of reliability

From the provider's perspective, mainly cost savings have been mentioned as a reason for their customers to implement PSS.

Thus, the experts named different reasons, which correlate to the above mentioned reasons for PSS in the literature (see chapter 2), but do not explain why PSS are not used yet. Therefore experts were asked to give their estimations on how far barriers and chances of PSS dominate the decision process (**H3**).

Barriers perceived: In the course of the interview, four experts stated that they fear a **loss of know-how concerning their core competencies**, only one was not concerned at all. Especially contractual work like long term contracts and non-disclosure agreements were mentioned but not rated as satisfactory. One of the four stated clearly that the use of PSS and even the use of external services is inconceivable because of transferring know-how to another company and hereby losing competitive advantages. These fears were communicated to the providers of PSS, who stated this fear as the customers' main barrier as well. One expert stated that he is not willing to offer PSS for a second time (the first time he was asked to make an offer which was not

[41] Hirth et al., 2007
[42] Hirth et al., 2007

accepted by the customer) unless he is **sure about making profit** using his model. Currently this seems not probable to him due to risks in the production processes owned by the customer. One provider of PSS mentioned that his customers fear to become **dependent on providers** and this would not change as long as there are not a minimum of two or three providers in direct competition on the market. As long as there are only a few experts offering PSS on the market, it would be too time-consuming and cost-intensive to break up with a provider. **Legal barriers** were mentioned by three providers of PSS, though with different conclusions: Two experienced them to be less restrictive than expected and therefore not as a barrier. Only one expert stated the fundamental relevance for designing PSS in this sector.

Chances for PSS for the steel and metal production: All experts agreed on the thesis that **service provider have better competencies** because specialised companies possess a better / more adequate know-how about detail-processes. Even the **focus on core business** to reduce the number of employees and costs and to increase flexibility was mentioned by four experts. However, one provider of PSS stated quite the opposite: Nowadays, steel producing industries in source more shredder- and recycling-processes than before despite the fact that these processes could even be outsourced or are actually offered by manufacturers of shredder-machines. Another argument of the customer's side was the **reduction of qualification measures** as the service provider possesses special equipment and technological core competencies for using it. Two experts stated that these services were used with the aim to reduce the number of employees and thus the investment in their technical qualification. The fourth chance of PSS, mentioned by all experts, was to realize **cost savings** by using PSS.

Summing up the experts' answers, **hypothesis 3** can be widely supported. Value and risks of existing models, especially concerning know-how-transfer are not seen as balanced.

Hypothesis 2 was only partially supported by the experts. They confirmed that the use of PSS implies an increase of efficiency and thus leads to a reduction of material and energy consumption. However, PSS are mostly seen from the angle of cost savings and focusing on core business and not from the angle of raw material savings. One of the customers interviewed even remained of the conviction that there is no influence on raw material consumption by services or PSS. From the provider's point of view none of them mentioned raw material savings as an argument for their offer. To sum up, experts are mainly persuaded by the fact that it is possible to realize raw material savings by using PSS, but they are unsure about the possible amount of savings and about finding and choosing a fitting model for their business.

4.2 Coatings / Chemical Industry

Germany is one of the three biggest chemical industries worldwide (1. USA, 2. Japan, 3. Germany). In Germany, the chemical industry is the fourth biggest sector. The international busi-

ness is characterized by a rising consumption of chemicals (more than 3.7 % progression per year).[43] In our current industrial society chemical products or methods are of significant relevance for innumerable industrial sectors. The literature of the past years has brought up several models for PSS within this sector e. g. chemical management services or chemical leasing. A study of the Austrian market in 2003 came to the conclusion that by using PSS, for example chemical management services or chemical leasing, raw material input could be shortened by 33 % (herein 10 % waste air, 15 % waste water and 75 % material waste) which is an equivalent of 53,000 tons of raw material per year.[44] Similar results in terms of percentages could be expected for the German market.

Hypothesis 1 seems to be completely true (see above). When asked for the reasons for a (possible) use of PSS, the customers as well as the providers for PSS from the coatings / chemical industry sector specified the following (sorted by relevance):

- **cost savings**: reduction of lifecycle costs
- service provider has **better competencies**: specialised companies possess a better / more adequate know-how

Moreover, the providers interviewed indicated that they can react more flexibly than the customers.

Various reasons were named by the experts, which correlate to the above mentioned reasons for PSS in the literature (see chapter 2), but do not explain why PSS are not yet used. Therefore experts were asked to estimate on how far barriers and chances of PSS dominate the decision process (**H3**).

Barriers perceived: Within this sector barriers are dominated by **legal barriers** – concerning employment (labour law) and necessary permissions related to toxic materials. These are especially relevant to the providers of PSS. Secondly, two experts stated **loss of know-how** as an important barrier, two were not concerned at all. However, this concern was only stated by the providers interviewed. **Dependency on providers** was only mentioned once by a supplier as a perceived risk of the customers. However, this was again connected with the comment on the weak market and the risks of breaking up with a provider whilst having neglected the necessary know-how. One of the providers mentioned **internal barriers from staff and shop committee**. Surprisingly time and effort for planning and realizing a PSS were estimated as comparatively low and not seen as a barrier. One provider added a **lack of demand from the customer's side** to the list of barriers. He had already offered result-oriented PSS to his customers, but the customer had accepted this. Finally he gave up offering PSS and fell back to offering the traditional

[43] Hirth et al., 2007
[44] Jasch et al. 2006

business model. To sum up, barriers seem to be the same as in the steel and metal sector, but with slightly different relevancies.

Chances for PSS for the coatings / chemical industry: all experts agreed on the chance of **cost savings** through PSS. The idea of raw material savings, which eventually leads to cost savings was not mentioned at all. Furthermore, the **stabilization of the business relationship** through PSS was seen as a big chance by the customers as well as the providers. Two experts referred to existing long-term-relationships, although they have not been involved in a running PSS yet. One provider of PSS explained the chance of **decreasing quality problems**, especially concerning coatings on new materials through PSS. Surprisingly the focusing on the core business was not mentioned within this sector. This may be connected with the relevance of chemical products throughout the whole production processes or even with the comparable minor amount of chemicals in relation to other raw materials (e. g. metal). Summing up the answers, **hypothesis 3** can be widely supported. Value and risk of existing models, especially concerning the legal situation, are not seen as balanced.

Hypothesis 2 was partially supported by the experts. Two of the interviewed providers stated that their companies have been directly involved in raw material efficiency measures. One of the interviewees measures raw material efficiency as one indicator of the offered energy-management-system. The other provider tries to push awareness by marketing measures. Another provider pointed out that resource savings are not part of their marketing which is focused on cost savings and quality. When asked directly, all experts can imagine saving raw materials by using or offering PSS, but they are unable to estimate the possible dimensions. None of the experts have ever demanded services in the field of resource or raw material savings. One provider stated that a possibly existing demand for PSS in general might be only politically triggered, as companies want to legitimate their own existing departments by presenting high costs of a PSS.

To sum up, this seems to be a problem of awareness and the existing market in Germany. Especially models like chemical management services or chemical leasing are accepted and successful in the USA in similar circumstances. The same chances have been proven by a study for the Austrian industry.[45]

4.3 Recycling

The significance of the recycling sector is increasing due to the rising amount of residues and simultaneously growing scarcity of resources. Thus, the need for improved recycling systems as

[45] Jasch et al., 2006

well as suitable services and PSS can be observed.[46] Since recycling-related services and PSS are offered by various companies as being part of different industries according to the NACE[47] codes, this area can be seen as a cross-sectoral industry. As a consequence, measuring its size is not possible.

The willingness to outsource recycling activities and to use recycling services and PSS basically exists, as recycling activities are generally not related to the core competencies of the companies. The need for recycling concepts is further emphasized by the increasing product stewardship of companies due to political directives such as the WEEE Directive[48] (Waste Electrical and Electronic Equipment)[49]. Moreover, recycling activities have a huge impact on the raw material efficiency potential, due to the untapped or only partly tapped potential of these secondary resources, which can substantially reduce the amount of primary resources in the future.[50]

Within the scope of the interviews conducted, experts from companies offering or using services and PSS focusing on recycling solutions for e. g. metal and steel as well as non-ferrous metals, such as copper, aluminium and zinc were interviewed.

Hypothesis 1 seems to be completely true (see above). When asked for the reasons for using PSS or a possible use of PSS, the customers and providers for PSS from the recycling industry sector specified the following (sorted by relevance):

- **Cost savings** are achieved by using the service or PSS due to an increased durability of the plant, a reduction of the needed material and resource input or due to a more efficient production.
- The service provider offers **better competencies** as the company may be specialised for performing certain processes and possesses better know-how and experience than the customer. However, processes are only outsourced as long as they are not related to the core business.

The (possible) customers of PSS added the following reasons as well:

- By using PSS, the companies could **increase their system performance**, e. g. an increase of availability, output as well as time saving could be observed.
- The usage of PSS allowed the interviewed companies to **focus on their core business**. Thus, the company is more flexible and saves costs. Moreover, the service provider possesses the necessary and better know-how.

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46 Jasch et al., 2006
47 NACE = Nomenclature statistique des activités économiques dans la Communauté européenne
48 European Commission, 2003
49 Jasch et al., 2006
50 Albrecht et al., 2012

The various reasons stated by the experts show the benefits of using PSS and correlate to the results of the literature review. However, these reasons do not explain why the use of PSS in these sectors is low. Hence, the experts have been asked which barriers and risks, but also which chances they perceive regarding the use of PSS (**H3**).

From the **customers' perspective** the **loss of know-how regarding their core competencies** was mentioned as a conceived risk. Using PSS in this area would imply a loss of their competitive advantage. As a consequence, PSS could only be used in those areas, which are not critical regarding the loss of know-how. Other interviewees state the necessity of confidentiality agreements and the need to create a long-term cooperation between the service provider and the company to avoid a loss of experience by changing the service provider. However, one of the interviewees mentioned that exchanging the know-how between the service provider and their company as well as selling their know-how is done intentionally in order to learn from each other. In relation to this risk, the experts referred to the issue of **creating dependencies** by cooperation. This is especially unfavourable, if there is only one service provider available on the market. One of the interviewees pointed out that only services such as external consulting were used to reduce possible dependencies. Another fear which was mentioned is the **insufficient degree of availability and / or reliability** of the PSS. Once again, this is one of the reasons why services are avoided for core processes. Besides, if the service provider vanished from the market, additional efforts would be necessary to search for a new service provider.

From the **providers' perspective**, the **costs aspect** is seen as a major entry barrier. Only one of five experts was not concerned. Especially if political regulations are unclear, it is risky to start investing. **Political regulations** have been mentioned as another major barrier due to the following reasons: They are seen as a barrier when offering PSS abroad and the implied high costs may lead to the fact that the service is not competitive anymore. Others stated that currently political regulations are missing to make PSS more attractive. Only one expert mentioned the difficulty of **organisational interfaces** as a risk for providing services. The necessity to provide the right competencies and customer proximity to provide the service are seen as important, but are not estimated as a major entry barrier.

Chances for PSS are the possibility of **ensuring the competitive advantage**, e. g. by increasing the availability and by creating a unique selling point compared to the competitors. This has been mentioned by customers as well as providers. Moreover, the **stabilization of the business relationship** is seen as an economical chance by the customers of PSS to ensure long-term planning for future business opportunities. The **reduction of life cycle costs** is only partly seen as a chance for using PSS. In this context, customers as well as providers of PSS emphasized several issues such as the lack of reliability of the provided data to calculate the savings and the problem of standardization. Surprisingly, chances due to **political regulations** only have a mi-

nor influence and are seen as insufficient from the providers' perspective to create demand for PSS.

To sum up, **hypothesis 3** can be widely supported, as the fear of loss of know-how and the insufficient degree of availability as well as the political regulations, which are perceived as insufficient, do not balance the chances.

When asked about the material efficiency potential of the services currently offered and PSS, customers and providers of PSS mentioned several aspects, such as processing of by-products, which can lead to different product qualities, the extension of the durability, an increase of the availability and the use of secondary products. Besides the material savings achieved by using PSS, one of the customers interviewed mentioned the reduction of emissions. However, most of the services offered which focus on material efficiency are external consulting to create awareness of the possible saving potential. Reasons for offering and using these PSS are mainly costs savings and other economical reasons. Regarding the competitive context, the providers of PSS could not name any other competitors, who are offering services which focus clearly on material savings. Even the demand for these services was only stated by one provider. Thus, **hypothesis 2** can partially be supported by the interviewees of the recycling sector as there is a certain awareness of the material saving potential of PSS, but it is estimated to be rather low.

5 Conclusions and Need for further Research

This paper contributes to PSS research by exploring the actual relevance of PSS for raw material savings in three industrial sectors: Steel / metal producing industry, coatings / chemical industry and recycling industry. Three main hypotheses were described and tested in 14 interviews with experts from each sector. The outcomes show that the usage of PSS in the three sectors is still low and, related to this fact, the awareness of effects on raw material savings by using PSS as well. The experts are aware of the risks of PSS for their companies but these identified risks are not the reasons for the denial of PSS. Reasons have to be seen on the market-side: the market is still too small – both on the customers' and on the providers' side. Therefore customers fear dependencies and lack of information and experiences. The providers' side is not willing to take any risks that come with new business models as long as the demand for classical, physical products is still satisfactory and there is no pressure from the market.

For future research it would be interesting to examine how these barriers could be overcome to establish PSS as a concept contributing to raw material efficiency. Besides already existing PSS, it has to be analyzed which PSS could fit to the different sectors, what is the saving potential and which approaches can be used best.

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