Remanufacturing for the Circular Economy: A Business Model analysis

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Abstract: Business models based on remanufacturing are among the most promising ones for achieving Circular Economy. However, companies still find difficulties in understanding how business models could be reshaped to remanufacturing for the Circular Economy. In literature there is a paucity of contributions that define common guidelines on how to configure remanufacturing business models for the Circular Economy. Thus, this paper aims to outline a full list of configuration options that can be used in the development of remanufacturing business models for the Circular Economy. Configuration options are defined as key recurrent and common elements that are needed to setup a particular type of business model. A case study approach has been adopted to accomplish this aim. As a result, this study provides a case-based configuration of a generic remanufacturing business model for the Circular Economy. The full list of configuration options can be utilized to assist manufacturing companies in reshaping their value proposition, value delivery, value creation and value capture towards circularity based on remanufacturing.

Keywords: Circular Economy, Remanufacturing, Business Model, Case Study.

I. INTRODUCTION

The linear economy model causes many negative externalities such as the increase of waste in landfills, the exploitation of natural, finite resources and climate change issues. Circular Economy arises as a promising answer to these limitations since it aims to decouple economic growth from environmental issues by keeping products and materials in use for as long as possible. [1,2]. Business Models based on remanufacturing are among the most promising ones for achieving Circular Economy [3]. However, companies still find difficulties in understanding how business models could be reshaped to remanufacturing for the Circular Economy. From a scientific point of view, there is a paucity of contributions in literature aimed at helping them in developing remanufacturing business models for the Circular Economy [4]. More specifically, literature presented some archetypes or common configurations, albeit with some limitations [5].

Consequently, this paper aims to outline a full list of configuration options that can be used in the development of remanufacturing business models for the Circular Economy, in order to help manufacturing companies in reshaping their value proposition, value delivery, value creation and value capture towards circularity. For the purpose of this paper, configuration options are defined as key recurrent and common elements that are needed to setup a particular business model – in this case, a remanufacturing business model for the Circular Economy. A case study approach has been adopted to accomplish this aim. The remainder of the paper is structured as follows. In Section 2, the concepts of remanufacturing and Circular Economy are introduced and presented. Section 3 outlines the case-study methodology that has been adopted during this research. Section 4 presents the case study. In Section 5, a cross-case analysis is carried out, using the Business Model Canvas as a theoretical lens [6]. Section 6 discusses the results and proposes the general configuration of remanufacturing business models. Conclusions, limitations and new research directions are included in Section 7.

II. REMANUFACTURING AND CIRCULAR ECONOMY

Remanufacturing is one of the main business models of the Circular Economy [7]. It aims at collecting products that the consumer wants to dispose of, disassemble them and reuse components and materials in the production of new products. By doing so, remanufacturing avoids the materials and energy consumption needed to manufacture new components, so reducing CO_2 emissions. In fact, remanufacturing enables the reduction of raw materials consumption (that is important especially when components contain critical materials), the reduction of energy consumption (since fewer energy is needed in remanufacturing compared to the production of new products), and the reduction of materials sent to landfill. Thus, Circular Economy based on remanufacturing business models can provide an answer to most of the environmental problems generated in linear economy systems (Table I).

Remanufacturing is defined as a process that allows a product to return to at least its original performance with a warranty that is equivalent (or better) than that of newly manufactured products [3]. Indeed, remanufacturers often improve the product by updating it to the latest version [8]. In general, remanufacturing is made up of different phases: initially, old products are

collected from customers, then they are completely disassembled, and each component is controlled in order to understand whether it is still in a good condition or not. If the component is not reusable, it is often recycled (wherever possible). The parts of the product which are in good conditions are washed with cleaning machines and then they are tested in order to be sure that they are still reusable. Rebuilt parts undergo an extensive re-manufacturing and testing process and must meet the same industry specifications for performance as new parts. Successively, the product is newly reassembled: remanufactured components are assembled with new ones that replace old, damaged parts. Once the product is assembled back, a final testing of the product is carried out. If the product passes the tests, it can be sold as a remanufactured product.

TABLE I
ENVIRONMENTAL ISSUES AND REMANUFACTURING RESPONSES

Issue	Description	Remanufacturing response
Resource scarcity	Most natural resources are finite	Increase the use of regenerated products
Waste generation	When a product breaks down or becomes obsolete, it becomes waste	Redesign products for remanufacturing (product life extension, easy to disassembly, etc.)
Wrong way to waste disposal	Waste is often disposed of not respecting collection and sorting requirements	Increase end-of-life products management remanufacturing procedures
Climate change	Climate change is also caused by the extraction of resources	Reduce extraction of natural resources and emission of CO_2 through remanufacturing

For many industries, remanufacturing activities are gaining ground with different levels of maturity. Good candidates for remanufacturing are industries who provide expensive products or where products are made up of different components, such as automotive or machinery equipment [9]. In addition, also technological sectors such as information and communication technology are experiencing a high diffusion of remanufacturing activities, especially due to the fast obsolescence of their products [10]. Remanufacturing can be made by companies who cover different role in the supply chain [9]. They can be original equipment manufacturers (OEM) who remanufacture their own products arriving from service centres, retailers or end-of-lease contracts. But these businesses can be also managed by contracted remanufacturers who are contracted to remanufacture products on behalf of OEMs. This means that the OEM normally maintains ownership of the products but does not perform the actual remanufacturing activities by itself. Another case is the presence of independent remanufacturers, who remanufacture products independently from the OEM. In this final case, usually the OEM is no interested in - or have little control on - product flows.

III. RESEARCH METHODOLOGY

In the literature, there is a paucity of contributions that aim at defining common guidelines to configure remanufacturing business models for the Circular Economy. Many papers dealt with Circular Economy and different circular business models. Lüdeke-Freund et al. (2018) analyse and classify several Circular Economy business model typologies through a morphological analysis, identifying six major patterns which can support closing the resource flows in a Circular Economy: repair and maintenance; reuse and redistribution; refurbishment and remanufacturing; recycling; cascading and repurposing; and organic feedstock business model patterns [5]. Diaz Lopez et al. (2019) dealt with the implementation of various resource efficiency measures related to clear business model changes. They found that supply side measures are mainly related to business model changes in supply chain and internal processes, while demand side measures are mainly related to business model changes in the value proposition [11]. Despite these attempts, a full list of key recurrent and common elements that are needed to setup a business model based on remanufacturing for the Circular Economy is still missing. Consequently, the objective of this research is to outline a full list of configuration options that can be used in the development of remanufacturing business models for the Circular Economy, to help start-up and manufacturing companies in reshaping their value proposition, value delivery, value creation and value capture towards circularity. Thus, a case study approach has been adopted. Case companies were searched online and through documents released by specialized organizations on Circular Economy (e.g., the Ellen MacArthur Foundation, the European Remanufacturing Network, etc.). Three companies were selected and analysed, where information and primary data was collected directly from the companies through company interviews (Table II). Different company roles were consulted, from CEOs to the head of the remanufacturing division.

Each company case was analysed according to the dimensions of the Business Model Canvas tool [6]. This tool was chosen given its practical usability and the global success it has reached. It visually represents the way a company creates, delivers, and captures value for its customers. It provides a simple and intuitive way to understand complex elements that affect the operation of a company. The tool is composed of several intertwined blocks: the value proposition, the value

delivery (customer segments, customer relationships, and channels), the value creation (key resources, activities and partnerships), and the value capture (costs and revenues). The systematization activities were conducted according to three steps. First, all the information needed to depict the business model canvas of each case were collected. A narrative for each case was drafted, covering company general information, with a description of the circularity of each remanufacturing initiative. Second, the information collected were divided and used to fill the business model canvas elements of each company. Third, a cross case comparison of the business models allowed us to find common and repetitive elements of remanufacturing. Following an iterative cycle of analysis and refinement, common configuration options of a remanufacturing business model for the Circular Economy were drafted. A generic remanufacturing business model was finally developed from the analysis.

TABLE II
CASE STUDY COMPANIES

Case	Industry	Region	Turnover	Employee
Alpha	Equipment	Italy	€ 600 mln	2000
Beta	ICT	UK	$ 45 mln	200
Gamma	Electronics	Italy	€ 3.5 mln	40

IV. CASE STUDY

A. Alpha

Alpha is the Italian leader in the fitness and wellness sector. It produces sport and fitness equipment, employing nearly 2.000 employees worldwide. Recently, the company started offering a remanufacturing service on its own old products, covering regeneration activities developed in line with the company quality standards. The company remanufactures nearly 8000 products a year. Through this initiative, fitness equipment is completely remanufactured and tested to provide the same performance as a new product. All components are inspected, tested and, only if needed - replaced with original spare parts. The company remanufacturing business model is described hereafter. Regarding the value proposition, Alpha offers to its customers the possibility to buy fitness equipment at a lower price guaranteeing a product of high quality. In fact, the company restores used equipment and updates it with spare parts and original software at the latest available version. Concerning the value delivery, Alpha wants to give the possibility to people to buy a fitness equipment and do gym at home. However, fitness equipment is usually expensive: customers need an appropriate storytelling to getting involved and to understand that remanufactured products are cheaper. Alpha is thus committed for creating an online customer relationship and provide a full customer experience: it often publishes news about its products but also about the right diet or sport to do in order to create a tighter bond with clients (long-term relationship). Regarding the value creation, Alpha designs its equipment in a modular way, to enhance remanufacturing opportunities. Remanufacturing products are still sold through traditional retailers, using the well-established Alpha supply chain. The equipment usually lasts 5-6 years. After this period, the company resells a new product and collects the old one. Then, reverse logistics is activated. Collected machines are stocked in a warehouse where they are inspected and valued eligible for remanufacturing or not. If the equipment is eligible, it is remanufactured directly in the headquarter, in Italy. The key activities internally carried out are the disassembly of the useful components, the management of spare parts, the reassembly, and final quality tests. Remanufacturing is carried out in the same production lines where new products are generally assembled. Alpha also offers technical support and after-sales services on remanufactured equipment. The company has about 600 technicians, of which 200 are direct employees. Lastly, regarding the value capture, costs are mainly related to reverse logistics activities (transportation and stocks) and to the remanufacturing process, which involves the workforce, the replacement of original spare parts, the updating of the software and the test of the equipment. Moreover, there are also after-sale services and maintenance costs. The main source of revenues comes from the sale of remanufactured products, which maintain a fair value over the time because of long-term contractual agreements which guarantee their upgrade.

B. Beta

Beta is a large-scale Secondary Equipment Manufacturer (SEM) focused on the remanufacturing of laptops. It produces carbon neutral remanufactured laptops. It was founded in 1992 in Portsmouth (United Kingdom) and, in 2021, the company had over 200 staff dedicated to delivering remanufactured laptops through a network of distribution and reseller channels. It has a built capacity of up to 10,000 units per month. It has distributors in Europe but also in America. Beta mission is to create a more ethical, sustainable and socially responsible way to buy IT equipment. According to the company estimates, over 160,000 laptops are disposed every day in Europe and often these laptops are yet thin, light and powerful enough to last far longer. So, the company decides to collect HP, Lenovo and Dell laptop models at the end-of-life and remanufactures them replacing used components, upgrading selected components to give them a performance boost and testing the quality and the operating. Lastly, Beta offsets CO_2 emissions from the remanufacturing process so that the laptop is a certified carbon-neutral product. The company remanufacturing business model is described hereafter. Concerning the value proposition, Beta remanufactures only selected models of laptops. It replaces worn components, upgrades and extends the usable life of the product guaranteeing a high quality (the company follows British Standard BS8887 design

guidelines for the manufacturing, assembly, disassembly and end-of-life processing) at a lower price than new ones. Beta offers the possibility of giving back a laptop if the customer is not satisfied; moreover, the factory guarantees to the client 3 years of warranty. But the most important value that Beta offers is on the environmental and social sides: for each laptop, the company is committed to plant 5 trees to compensate its CO_2 emissions. Regarding the value delivery, Beta mainly targets its offering to people working remotely who want identical performance and reliability to a new machine, but at lower cost and with immediate availability. It especially contacts organizations such as companies, schools, colleges, universities, and public institutions (B2B). The company creates a strong relationship with its customers trying to increase their awareness about sustainability and environmental potential. The company is highly active on social network, where it publishes many articles or e-books about sustainable issues. Concerning the value creation, one of the key activities is the selection of the right laptop models as well as the activation of the reverse logistics to collect old laptops. A well-established product knowledge is an essential resource needed to select the right models on which to carry out remanufacturing. Beta sells its products through its distribution network, which includes distributors in Europe and in USA. The company exploits the potential of environmental standards, labels and certifications (e.g., the abovementioned BS8887 Standard on the remanufacturing process). The company also invests on education and training: it has created a web portal for its partners where it also offers courses about sustainability. Concerning the value capture, the company bears remanufacturing and reverse logistics costs, as well as the internalization of the environmental costs of carbon emissions into economic activities. Revenues are mainly generated from the sale of the remanufactured laptops in a traditional way, where material cost savings from the reuse of components play a critical role.

C. Gamma

Gamma is an Italian company that provides maintenance and repair services for industrial electronics, machinery and equipment. It is an official Siemens service partner for the repair and remanufacturing of electronic boards. The company was founded in 2007 and, today, it has almost 2,500 customers, employing 40 employees with 3.5 million € of revenues. Gamma remanufacturing initiative started several years ago by recognizing the lack of electronic board spare parts for old industrial equipment. If spare parts are not found, the whole infrastructure must be replaced; this process takes much time thus leading to high downtime costs for customers. Consequently, the founder has the idea to take home faulty equipment, repair them and – at the same time- provide remanufactured equipment to cover downtime. As a result, Gamma started offering the so-called Easy Regeneration service, to restore industrial electronic products by eliminating the downtime of machines thanks to the replacement of the fault equipment with a (previously remanufactured) clone. The company remanufacturing business model is described hereafter. Concerning the value proposition, Gamma offers repaired or remanufactured electronic products at a lower price than new ones, respecting the standards imposed by Siemens. Regenerated products are more slightly more expensive than repaired ones, but they also have more value for customers because they are immediately ready. Every remanufactured product has a warranty of twelve months. But the main added value is the reduction of downtime thank to the substitution of fault equipment with a remanufacture clone. In fact, the initiative main aim is to reduce customers' downtime costs. Waste prevention is not the main aim, but an additional benefit. In addition, the company offers specialized advice to customers in order to plan the preventive maintenance of the electronic boards. Regarding the value delivery, Gamma customers are manufacturing companies in several industry (food, paper, drugs, etc.) who use industrial equipment and machinery in their production lines. It especially addresses companies that own many machines, so to lose much money if the machine suddenly breaks. The relationship between the company and the customer is durable because of the equipment lifetime. Gamma monitors customer's data along the time, managing maintenance. Customers can login in a reserved area where to see maintenance activities, intervention requests and administrative documents. To involve customers and increase the culture of repair and second-hand product, Gamma is starting a project together with a company who collects waste to organize a Repair Café event to increase the culture of repair and second-hand products. Regarding the value creation, key activities of the remanufacturing processes are related to cleaning, inspection, replacement of fault components, and delivery. The remanufacturing process is purely manual, but the company invested on its engineering because of repetitiveness of failures. For this reason, the company created specific repair kit for the most frequent failures to speed up remanufacturing process. Thanks to its IT infrastructure, the company is also able to provide a detailed report on the state of the electronic components of the system (through sensors) and to create a personalized preventive maintenance plan. Despite the partnership with OEMs, the latter do not share technical manuals and instruction of its equipment. Thus, workers' competences are crucial in this regard, especially concerning the 'reverse engineering' of the product to diagnose and find the reason for not working. The staff is made up of experienced electronic technicians and engineers with a specialized knowledge on electronic boards. One of the major problems is to find skilled employees and train them, since there are no specific courses that teach how to repair or regenerate electronic boards. For this reason, the company is establishing relations with schools to create post-diploma courses where students can learn how to repair

and remanufacture objects. Concerning the value capture, Gamma incurs in the repair and remanufacturing process costs, especially in labour, equipment and spare parts. The revenues come from the sale of the repaired (45% of turnover) and remanufactured products (35% of the turnover). A small share also comes from maintenance agreements.

V. Discussion: A Remanufacturing Business Model Analysis

In this Section, the data of the different companies are compared and analysed with the aim of finding general peculiarities and common configuration options that can describe remanufacturing business models for the Circular Economy. The analysis is presented for each business model canvas element.

A. Value Proposition

A remanufacturing business model generally offers 'as good as new' products, having the same quality of new products and respecting standards and normative. The difference between a remanufactured product and a new one is the price: the former has a lower price considering that companies use already existing components and less raw materials. Thus, remanufacturing business model allows customers to buy high-quality products at an affordable price. For instance, Alpha remanufactured equipment has the same quality of new products but a lower price; and the same holds for Beta and Gamma who offer 'as good as new' products with a reduced price. Moreover, the remanufacturer always guarantees a period of warranty. This period often is the same of that of a new product. The warranty is a risk for the company because if during this period the product breaks, the remanufacturer must face all the costs. On the other hand, customers are more tempted to buy a remanufactured product if the duration of the warranty is longer. For instance, Beta guarantees three years of warranty, as a measure of product quality. In addition to the sale of the remanufactured product, in remanufacturing models, the companies sometimes offer the possibility to include the remanufacturing offering into a product-service system offering. Maintenance agreements are sometimes proposed to customers. Gamma, for instance, proposes maintenance contracts where they also plan substitution of fault equipment with remanufacturing ones. Some companies also propose to lease or rent their product instead of buying, as a way to reduce the initial investment connected to the acquisition of expensive equipment. In this case, customers use remanufacturing products without owning them and paying a fixed or variable fee. Lastly, remanufacturing products contribute to environmental and social benefits. Remanufacturing business models extend the lifespan of products and reduce waste and the need of raw materials. Given their labour intensity, remanufacturing process creates jobs opportunities.

B. Value Delivery

One of the main characteristics of customers of remanufacturing business models is the attention to product quality. Awareness to the fact that remanufactured products are 'as good as new' should be created. This concept is not so obvious, since in fact there are still many people who believe that remanufactured is synonymous of shoddy. This is why many companies such as Beta are continuously investing in brand awareness and communication. Surely, among these customers there are also people who choose remanufacturing products because of their environmental impact awareness. Remanufacturing business models are also chosen by customer companies that look for saving money. Traditional sale models generally establish relationships with customers limited in time to the sale of the product. However, many companies adopting a remanufacturing business model try to create a long-term relationship providing contracts or guaranteeing services (included also in the warranty). Companies often offer maintenance contracts or technical support. For instance, Gamma offers the possibility to choose among different typologies of contracts that usually include maintenance and upgrading services. By creating a long-term relation, the companies retain customers and make sure on future demand and supply for remanufacturing. Remanufacturing business models also use storytelling to create a deeper bond with their customers. The companies want customers to know their initiatives and also the consequences of choosing remanufacturing products. They usually publish data and analysis about their environmental impact and benefits. They also try to make people more sensitive to themes of sustainability. Moreover, they publish environmental advises about how use remanufacture products to guide their clients during the whole lifecycle. For instance, Alpha regularly publishes on its blog advises about health caring and fitness; instead, Beta provides a set of data regarding the environmental impact of the production of laptops and regarding the benefits of its initiative. Each company leverages on its website (online channel) to showcase their products and the story behind them. The companies often write about their aims, the circular initiative and the results already reached. Sometimes they have also a blog where they publish news or articles about them or maybe about environment. Moreover, they use social media and information channels to get to know from a major audience. Physical stores are an important channel too since they give the chance to customers to touch by hand remanufactured products. They are showrooms where customers have the possibility to control the product and its quality.

C. Value Creation

The main resource emerged from the cases is the product-related knowledge. Remanufacturing companies shall know very well the product because, when it arrives broken in their laboratories, they must know how dissemble and assemble it, and to understand the cause of the faults. For instance, Gamma has a long-

lasting experience in Siemens electrical boards. Important key resources are also digital technologies, especially for business models who also provides additional services such as maintenance and repair. For instance, Gamma places sensors on the customers' machines to monitor their functioning. Digitalization is often used to trace products, so that, once they are at the end of their life, the company can find and collect them. Lastly, for remanufacturing business models is important to prove the quality of remanufactured products. For this reason, many companies provide labels and certifications that attest the quality of products and processes. For instance, Beta remanufacturing processes is certified according to the British Standard BS8887. Modular design has been encountered as a key activity in many remanufacturing business models. This is essential especially in the cases where the OEM performs remanufacturing. In the case of Independent Remanufacturers, who are not responsible for the design of products, the key is to appropriately select products that has been already designed in a modular way. Modular products are designed in a way they are easy to be dissembled and reassembled, as exemplified by the Alpha case. Another important key activity is reverse logistics. Companies are called to collect broken products that are adequate for remanufacturing. In some cases, end-of-life products come from donation by users. In other case, this activity is outsourced to other supply chain partners. Then, remanufacturing activities (disassembling, cleaning, replacement, assembling, testing) play a key role. Each case analysed has a particular process of remanufacturing, but it is based on the same main activities. Spare parts management is critical in this regard. Remanufacturing usually needs many components to replace worn parts. So, company often store many components and manage many warehouses. Gamma is a best practice in this regard, which can combine remanufacturing with spare parts management.

Remanufacturing business models usually do not manufacture the original products. Instead, they establish partnerships with OEM. For instance, Gamma is an approved partner of Siemens. In addition, spare parts providers are needed to find the right replacements for the worn parts and to guarantee the quality of the original brand even in remanufactured products. Reverse logistics service providers are another key partner. Remanufacturing companies need someone who collects old products and distributes remanufactured ones to customers. Companies often entrust to other societies this activity because they are not able to carry out the minimum volume of activities required to achieve the break-even point, which is highly affected by fixed costs such as trucks, logistics infrastructure, and workers. Lastly, remanufacturing business models often have "green" partnerships with associations, foundations or non-profit organizations to guarantee the achievement of environmental and social objectives. For instance, Beta has established a partnership with an association to compensate the carbon footprint of remanufactured products through reforestation.

D. Value Capture

Most of remanufacturing activities can be carried out only manually. In fact, the dissemble, the check of the components, the replacement of the worn parts and the reassemble are rarely automated. Thus, remanufacturing labour costs are relevant. For instance, nearly the 75% of the employees of Gamma works in the remanufacturing laboratories. Other costs usually incurred in remanufacturing business models are directly linked to remanufacturing activities, such as the equipment and materials needed to carry out them. Companies must be equipped of adequate machines for remanufacturing process, specially, for the phases of cleaning of the components and testing of the products (remanufacturing process costs). For instance, Gamma uses a washing machine with ultrasonic tub for grease removal and, if it is necessary, a sandblasting machine for resin removal and a drying oven for the cleaning phase. In addition, it uses special 'totem' opportunely designed to stress tests. Another important cost is related to reverse logistics. This activity implies costs for the transportation but especially for the whole management of end-of-life products. Among the studied cases, both Alpha and Beta incur this cost. In addition, spare parts and replacement components sometimes are not easily findable because they are obsolete and not cheap at all. On the other hand, they face the risk of obsolescence of old spare parts. Stocking involves costs because there are all spare parts management and logistics costs. Moreover, companies who offer also contracts of leasing and rental generally incur in technical support and assistance costs, as in the case of Alpha. Lastly, many companies incur in 'green' costs, given their marketing activities and due to their commitment in decreasing the environmental impact of their products e.g., through reforestation. Revenues in remanufacturing business models generally come from the traditional sale of remanufactured products. Indeed, profits come from the savings in materials thank to the reuse of components and especially for using less resources and energy compared to linear manufacturing processes. Given their detachment from natural resources and virgin materials, remanufacturing business models are less subjected to the volatility of the price of raw materials. Other revenues may come from the sale of additional services (maintenance, leasing contracts).

The overall configuration of the general remanufacturing business model is depicted in Appendix A, as a list of configuration options.

VI. CONCLUSION

Despite their relevance, Circular Economy business models based on remanufacturing are still poorly applied in practice, since companies still find difficulties in understanding how they can be configured. This topic has been also little investigated in literature, since few

papers addressed the development of remanufacturing business models for the Circular Economy so far. Consequently, this paper adopted a case study approach to outline a full list of configuration options that can be used in the development of remanufacturing business models for the Circular Economy. Three case studies were analysed using the Business Model Canvas as a theoretical lens. Then, a cross-case comparison was employed to find common configuration elements which are representative of Circular Economy business model based on remanufacturing. The main contribution of this study is a case-based configuration of a generic remanufacturing business model for the Circular Economy, which overcome current limits of literature. From a managerial point of view, the full list of configuration options can be utilised by start-up and manufacturing companies who want to design a Circular Economy journey based on remanufacturing. It provides a visual tool which helps companies to understand the common key configuration elements and the main implementation requirements for each Business Model Canvas building block. Results can be also easily implemented in a configuration tool, which can be used to support open innovation during workshops with companies.

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Appendix A. Remanufacturing Business Model