1. INTRODUCTION

United Nation’s Millennium Development 7th Goal states that it is necessary to ensure environmental sustainability to allow poverty alleviation. Specifically, target 7d mentions that at least 100 million slum dwellers should see a significant improvement in their lives [1]. This statement confirms the validity of the three pillars of sustainability: considering on an equal priority economical, ecological and social dimensions of human activities. An essential solution for reaching this objective is to develop innovative and practical practices to allow decision makers in companies a progression in each of these three dimensions.

In the contemporary context of globalized market economy, the economical dimension is considered as the most important motivation factor for decision making in companies. Hence, cost reduction measures have been the cornerstone of manufacturing companies, motivating to apply minimal value added to the product during its fabrication, allowing a valid and responsible policy definition for both private and public institution [5] - dangerously lacking in numerous developing countries, including Brazil.

Characteristics of the Brazilian industrial sector

The Brazilian policy makers have been recently contributing to a better consideration of the sustainability dimensions. In 1998, the country enacted its first Environmental Crimes Law, inserted in the national penal law. This document also integrates a mandatory restoration of the damages caused. If Brazil is one of the few pioneering developing countries that enacted environmental public policies – alongside with South Africa, Namibia, Ecuador, Costa Rica, Vietnam and India – it is unique to embed the notion environmental restoration [6]. However, if compared to European legal environmental framework applied to manufacturing such as ROHS and WEEE legislations, Brazil environmental policy can be regarded as permissive or incomplete.

Remanufacturing as a potential enabler for sustainability

The private sector has potential to generate pathways to sustainability regarding their industrial activities. A sustainable production management has the potential to allow better access to goods to the poorest while opening new markets for company. An exemplar application is the concept of circular economy. The circular economy was defined for the first time in 1976 by Walter Stahel and Genevieve Reday as follows: the vision of an economy in loops (or circular economy) and its impact on job creation, economic competitiveness, resource savings, and waste prevention [7]. Beyond pure environmental concerns, the concepts has from its beginning focused on sketching “potential for substituting manpower to energy” through increasing economic competitiveness while achieving social development targets.

Some approaches are being considered by companies for defining recovering strategies for products that reaches their end of life (EOL) stage. Beside waste reduction, remanufacturing is the most promising strategy for enabling several product life cycles [8]. The EOL product, also named core, returns to the production process and pass thought steps like disassembly, cleaning, refurbishment, inspection and assembly, thus originating a product with the same quality and warranty as a new one. In addition, remanufacturing process preserves part of the raw materials and value added to the product during its fabrication, allowing companies to increase their productivity [9].
Motivations to implement remanufacturing can be highlighted. Environmental and economic issues and market strategy are examples it [10]. By performing remanufacturing, companies can increase the degree of competitiveness, gain new customers as well as contribute toward more sustainable production and consumption, by being responsible for the management of EOL products [11-12]. Only few Brazilian companies are committed with the final destination of the used products they manufacture, although this situation is expected to change in the near future because of the enacted National Policy on Solid Waste in 2010.

**Potentials of the Brazilian remanufacturing industry**

The potential of remanufacturing is still underexploited in many countries. Particularly in Brazil, remanufacturing is underdeveloped and its growth has been stimulated by discussions concerning the international trade of products [13]. Some of the difficulties found to implement remanufacturing are described by specific legislation [14-15] and the low credibility that some companies attribute to remanufacture, as many believe that this end of life strategy can have a negative effect on their main goal, which is the production and selling of new products [16].

Despite the motivations to remanufacture, the lack of exploration on remanufacturing is related to some challenges companies face to implement and manage a remanufacturing system [9]. These challenges are mainly related to reverse logistic activities [10], remanufacturing process [17-19], EOL product acquisition [20] and demand for remanufactured products [20-21].

This paper’s aim is to describe remanufacturing attractiveness criteria that could improve or contribute to the development of remanufacturing oriented business models. The attractiveness criteria cover laws, challenges and motivations influencing remanufacturing in Brazilian. In addition, influence of the new Brazilian law (National Policy on Solid Waste) was evaluated to identify new motivation sources for remanufacturing. To reach this goal, a survey was created and answered by companies that are doing remanufacturing. This survey was created with the support of a literature review about remanufacturing challenges and motivations. Following, a detailed explanation of the methodology and description of the survey application can be found.

This research has been carried out in the context of the project “Networking of small and medium enterprises for competitive remanufacturing”, which is part of the BRAGECRIM Program - Brazilian and Germany Collaborative Research Initiative in Manufacturing.

### 2. METHODOLOGY

The methodology carried out contains three steps. First, a literature review was done to identify which are the challenges and motivations of remanufacture.

These challenges and motivations were then used to create a questionnaire for application in a survey. After the identification from the company profile; a first section relates to the main motivations for remanufacturing. The second section concerns the challenges. Answer options for these two questions were the data acquired by literature research, which are described on section 3. Questions about the company profile, such as activity sector, position in the value chain and company size also composed the survey questionnaire.

The third step is the administration of the questionnaire through a survey. Thanks to the existing collaboration within CNI/SENAI, it was possible to participate to the FIMA! Fair (Feira do Meio Ambiente Industrial e Sustentabilidade – Fair for Environmental Management and Sustainability Industry), a major industrial fair for the environmental management industry in Brazil that took place in Sao Paulo in August 2012.

The questionnaire has been exclusively administrated by means of personal interviews with sales or technical manager available in the fair. Interviewers were informed about the research background and concepts of the main topics of the research prior to the administration of the survey.

### 3. REMANUFACTURING CHALLENGES AND MOTIVATIONS

#### 3.1. Remanufacturing Challenges

The acknowledgement about remanufacturing challenges can support companies of increasing remanufacturing effectiveness, since they can explore the main problem sources and develop solutions to face them adequately.

The most common challenges identified during literature review are: reverse logistics costs, complexity and costs of remanufacturing processes, difficult on acquiring cores, low demand for remanufactured products and competition for acquiring core. Their descriptions are presented below.

**Reverse logistics (RL) costs**

Challenges related to reverse logistics are mentioned by Kato and Laurindo [10]. The author addresses that difficulty in predicting volumes, return times, and quality conditions of EOL product hamper the planning of the remanufacturing operation.

The costs related to reverse logistics activities can increase because of some challenges such as: difficulty to control EOL products’ flow to be remanufactured and thus to measure its remanufacturing potential before they enter into the reserve flow [17,20,23]. In addition, the great variety and spread of EOL products that can be collected hamper economy of scale potentials for remanufacturing activities [19].

**Remanufacturing process complexity**

The remanufacturing process is also considered complex and costly for many companies, mainly because of the complexity of process steps. There is little precision on inspection step and difficulties are addressed to execute this step [17,19]. Cleaning step is considered complex since there is a variety of cleaning agent and the choice of one will dependent on the EOL product to be remanufactured [12,24]. Also, the cost of remanufacturing process is assigned to the low automation of the process [18].

**Core acquisition**

Another challenge to remanufacturing companies is the difficulty on acquiring EOL products, the raw material for remanufacturing process. A lack of collaboration in the relationship between the remanufacturer and his supplier is considered one of the main causes for this challenge [20].

**Demand for remanufactured products**

Many customers believe a remanufactured product is a second hand or low quality product because it contains parts...
that previously composed other products. This leads to a low acceptance of remanufactured products [21] and thus to a low market demand [17,22,25]. Uncertainty of the quality of these products increases customer distrust to buy them [25,26].

**Competition for cores**

Another problem is that other companies, known as independent or third-part remanufacturing companies, compete with EOL product. They acquire them and recondition some parts and label it as remanufactured goods. This fact leads to two problems. First, the commercialization of low quality products which increases the belief that remanufactured products has low quality. Second, a smaller quantity of cores will be available for OEM (Original Equipment Manufacturer) to execute remanufacturing [27].

**Challenges for remanufacturing**

<table>
<thead>
<tr>
<th>Challenges for remanufacturing</th>
<th>Description</th>
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</table>
| Reverse logistics costs        | - Prediction of quality, quantity and moment when products can return  
                                 | - Product variety and geographical spared |
| Remanufacturing process       | - Low precision of cores inspection  
                                 | - Setting of the cores inspection  
                                 | - Cleaning agent choice  
                                 | - Low level of process automation |
| Core acquisition              | - Lack of relationship between remanufacturer and core supplier |
| Demand for remanufactured     | - Low acceptance from customers  
                                 | - Low market demand  
                                 | - Variable product quality |
| products                       |                          |
| Competition for cores          | - Low product quality  
                                 | - Low quantity of cores available for OEM |

Table 1: Overview of main challenges for remanufacturing in the literature

**3.2. Remanufacturing Motivations**

Companies usually have motivations when deciding to implement new processes and systems. Sundin states that the motivations for companies to remanufacture are environmental issues, pressure of laws and market demand [17]. Amezquita, like Nasr and Thurston added financial motivations on remanufacturing decision [12,28]. Ijomah agreed with the four motivations described above [21].

Motivations for the OEM to remanufacture are also presented by Toffel [25]. These motivations are decrease of costs and resources on production processes, reinforce and protect the branch image and protect the market share. USA and Europe have differs when it comes to their motivations to execute remanufacturing [12].

**Market demand**

The research of Lindahl, Sundin and Östlin [31] concludes, according to literature review and case studies, that remanufacturing is preferable compared to the manufacturing of new products since it requires less resources which is economically advantageous for companies. For Giuntini and Gaudette [9], remanufacturing cost can be 40-65% smaller when compared to the manufacturing of new products. In addition, these authors affirm that the price of a remanufactured product can be 30-40% less than the price of a new product, which creates a demand for the remanufactured ones, since the quality and warranty of it need to be equal as a new one. Thus, the smaller price of the remanufactured products is considered one of the main motivations to execute remanufacturing [12].

**Legislation**

The great amount of waste generated by manufacturing processes is leading to the creation of laws that forces companies to reduce the environmental impacts of their products and processes [21]. Therefore, OEM is establishing ways to return and remanufacture EOL to comply these laws [32].

**Environmental impacts (EI) reduction**

As mentioned, remanufacturing process can lead to the decrease of resources regarding raw material extracted and energy consumed during the process [12]. Ayres, Ferrer and Van Leynseele [33] agreed with Amezquita et al [12] about the two main environmental effects of remanufacturing. The first is on the production process as the remanufacturing process uses EOL products and parts instead of raw material. The second effect is related to resources conservation, since remanufacture offers an alternative for EOL products, which can reduces the amount of waste generated.

**Motivations for remanufacturing**

<table>
<thead>
<tr>
<th>Motivations for remanufacturing</th>
<th>Description</th>
</tr>
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</table>
| Market demand                  | - Potential for higher profitability than new production  
                                 | - Cost effectiveness  
                                 | - Reach of new markets |
| Legislation                    | - Waste reduction  
                                 | - Law compliance |
| Environmental impacts reduction| - Lower need for raw materials  
                                 | - Resources conservation |

Table 2: Overview of main motivations for remanufacturing in the literature

4. SURVEY APPLICATION AND RESULTS

4.1. Description of the companies' sample interviewed

First section of the questionnaire aims at defining the basic profile of the company interviewed. The information requested on this matter can be classified according to the following categories: activity sector, position in the value added chain and size in terms of number of employees currently working in the company.

**Respondents' sample**

Out of the 46 respondents to the survey, 14 companies informed that they already identified one product within their portfolio that has potential to be remanufactured. Out of the 14 companies, 12 provided information concerning the motivations and the challenges for remanufacturing. This is the sample selected for this paper.

**Activity sector**

The question concerning the activity sector has been formulated with closed categorical options with unique answer possibility. It contains activity categories customized to the companies taking part to the FIMAI fair. Possible answers are automotive, industrial machinery, consumer electronics, electronic equipment, personal goods, defense and aeronautics, packaging, chemical products, pharmaceutical
products and medical equipment. In case the companies have activities in more than one activity sector, it was required to mention the most significant activity only. Figure 1 gives a graphical representation of the answers obtained.

![Figure 1: Answers description for the activity sector](image1.png)

**Position in the value added chain**

An important aspect of the sample description is the position of the company within its value added chain. The question presents closed categorical options and allows multiple answers. It has been designed according to simplified description of the potential actor’s role within the remanufacturing operations’ process. Possible answers are Original Equipment Manufacturer (OEM), distributor, parts or component supplier and reverse logistics (including every post-EOL operations). Figure 2 shows the percentage of positive answers from respondents on the base of the maximal possible answers. This representation is chosen to represent the multiple answer nature of the question.

![Figure 2: Company sample profile according to its position on the value chain](image2.png)

**Company size by number of employees**

Another element of appreciation for the company profile is the number of employees currently under contract. This question was closed and offered ranges as answer options. The ranges were defined according to IBGE (Instituto Brasileiro de Geografia e Estatística). Figure 3 represents the distribution of respondents for this question.

![Figure 3: Answers description for the company size](image3.png)

**4.2. Results for Remanufacturing Challenges**

It can be noticed that no new challenge has been added and also that there is a homogeneity on the answers. Figure 4 indicates that most of the challenges companies’ faces are related to the remanufacturing process itself. Cost and complexity of this process sum 53% of the challenges reported by companies.

Some practices can help companies in minimizing these challenges. First, abilities, knowledge and knowhow of employees working on remanufacturing process are essential to achieve an efficient process [34-36].

Another suggestion is to execute the remanufacturing process using the same facilities than the manufacturing process, in case when OEM remanufactures. It could facilitate the dissemination of knowledge between the employees evolved in both process and the knowledge transfer between the two processes, since manufacturing is more understood and structure than remanufacturing [29].

A third orientation is regarding how products are designed. Complexity and even costs of remanufacturing process can be higher if the product has a low level of remanufacturability, which means that it was not designed to be remanufactured on its end of life. That is why Design for Remanufacturing must be included into product development [9,19,21,22,37].

![Figure 4: Challenges for remanufacturing mentioned by the company sample](image4.png)

**4.3. Result for Remanufacturing Motivations**

There is heterogeneity on the motivations companies have to do remanufacturing. As shown in figure 5, 41% indicated doing remanufacturing aiming to reduce environmental impacts (EI). This shows an increase of environmental conscious both for companies concerned by decreasing the environmental impacts of their products and processes, and clients demanding more environmentally-friendly products.

![Figure 5: Motivation for remanufacturing mentioned by the company sample](image5.png)

A new motivation was reported from respondents: the opportunity to increase services offering and customer satisfaction. This fact suggests that companies are increasing services offer, which goes in the same direction as researches that shows the increase of manufacturing companies integrating service on their products by means of Product-Service Systems (PSS). These researches consider remanufacturing and PSS as synergistic approaches for reaching the sustainability dimensions [36,38,39].
Two of the motivations reported on the literature review were not selected as expected by companies: legislation and competition for the core. The low selection of the competition for core option is quite unexpected since most of the sample is OEMs. As a new legislation had been approved in Brazil, a specific question about the influence of this law on remanufacturing decision was inserted on the questionnaire. Next item shows the answers for this question.

4.4. Law as a motivation or a challenge?

A question about the new Brazilian law was inserting on the questionnaire. Aim is to evaluate if the new Brazilian law, named National Policy of Solid Waste [40], is influencing the remanufacturing activities of the investigated companies. The answers percentages are shown of Figure 6.

Figure 6: Influence of the Brazilian law on solid waste mentioned by the company sample

According to the companies participating on the survey, 62% of them believe the Brazilian law is influencing their remanufacturing activities. Despite of that, just 12% of them consider laws as a motivation to remanufacture. This could indicate some statements. First, despite companies are been influenced by the law, they don’t consider it as a motivation. Second, as the law was approved in 2010, some companies still didn’t realize it as a motivation. Third, there is a lack of guidelines to support companies on developing concrete actions to be complying this law. Guidelines could hasten the reduction of environmental impacts caused by industries and also works as motivation not only for remanufacturing but also for the implementation of other end-of-life strategies, such as recycling and repairing.

5. DISCUSSIONS

According to the most frequent patterns, some considerations can be outlined aiming to provide solutions and improve the business model of remanufacturing enterprises. Thus, considering the challenges reported in thus research and the current vision of Brazilian remanufacturing companies about the National Policy of Solid Waste, some suggestions were developed. They are:

- Develop solutions for remanufacturing process aiming to increase knowledge and efficiency and decrease costs and complexity;
- Include Design for Remanufacturing in Product Development Process;
- Increase the service offer and provide PSS and remanufacturing as synergic approaches;
- Create guidelines to support Brazilian companies on complying National Policy of Solid Waste.

This paper discussed about challenges and motivations for remanufacturing, including the influence of a specific Brazilian law on remanufacturing activities. By means of 12 remanufacturing companies, some highlighted were presented.

Regarding remanufacturing challenges, the results showed that there was relevant challenges indicated by the companies since the percentage of answers for the different challenges was homogeneous. In respect to the motivations, one of them appeared to be most significant, at least for this set of companies. The concern on decrease environmental impact is considered the main motivation of the companies. Also, a motivation that was not included on the survey answers was indicated by the respondents. Companies are been motivated to do remanufacturing as a way to provide a service to the customer and thus increase the value offered and delivered to them.

Concerning Brazilian law, it was possible to realize that despite companies know and is influenced by this law; they do not consider it a motivation to remanufacture. Therefore, considering the answers of the sample and highlights from literature, four suggestions to improve the business model of remanufacturing enterprises were deployed. However, this is a first attempt to support Brazilian remanufacturing enterprises and these suggestions must be detailed in concrete actions and activities in future studies.

A limitation of this research is the reduced number of companies’ sample. However, this questionnaire had been improved and currently another survey are been carry out which intend to reach a bigger sample and thus allow qualitative analysis. By the end of 2013, the research team expected to have more confident results for future researches to support the improvement of remanufacturing in Brazilian companies and further in development and emergent countries.

6. REFERENCES

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repealing certain Directives (75/439/EEC, 91/689/EEC and 2006/12/EC)


