European Commission

A report by the partners of:

European Remanufacturing Network

Map of Remanufacturing Product Design Landscape

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Ace Reuse Technology
Armor
Kyocera Document Solutions
Orangebox
RICOH
Faral
Neopost
Philips Healthcare Refurbished Systems
Martela
AGCO
Recover-E Foundation
High Speed Sustainable Manufacturing Institute

Glossary

APRA Automotive Parts Remanufacturers Association

B2B business-to-business

B2C business-to-consumer (market)

CRM ‘critical’ raw material

DfREM Design for Remanufacturing

EEE electrical and electronic equipment

EIP-RM European Innovation Partnership on Raw Materials

ERN European Remanufacturing Network

HDOR heavy-duty and off-road equipment

ICT information and communication technology

SME Small-to-medium sized enterprise

MRI magnetic resonance imaging

OEM original equipment manufacturer

WP work package

Contents amendment record

This report has been amended and issued as follows:

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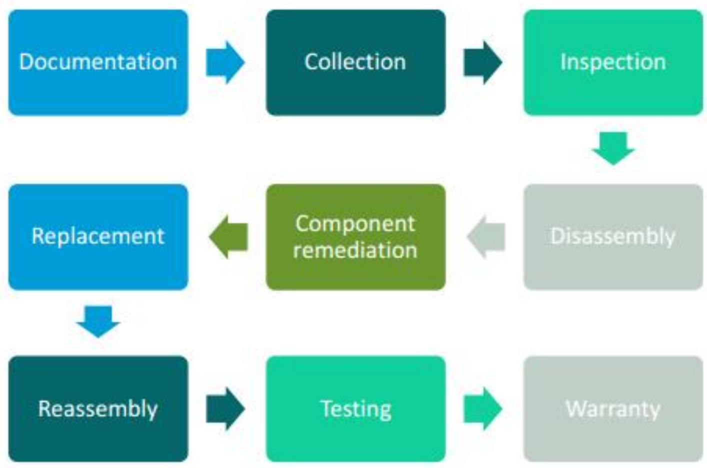
1	18/02/16	Deliverable report: WP 3	SP	

1 Introduction

Work Package 3 (WP3) aims to map *best practices* and *challenges* with respect to design for remanufacturing (DfRem), business models for remanufacturing and remanufacturing processes. This report focuses on the outputs of Task and Deliverable 3.2. In this body of work, we approach this by defining the distinctive thematic threads and activities, within the sphere of DfRem. In particular this includes the requirements for successful product design practice, an evaluation of the economic, social environmental benefits of remanufacturing and the challenges within DfRem.

Remanufacturing is a manufacturing process that involves dismantling a product, restoring and replacing components, and testing the individual parts and the whole product to its original design specifications (ERN, 2016). Remanufacturing throughout Europe includes a range of activities and this varies depending on the type of remanufacturer (OEM, independent), the sector and Member States within which a given actor operates (ERN, 2016). Steinhilper (1998) describes remanufacturing as a form of "recycling by manufacturing 'good as new' products from used products". Lund & Hauser (2010) state remanufacturing is "the process of restoring a non-functional, discarded, or traded-in product to like-new condition". The British Standard (2010) defines remanufacturing as "the process of returning a used product to at least its original performance with a warranty that is equivalent to or better than that of the newly manufactured product". For the purposes of the European Remanufacturing Network (ERN) project a broad, process-oriented definition is adopted which captures the breadth of remanufacturing activity happening throughout Europe (Fig 1).

Figure 1: A generic remanufacturing process (ERN, 2016)



Remanufacturing is represented as an 'inner loop' in Circular Economy (CE) models, conveying its high potential to preserve the embedded value (energy, materials and labour) of products (Ellen MacArthur Foundation, 2013a, 2013b). Indeed, remanufacturing can often achieve energy and carbon savings (Gutowski, 2011). In addition, the potential economic benefits of remanufacturing are recently outlined in a market survey by the European Remanufacturing Network (ERN) which estimates the value of remanufacturing to the European economy at up to €100bn (ERN, 2016). In summary, the potential benefits of remanufacturing are compelling and remanufacturing is perceived to play a key role in a future sustainable CE.

Product design is widely acknowledged to play a significant role in determining the ease with which a product can be remanufactured (ERN, 2016) and has therefore been defined as a core theme within the ERN. DfRem can be described as "a combination of design processes whereby an item is designed to facilitate remanufacture" (Charter & Gray, 2008).

This report summarises the current status of DfRem in Europe, through a review of academic and grey literature, desk research, case studies and analysis from key sectors relevant to remanufacturing. In particular the cases describe strategies for DfRem (design for durability, upgradability, disassembly), the role of advanced materials and technological shifts in product life cycle technologies.

2 Research Questions & Objectives

The aim of this work is to map the remanufacturing product design landscape and the specific objectives of D3.2 are to build knowledge on DfRem by:

- examining different design strategies for multiple product lifecycles, such as product durability, modular design, standardization, refurbishment, upgrading and upcycling
- exploring the product's ability to react positively to essential technological shifts or changes in requirements during the entire lifecycle of the product

3 Methodology

The ERN project seeks to map current best practices in remanufacturing in Europe. Hence, interviews with companies operating in this space were found to be the most appropriate methodology. Multiple qualitative semi-structured interviews were conducted over the phone and face-to-face with senior members at the chosen case companies, summarised in Table 1. Where possible, site visits were undertaken. The interviews are supported by a review of grey literature and company literature. These methods are summarised in Table 2. The cases are analysed thematically across and within-cases, with respect to the remanufacturing design literature.

The cases are structured as following:

1. Company motivation for remanufacture
2. Product description
3. DfRem strategies utilised
4. Economic, social and environmental benefits of remanufacturing
5. Future challenges

A total list of thirty-nine companies relevant for the design survey were identified through the ERN Market Survey (WP2 Task 2.2) and from this a final list of twelve cases were willing to participate and are presented in this report. The selection criteria for the cases include:

- Representative of key remanufacturing sectors
- Representative of a range of company structures (Independent, OEM)
- Representative of a range of actors, from small independent remanufacturers to multinational OEMs
- Recognisable activity in DfRem in Europe

Table 1 Overview of Case Companies

Company	Sector/product	Region	Structure
Ace-Reuse	EEE/motor	NL	Independent remanufacturer
Armor	EEE/printer cartridge	FR	Independent remanufacturer
KYOCERA	EEE/printer	UK / Global	Multinational OEM
RICOH	EEE/printer	UK / Global	Multinational OEM
Neopost	EEE/franking machine	FR	Multinational OEM
Microcab (and consortium partners)	Automotive /fuel cell vehicle	UK	Consortium of companies
Faral	Automotive/engines and parts	FR	Independent SME
Recover-E	ICT/laptops, desktops	NL	Foundation
Philips Healthcare Refurbished Systems	Medical Devices/X-ray scanner	NL	Multinational OEM
Martela	Furniture/Office chairs, desks, partition walls, shelves	FI	Medium-Sized OEM
Orangebox	Furniture/chair	UK	Medium-Sized OEM
AGCO Power	HDOR/engines	FI	Multinational OEM

Table 2 Description of Case Study Methods

Case	Company	Method	Interview/ Site-Visit Date	Date Follow-up
Case A	Ace-Reuse	Site visit & interview (x1) Follow-up emails Follow-up phone call	3rd Sept.	9th Nov. 2015
Case B	Armor	Site visit & interview (x1) Follow up email Follow-up phone call	5th Nov. 2015	Nov - Dec 2015
Case C	KYOCERA	Responses via email (x1) Follow up email exchange		Oct - Nov 2015
Case D	Orangebox	Phone interview (x1) Follow-up email	16th Oct. 2015	Oct - Jan 2015/2016
Case E	RICOH	Site visit & interview (x 2) Follow up email	23rd Sept. 2015 2nd Oct. 2015	Nov-Dec 2015
Case F	Faral	Site visit and interview (x1) Follow up phone call Follow up email	4th Nov. 2015	Nov - Dec 2015
Case G	Neopost	Skype interview (x1) Follow-up email	2nd Sept. 2015	Nov - Dec 2015
Case H	Recover-E	Interview & Site Visit (x1)	3. Nov. 2015	Dec 2015
Case I	Philips	Site visit and interview (x1) Follow up phone call	3rd June 2015	Sept. - Jan 2015 / 2016
Case J	Martela	Site visit and interview (x1)	2nd Oct. 2015	Nov 2015
Case K	AGCO Power	Site visit and interview (x1) Follow up e-mail	9th Dec. 2015	Dec 2015
Case L	Microcab (and consortium partners)	Site visit (x1) Responses captured via email	29th Oct. 2015	Oct - Nov 2015

4 Literature Review

This section introduces the literature on DfRem in particular focusing on design guidelines for remanufacturing, followed by a summary of published DfRem case studies. Certain product properties can have a positive or negative effect on remanufacturability (Hatcher et al., 2011) and the importance of DfRem is endorsed by remanufacturing industry representatives, such as the Automotive Parts Remanufacturing Association (APRA)[1]. DfRem can increase the profitability of remanufacturing by making the process of remanufacturing more efficient. Nevertheless, while there is some research to-date on the topic of DfRem, it is broadly accepted that there is a deficit of research and practical cases studies on the topic of DfRem in general, resulting in a lack of knowledge on the topic in general (Ijomah et. al, 2007; Hatcher et al., 2014).

4.1 Factors Affecting Product Design for Remanufacturing

It is precisely because certain product characteristics can have a positive or negative effect on remanufacturing, that certain types of products are well suited to remanufacturing. In summary, typical products that are seen to be remanufactured to-date are those that have a slow pace of technology evolution (Charter & Gray, 2008; Hatcher et al., 2011), are durable enough to withstand multiple life cycles have a relatively high residual value and are possible to either reverse engineer or disassemble ref (Hatcher et al., 2011). This literature discusses elements such as a product's 'suitability for remanufacturing' and from this, good practice guidelines that determine a product's suitability for remanufacturing have been developed. For example, automatic transmissions are identified, because these are high value products, with a steady pace of technology evolution.

Well-coordinated product development processes require skillsets of two distinct areas within design; those who are experts in strategic design and those skilled in detailed product design. DfRem involves, "considering the product strategy (marketing, reverse logistics) and the detail engineering of the product in terms of remanufacture" (Nasr & Thurston, 2006). The DfRem literature has almost exclusively focused on the latter of these two areas (eg Yang et al, 2015). To foster greater success in the development of products for remanufacturing Sundin & Bras (2005) describe specific product properties with respect to the process of remanufacturing. Similarly, Gehin et al (2008) developed a tool which focuses on decision-making during product development based on a set of key criteria which render a product more or less remanufacturable.

Despite '*Design for X*' research having the most focus, Hatcher et al (2014) state that such research areas (discussed further in section 4.2) must take greater consideration of the product life cycle, to demonstrate economic benefits of remanufacturing through approaches such as Life Cycle Costing or environmental benefits through Life Cycle Assessment (LCA). In addition, DfRem research to-date needs to consider organisational factors in companies, which can contribute to the success of DfRem (Hatcher et al., 2014). Indeed, Hatcher et al (2014) describe the combination of technical, market and operational

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[1] *https://apra.org/?page=Remanufacturing*

factors which in tandem contribute to the success of DfRem. Table 3 summarises the market and operational factors internal and external to the company (technical factors are dealt with separately in Section 3.2 as identified by Hatcher et al (2014).

Table 3 Organisational and Operational Factors internal and external to the company affecting DfRem (Adapted from Hatcher et al., 2014; Prendeville et al, 2014)

Internal	External
Business Business model Design priorities Supplier relationship Internal strategy **Design** Product design specification Design reviews Design tools Innovation potential **OEM-Remanufacturer Relationship** Remanufacturer commitment Communication **Socio-Psychological** Management commitment Designer knowledge and understanding Designer motivation Capabilities (skills / know-how)	**Customer demand** For either whole products or spare parts **Sustainability** Business benefits linked to sustainability (eg CSR, brand value) **Competitiveness** Market trends / opportunities for remanufacturing Cost savings New Markets Competitor behaviour **Profit** DfRem can increase profitability of remanufacturing by increasing remanufacturing process efficiency **Products suited to remanufacture** Product's poses characteristics that render them well-suited to remanufacture **Regulations** Some companies sit within sectors that are regulated and therefore required to take-back goods placed on the market, which then stimulates remanufacturing

Other authors have demonstrated the role of DfRem through standalone case studies on remanufacturing practices. For example, through case studies of three Chinese companies, Hatcher et al (2013) find that current design of electronic and electrical components are not well suited to remanufacturing. Critically, other authors have found that remanufacturing of energy-using products is not consistently beneficial for the environment, particularly when energy efficiency can be improved through new technological innovations (Bakker et al, 2012). This is also reflected in a separate paper, which discuss the shifting of life cycle hotspots on account of (1) efficiency improvements and (2) consumption patterns (Gutowski et al, 2011). These studies illustrate the need to integrate life cycle and environmental assessment approaches within remanufacturing studies.

A recent case study, commissioned by the Scottish Government, shows first-hand the impacts of the lack of a system-wide remanufacturing approach in the automotive sector. Here lightweighting, to foster fuel efficiency (driven by the ELV Directive) is a priority design strategy. However, lightweighting makes it increasingly difficult to remanufacture parts and components down the value-chain. This is because, material substitution activities, compromise the durability of the parts. Material selection needs to consider trade-offs along product life cycles for a broader perspective when applying what appear to be straightforward design guidelines.

Importantly, distinctions between design for recycling, DfRem and other 'DfX' methodologies are beginning to emerge. For example, other authors state that certain strategies typically associated with remanufacturing (ease of access, handling, disassembly, and reassembly) are simply not important when considering recycling (Hatcher et al, 2013). In contrast, one study on design for recycling found that, considering design for easy separation of parts is a valid design strategy and can generate important solutions to improve automated recycling processes (Fakhredin et al, 2014). Some other conflicting findings have been identified. It has also been suggested that certain product characteristics (the high value of certain parts, reverse logistics), which make some products suited to remanufacturing, are outside the remit of control of the designer (Hatcher et al, 2013). In contrast, a more recent study indicates that design for reverse logistics is within the product designer's responsibility and reverse logistics needs to be considered during product development processes (Yang et al, 2015).

In 2003, Guide et al stressed that remanufacturing research has focused too much on operational aspects such as reverse logistics and production engineering (eg Wang & Chen, 2013), meaning that current research neglects more strategic design (eg developing new sales channels, ensuring effective service design) and business elements (eg ensuring the optimal pricing strategy) which can be even more important for successful remanufacturing activities. This gap has as yet to be bridged and the creative potential and problem solving benefits of design thinking are yet to be brought to bear on remanufacturing research.

4.2 Design Guidelines for Remanufacturing

This section summarises the literature on design guidelines for remanufacturing. Design guidelines are heuristics that assist designers to achieve an intended goal during New Product Development (NPD) activities. Unlike design tools, such guidelines can help to easily integrate good design practices without the burden of formal tools, which companies often fail to internalise. Examples of these strategies include DfRem, functional integration, light-weighting or right-weighting and material substitution.

The literature in this area is thematically similar and is commonly presented in the form of unordered lists of guidelines on durability; modularity; standardization; and upgrading. Some of this literature is summarised and clustered according to key thematic areas in Table 4 (Prendeville & Bocken, 2015). Yang et al (2015) and Sundin et al (2008) integrate product design properties and design strategies with the process of remanufacturing. This includes 'Design for Disassembly and Reassembly' as well as 'Design for Cleaning, Handling and Maintenance'. Aside from these, the following four key areas have been identified from the literature (summarised in Table 4): Design for Technology Integration; Design for Reverse Logistics, Detailed Design and Material Selection, and Designing for Standards and Reducing Complexity. In summary:

- **Design for Technology Integration** encompasses both the need to focus remanufacturing activities on products whose technologies are stable over one lifetime and/or which are upgradeable through integration of new software architecture through (modular) product upgrades to mitigate against obsolescence
- **Design for Reverse Logistics involves** consideration of the process of remanufacturing with respect to the product features and how these may improve or limit the efficiency of the process.
- **Detailed Design and Material Selection** involves choosing materials which are non-corrosive, wear resistant and therefore durable as well as ensuring details such as fasteners and connectors do not hinder dis- and re-assembly.
- **Design for Standardisation and Reducing Complexity** involves the simplification of product designs through the use of modular parts and design standards.

4.3 Section Summary

This section has summarised the literature on remanufacturing in the context of product design including a description of key terminology related DfRem guidelines (Table 4), an overview of critical operational factors (Table 3), and key case studies on DfRem published by authors in the field. While this literature review is not intended to be exhaustive, it provides a foundation in in terminology and current practice, used to inform the remainder of the work on mapping the product design remanufacturing landscape. In particular, the review begins to uncover the need for systems thinking in the context of products which can be suited to remanufacturing, the need for integration of product life cycle management approaches within remanufacturing activities, as well as the greater need to adopt creative and strategic design methods within remanufacturing businesses to capitalise on a broader and deeper set of business opportunities.

Table 4. Literature Summary of Design Strategies Suited to Remanufacturing (Summarised from: Yang et al., 2015; Sundin et al, 2008; Pigosso et al, 2010; Charter & Gray, 2008; Willems et al, 2008; Hammond et al, 1998)

Design for Technology Integration	**Design for Reverse Logistics**	**Detailed Design & Materials Selection**	**Design for Standardisation & Reducing Complexity**
Ensure technology exists to restore product (Charter & Gray, 2008)	Design for reverse logistics (Yang et al, 2015)	Number of different components, different components, and tools (Willems et al, 2008)	Product is made up of standard interchangeable parts (Charter & Gray, 2008)
Product technology is stable over more than one life cycle (Charter & Gray, 2008)	Define reverse logistics (Charter & Gray, 2008)	Consider fastening methods (Hammond et al, 1998)	Modular design (Charter & Gray, 2008)
Technology must be able to extract a component without damage (Charter & Gray, 2008)	Establish logistics for collection, distribution and analysis of uncertainty, including probable returns (Pigosso et al, 2010)	Use non-corrosive materials to prevent corrosion (Hammond et al, 1998)	Identify design standards (Pigosso et al, 2010)
Identify opportunities for upgrade (Pigosso et al, 2010)	Collection of Core Parts (Charter & Gray, 2008)	Increased part fragility (Hammond et al, 1998)	Reduce complexity (Hammond et al, 1998)
Platform Design (Charter & Gray, 2008)	Define how product will be collected (Charter & Gray, 2008)	Wear Resistance (Sunding et al 2010)	
Upgrade: functional and interfaced decoupling (Willems et al, 2008)			
Architecture structure (Willems et al, 2008)			

5 Perspective from Industry: Case Studies

This section presents twelve case studies showcasing successful DfRem in business and uncovering issues linked to DfRem practices. The cases are framed around the company motivations, products remanufactured, DfRem approaches adopted, economic, social and environmental benefits of remanufacturing, remanufacturing business model as well as the companies futures challenges. An overview of the cases as well as the case selection criteria are provided in Section 2.

5.1 Case Study A

Company Overview

Company:	Ace Re-use Technology BV
Location:	Horst, Holland
Product:	Oce Electric Motor (Main Engine) 7201546
Type:	Independent Remanufacturer
Maturity:	Experienced (c.25 years)
Contact:	Eduard Lebbink
Phone:	+31 (0) 77 398 0520 61
E-mail:	eduard.lebbink@acewikkeltechniek.nl
Web:	www.acewikkeltechniek.nl

Ace Re-use Technology specialise in electromechanical engine drives, ranging from small DC motors to larger, complex AC drives. It focuses on re-engineering, modifications, and remanufacturing, resulting in a drive that is equivalent or even better than comparable new products. The remanufactured devices are market competitive thanks to the new functionality and a reduced price. Ace Re-use Technology has a strong track record of collaborating with original equipment manufacturers (OEMs) based on their specific needs. Through remanufacturing it can serial overhaul electromechanical engine drives to achieve major cost savings when compared to new.

Motivation for Remanufacturing

Ace Re-use Technology aspires to the vision of a circular economy and believes that through remanufacturing additional value along product life cycles can be optimised. Ace Reuse is motivated by the likelihood of future materials shortages. As well as other valuable materials, copper is of concern as critical shortages are predicted within 10-13 years.

Product Description

Ace Re-use Technology remanufactures electromechanical engine drives whose function is to provide motion on imaging equipment machines. Each engine operates at two speeds. At high speed an engine has a lifetime of 2000hrs and at low speed it is 14000 hrs. Each engine is typically remanufactured 2-3 times.

Design for Remanufacturing

Ace Re-use Technology sees improving the disassembly of products as key to reduce costs and increase efficiency of the process of remanufacturing. Wear resistance of materials, hardness and durability of materials need to be considered at the material selection stage of product development, or during the redesign of components.

Ace Re-use Technology has redesigned some elements of the drive. Two examples illustrate the design-engineering challenges it had to address in order to successfully remanufacture the product. Through its experience of typical product failures, when products are returned after the first life, it identified that the bearings used in the motor are the key failure point. Replacing these bearings with higher quality, more durable ones increases the reliability of the parts and therefore the lifetime of the engine. Ace Re-use Technology also redesigned part a shield on the engine shaft to make it stronger, which in combination with the new bearings, mean the machine can be remanufactured several times. This design was created in partnership with the original equipment manufacturer.


Fig 2. Oce Electric Motor (Main Engine) 7201546

Environmental Benefits

Through remanufacturing, Ace Re-use Technology prevent worn or defective engine drives from being discarded, while also extending the life of the engines by adding value through quality improvements and testing.

Economic Benefits

Overhauling and repairing existing engines is significantly cheaper than producing new engines and the savings generated from engine remanufacturing are estimated at around 50% of typical production costs for the OEM.

Social Benefits

Remanufacturing of electric motors requires a highly skilled workforce. Ace Reuse technology provides an enabling environment with training opportunities for skills development, to support the retention of high value jobs in Holland.

Business Model

The business model is critical to ensure that cores can be accessed through the right partnership, to ensure continuous supply of products. It's partnership with an OEM has been the basis of its remanufacturing activity for many years, yet it seeks to diversify its business building new remanufacturing activities in new sectors and products.

Future Challenges

Ace Re-use Technology believe that national and supra-national standards (such as quality approval certifications), to validate the high quality of remanufactured goods are needed. Moreover, Ace Re-use Technology sees the need to foster collaborations (logistics, sales partners) as a means to scaling up its remanufacturing services.

5.2 Case Study B

Company:	ARMOR
Location:	Nantes, France
Product:	OWA laser ink cartridge
Type:	Independent Remanufacturer
Maturity:	Experienced
Contact:	Laurent Salzat
Phone:	+33240384147
E-mail:	Laurent.salzat@armor-group.com
Web:	www.armor-owa.com

Armor is an Intermediate Sized Enterprise (ISE) based in Nantes, France. Its annual turnover (2014) is €223M with 80% created from exports (up 55% from 2008). The company has 2000 employees (680 in France) across 26 subsidiaries and 11 production sites worldwide. One of its main activities is the remanufacturing of laser cartridges. Armor is a national and European market leader for remanufactured laser printer cartridges. Armor has a strong investment in sustainable innovation and R&D with €1.6M invested annually. Its remanufacturing facilities are located in Poland and Morocco.

Motivation for Remanufacturing

In Europe each year, around 350 million cartridges are sold, 70% of which are not properly processed at the end-of-life. Just 20% of cartridges are in fact collected by OEMs to be remanufactured and/or recycled. At EU level, the CE is being promoted in directives and new standards. Companies and organizations which use printing solutions are engaged with environmental management systems and some of them have to report their corporate social responsibility engagements. Armor provides these organizations with a range of remanufactured cartridges which meet the sustainability expectations of their customers.

Product Description

Armor's OWA range of remanufactured cartridges provide the end user with the knowledge that the cartridge will be properly treated at its end-of-life (remanufacturing in priority and if not possible material recovery). Armor's OWA approach ensures the collection of used cartridges through an online management service provided on its website.

Fig. 3 Armor's OWA solution

Design for Remanufacturing

Most cores collected by Armor are designed by an OEM and typically new cartridges are not designed for remanufacturing. Most cartridges are protected with patents, contain chip sets, are weak or are a made of many different materials which makes them more difficult to remanufacture. Armor has developed specific remanufacturing production lines to answer these challenges. The company sees design for durability and for disassembly as key strategies OEMs need to adopt to increase remanufacturing activities in Europe.

Environmental Benefits

In association with the French Ministry for the Environment, Armor carried out an experimental environmental labelling trial: a flagship commitment under the Grenelle Environment[2] programme, which provides consumers with information on the ecological impact of OWA products. The aim is to guide consumers towards the most environmentally-responsible products. Each LCA is performed with a dedicated tool for each range of OWA products. The CO2 impact of a remanufactured cartridge compared to a new one is 25 - 40% lower. The same tendency is observed for the raw material depletion indicator.

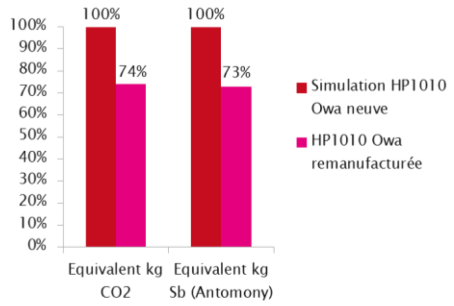

Fig. 4. LCA Results: Environmental impact comparison between a new cartridge and an OWA remanufactured one

Economic Benefits

Remanufacturing of products can reduce product costs by up to 40 or 50%, depending on the type of product. Product price is lower than 30% compared to a new product which is a significant benefit for the consumer.

Social Benefits

Armor's remanufacturing activity creates highly skilled jobs in Europe and North Africa. More than 6% of their employees are disabled people. Among the priority issues for company's growth there is the individual development of its employees and local solidarity.

Business Model

Through its OWA business offering Armor developed a brand proposition that covers not simply printer cartridges, but an overall circular economy solution. The business model assures the customer will get a guaranteed print quality, an optimal cost per page printed and most of all, a reduced environmental footprint compared to classic printing solutions.

Future Challenges

For this independent remanufacturer, the growing number of patents on cartridges technologies is an issue that makes its business activity increasingly complicated. The development of European legislation on waste regulation between states is also an issue for the company which means it has to pay taxes to ship old cartridges outside of France and Europe.

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[2] *http://www.developpement-durable.gouv.fr/IMG/pdf/Grenelle_Loi-2_GB_.pdf*

5.3 Case Study C

Company: KYOCERA Document Solutions
Location: UK sales subsidiary of Japanese-owned manufacturer
Product: Single and multi-function printers
Type: Multinational OEM
Maturity: Experienced (in DfRem)
Contact: Tracey Rawling-Church
E-mail: tracey.rawling.church@duk.kyocera.com
Web: www.kyoceradocumentsolutions.co.uk

KYOCERA is a diverse global corporation centred on core expertise in ceramics. One of the applications of ceramic technology is the manufacture of laser print drums that are far more durable than those made from other materials. This has enabled the development of an innovative print engine design where all functional parts are part of the printer, not part of the consumable. This avoids the need to repeatedly replace multiple working parts throughout the life of the product, thereby saving the raw materials, manufacturing, transport and waste emissions associated with those parts.

Motivation for Remanufacturing

Resource efficiency has been a strategic focus on KYOCERA for many years, underpinned by the company's philosophy. It is part of a holistic approach that aims to reduce product environmental impacts at every stage in the lifecycle.

Product Description

Single and multi-function printers (Fig. 5a) designed for all general office applications and aimed at business users, are increasingly sold as part of a managed document service that includes software, consumables, maintenance and professional services, which are charged for on a consumption basis. The hardware is a totally industry-standard in its functionality and comparable in price to conventional competitors.

Fig. 5a KYOCERA Single and Multi-function Printers

Design for Remanufacturing

KYOCERA has developed its own in-house ECOSYS[3] process, which focuses on developing long-life products for the outset and uses an evaluation checklist to ensure each design meets specific standards[4]. A durable, robust metal sub-frame provides structural integrity in a product that is designed for using long-life components. The design is upgradeable and modular upgrades are available to support changing customer requirements, avoiding the need to replace the whole machine when all that's needed is an extra paper cassette, for example. Care has been taken to design the product to enable easy serviceability through replacement of parts, to minimise the time it takes to repair and reduce down-time, and to increase the period between routine maintenance interventions. Design for disassembly is achieved by minimising fastener use and all screws used have the same head, so a single screwdriver can be used to remove them all. Plastic parts clip apart and a symbol is embossed on them to indicate where to apply pressure, as well as the polymer ID symbol.

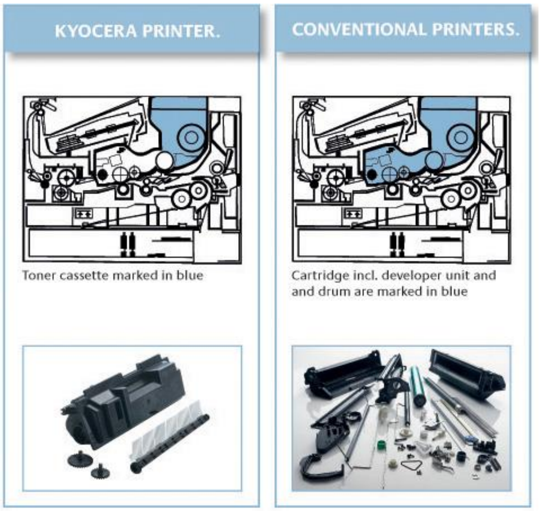

Fig. 5b KYOCERA's innovative print design demonstrating material efficiency in comparison with a conventional design

Environmental Benefits

The amount of material consumed during manufacturing as well as waste created by discarding consumables are reduced, as are the impacts of shipping consumables as the simpler ones are lighter and more compact. Compared to previous models, global warming potential can be reduced by 16%[5]. Simple toner cassettes are much easier to recycle as they contain only one or two polymers and no metals or other materials. Long life components also mean fewer replacements and less consumption of materials and energy during the product's lifetime.

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[3] *http://www.kyoceradocumentsolutions.com/ecology/product/ecosys.html*

[5] *http://www.kyoceradocumentsolutions.com/ecology/product/lca.html*

Economic Benefits

Because the consumable is much simpler, the consumables cost per page is much lower. Extended service intervals and serviceability also mean there are lower maintenance costs.

Social Benefits

The indirect sales business model creates jobs and generates revenue in the UK economy. Also, KYOCERA factories are all owned by the company and operated in line with its global CSR guidelines, negating the risk of labour rights violations.

Business Model

Channel to market is indirect, with products sold through so-called 'Servicing Dealers' that lease the product and use their own engineering resource to provide service support. Dealer engineers are trained by KYOCERA. Remanufacturing is done by these dealers, on their own premises, using parts supplied by KYOCERA. Depending on the dealer's own business model, remanufactured products may be sold or leased to new customers looking for a lower-cost alternative to the latest equipment, or supplied to an existing customer within a contract that does not specify that new equipment will be provided but instead commits to product performance and service levels. Dealers also routinely harvest viable spare parts from failed products to maintain machines in the field.

Future Challenges

The key limitation of this approach from KYOCERA's point of view is that it is not part of the remanufacturing system and therefore cannot collect data on remanufacturing or manage it. KYOCERA has so far not managed to find a way to achieve this that doesn't also add cost and complexity. The system works best when KYOCERA's channel partner leases the equipment – if the product is sold outright to the customer there is less opportunity to recover it and it could end up in the waste stream where, even if it is working, it will be treated as waste and opportunities for remanufacturing, re-use or disassembly for retrieval of individual high value materials, will be missed.

5.4 Case Study D

Company: Orangebox
Location: Treforest, Wales
Product: Ara Task Chair
Type: OEM
Maturity: Experienced
Contact: Gareth Banks
E-mail: Gareth.Banks@orangebox.com
Web: http://www.orangebox.com/

Orangebox is a market-leader in the design and manufacture of office furniture. It is committed to sustainable business practice and aspires to embed circular economy principles throughout its business. This can be seen through its efforts to maintain a local supplier network in Wales and the UK, as well as the use of Life Cycle Assessment (LCA) during product development. It recently undertook a remanufacturing pilot study[6] to explore the potential for remanufacturing within its business.

Motivation for Remanufacturing

Orangebox see a range of benefits of remanufacturing, from benefits to brand value through environmental stewardship to financial revenue generated through sale of remanufactured products. Material costs constitute 45% of Orangebox's total annual spend and therefore remanufacturing presents a great opportunity for cost savings as well as benefiting the environment.

Product Description

Orangebox has been bringing office task chairs (Fig. 6a: Ara) onto the market since 2007. A typical product lifespan of 6-8 years and is sold into Orangebox's key markets including corporate clients, hospitality, education and to the public sector.

Fig. 6a Orangebox Ara Task Chair

Fig. 6b Orangebox Fastener-free disassembly

[6] *Supported by the UK Innovation agency Innovate UK.*

Design for Remanufacturing

Orangebox's products are well suited to remanufacturing, through the selection of durable materials (such as aluminium), streamlining parts and integrating functions, allowing for easy manually disassembly to facilitate efficient remanufacturing. This efficient disassembly and reassembly is allowed for through an innovative design feature (inspired by Tupperware closures: Fig.6b) which allows the chair back to be fixed to the chair frame with limited fasteners. In addition, upholstery and castors (typically product replacement issues) as well as the seat foam can be easily removed and replaced on all Orangebox task chairs. Through the development of Ara and subsequent products (such as the Do chair), Orangebox continually hones its approach to DfRem. It aims to strike a balance between material efficiency without compromising the durability of the products it designs and develops.

Environmental Benefits

Through LCA Orangebox identify that the key environmental impacts of its task chairs are embedded in its material use during the extraction, product and end-of-life stages of the product life cycle. Remanufacturing can extend the life of the product by 4-6 years, achieving close to a twofold reduction in material and resource intensity.

Economic Benefits

Due to the high material input costs remanufacturing can contribute to significant material and energy savings during production. It can also add brand value as well as open up new markets.

Social Benefits

During a pilot remanufacturing programme undertaken in 2014, Orangebox initiated a partnership with a Welsh social enterprise, creating and upskilling a local workforce. Orangebox state that its remanufacturing and wider sustainability initiatives, instil pride in its workforce creating a positive company culture.

Business Model

Retrieving the chairs is the first part of the remanufacturing process and therefore the business model and process of remanufacturing are critical for success. Having a local supplier base is beneficial and through funding from the UK innovation agency, Innovate UK, Orangebox has recently been able to explore the business model options which can aid in reverse logistics to accelerate its remanufacturing activity.

Future Challenges

After undertaking its pilot activity in 2014-2015, the next step for Orangebox is to scale its remanufacturing activity throughout the business, which will require systemising and automating the process it has developed through initial feasibility tests. Orangebox products comply with UK, EU and US standards of new products, however it believes a certified mark would be beneficial to increase market uptake of remanufactured products.

5.5 Case Study E

Company: Ricoh Co., Ltd.
Location: Tokyo, Japan
Product: Multi-Function Printer (MFP)
Type: OEM
Maturity: Experienced
Contact: Yasunori Naito
Phone: +44 (0)20 74651217
E-mail: yasunori.naito@ricoh-europe.com
Web: www.ricoh-europe.com

Ricoh is a global technology company specializing in office imaging equipment, production print solutions, document management systems and IT services. Headquartered in Tokyo, Ricoh Group operates in about 200 countries and regions with over 109,900 employees.

Motivation for Remanufacturing

For the sustainable business growth of company into the future. Remanufacturing supports reduced new material consumption to sustainably utilise limited global resources. Resource conservation activities can reduce cost of products. Such activities are considered a key business factor to hedge against future risk of increasing resource cost and stable supply of our products in the market.

Product Description

In 1997, Ricoh launched the first remanufactured black and white colour Multi-Function-Printer (MFP) (Fig.7) in Japan, and since then it has widened its products portfolio of remanufactured MFPs. In 2009, Ricoh launched the first remanufactured full colour MFP which requires high quality standards. This introduction enabled Ricoh to provide products that can meet a range of customer needs. The digital full colour MFP MP C4000 RC is a remanufactured MFP MP C4000 sold in the Japanese market.

Fig. 7 RICOH Multi-Function Printer MP C4000 RC

Design for Remanufacturing

The Ricoh Comet Circle[7] underpins Ricoh's approach to sustainable design. In 1993 Ricoh developed its first policy on product design, for future reuse/recycling which includes, plastic grade identification, product strength design, reuse of high valued components, recycle of high quality grade materials, easy dismantling/segregation. This allows, for example, an

[7] *https://www.ricoh.com/environment/management/concept.html*

adaptable outer plastic housing for easy serviceability (cleaning and quick drying) and avoids use of stickers/labels over multiple components for easy disassembly. The efficiency of the remanufacturing process is greatly influenced by adopting such DfRem approaches (Matsumoto & Umeda, 2011).

Environmental Benefits

Through remanufacturing, Ricoh is able to reduce its environmental impact during production by 82% on the MP C4000RC when compared with an equivalent new model. Remanufacturing products can reduce processes for material and components production, which have large contributions to CO2 emissions in the total life cycle. On average 80% of the original components in weight are reused via Ricoh's product inspection, cleaning and remanufacturing process. In addition to the production phase, environmental impact throughout the total life cycle including in-use (depending on the energy mix) and end-of-life phases is lower by 17% annually.

Economic Benefits

Remanufactured products can contribute widen product portfolios, meeting various clients demands in the market, thereby opening up new market opportunities. Particularly, for clients who care about the environmental impact of the products they procure.

Social Benefits

Remanufacturing activities create job opportunities in the area where those products are collected and remanufactured.

Business Model

Ricoh's business model offers direct sales/service infrastructures where those products are collected by Ricoh for reuse/recycle purposes. Remanufactured products are dismantled, inspected, updated and rebranded to be sold as new. Ricoh has remanufacturing sites in each region including EMEA, Americas, Asia Pacific/China, and Japan. By combining design policy for future reuse/recycle and this infrastructure in each region, Ricoh can continue to offer its circular economy business model with high quality remanufactured products.

Future Challenges

Ricoh sees two key challenges to remanufacturing. The first issue is around compliance with future legislation on chemical management, meaning remanufactured products must comply with legislation which was applicable when the original products were produced. It may well be technically difficult to comply to new legislation with old technology, or commercially difficult to meet client demand on product price, considering the additional design changes required to meet any new legislation. Secondly, there are challenges with striking a balance between product life extension and technology innovation. On the one hand, promotion of the CE can extend product life, but on the other hand, it may limit opportunity for new innovation in technology.

5.6 Case Study F

Company: FARAL
Location: Laval, France
Product: Engines, Turbos, Gearboxes, Cylinder Heads
Type: Independent remanufacturer
Maturity: Experienced
Phone: +33(0)2 43 59 29 59
Web: http://www.faral.fr/

Founded in 1932, FARAL is a French supplier on the independent market of engines, cylinder heads, turbos and standard exchange gearboxes. Its annual turnover is €9M in 2014 and the company employs 75 peoples in 2015. The company is situated in Laval in France and all products are remanufactured in Laval's manufacturing facility.

Motivation for Remanufacturing

The main motivations for remanufacturing are its technical know-how (the company is engaged in these activities since 1965), environmental (availability of raw material and environmental benefits of remanufacturing), and economic benefits.

Product Description

FARAL remanufactures automotive parts (around 2000 engines per year, 6000 turbos, 1200 gear boxes and 2000 cylinder heads). The company has developed its own patented remanufacturing process for cylinder heads. More than 300 types of engines, cylinder heads and turbos (Fig. 8a) can be remanufactured by the company.

Fig. 8a FARAL engine *Fig. 8b FARAL's Ecolabel* *Fig. 8c Made in Mayenne Label*

Design for Remanufacturing

Cores collected by FARAL are designed by OEMs (PSA, Renaults, Ford, Opel and so on). In the case of engines most of the cores collected by Faral are designed to be remanufactured, but this is not the case for turbos and gear boxes. Engine parts are designed for milling and machining operations so they can be refurbished easily. Engines are also designed for durability which facilitates remanufacturing activities (core collections for example). For turbos and gear boxes, FARAL recommends that OEMs don't use parts that have to be changed frequently or where there is limited availability of spare parts, as doing so ultimately makes remanufacturing activities more complicated.

Environmental Benefits

Using environmental studies undertaken by OEMs, Faral calculated the environmental benefits of its remanufacturing activity. The company developed its own ecolabel (Fig. 8b), to ensure to the consumer that buying Faral's remanufactured engines decreases CO2 emissions, energy consumption and raw material depletion. Since it started remanufacturing, Faral has recovered more than 18000 tons of steel into new engines and automotive parts. Moreover, the company conducts measures to increase material recovery for parts that are not remanufacturable (waste sorting and partnerships with recyclers).

Economic Benefits

Remanufactured engines are sold to customers for 20 to 40% cheaper than new engines. For turbos and gear boxes, it is the same order of magnitude. Moreover, the production costs of remanufactured engines and parts are significantly lower than the production costs of new parts. The company strives to extract the highest possible economic value from old materials and parts.

Social Benefits

Every Faral product is associated to the "Made in Mayenne" label (Fig. 8c) which shows that the company is involved in the promotion of economic activities in the Mayenne 'department' (province) in France. This label demonstrates the company's willingness to train and recruit young workers from the region.

Business Model

Faral's business model is based on quality assurance and strong collaboration with partners (recyclers, providers).

Future Challenges

According to Faral, there is a necessity to improve the image of remanufactured products. The main challenge for the company is to change mind-sets to the circular economy and remanufacturing. In France, Faral thinks this can be accomplished through better communication of the main benefits of remanufacturing. Other challenges for the company are:

- Ensuring access to new cores, which is controlled by OEMs
- Preparing for oncoming new legislation (eg. tax regulation) that could impact remanufacturing activities
- Preparing for evolving new technologies that could facilitate remanufacturing activities (eg. additive manufacturing technologies)

5.7 Case Study G

Company: Neopost
Location: Le Lude, France
Product: IS- 350 Franking Machine
Type: Multinational OEM
Maturity: Experienced
Contact: Guillaume Moenne-Loccoz
E-mail: G.Moenne-Loccoz@neopost.com
Web: www.neopost.com

Neopost offers mail management (mailing solutions, franking machines) services to corporate clients, predominantly SMEs (80%) within the public and private sectors. It designs and manufactures a variety of products to facilitate mail management including the IS-350 seen in Fig 11. In 2011, it undertook a pilot remanufacturing activity, which led to an ambitious remanufacturing strategy which was deployed in 2012.

Motivation for Remanufacturing

Historically Neopost has taken a proactive approach to ecodesign, driven partially by specific legislation (WEEE, RoHS, Ecodesign Directive). The company states that its experience in ecodesign and previous activities in refurbishment, paved the way for its uptake of remanufacturing. Prior to investing in remanufacturing, it actively refurbished some products, though this was a 'less systematic' approach. According to Neopost remanufacturing offered the opportunity to improve its profitability, while also decreasing the environmental impacts of its activities.

Product Description

The IS-350 franking machine (Fig. 9a) is designed to process letters at speeds of 300 letters per minute. It is a certified Energy Star product, with a product life cycle of ten years (to facilitate two commercial life cycles of five years).

Fig. 9a IS- 350 Franking Machine

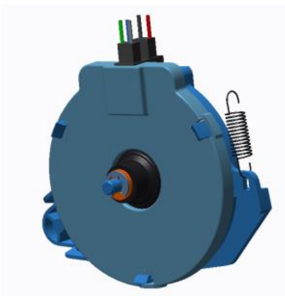

Fig. 9b IS- 350 Franking Machine

Design for Remanufacturing

Neopost's remanufacturing activity has centred on redesign. Two examples illustrate the design-engineering challenges it had to address in order to successfully remanufacture the product. Firstly, the IS-350 has a large number of bearings, which significantly slowed the remanufacturing process. In particular some bearings were difficult to access due to the design of the plastic housings (Fig. 9b) which needed to be prised open. Redesigning these bearings to be more easily accessible and reliable was beneficial for the efficiency of the process. By reducing the disassembly depth, Neopost reduced the cost of remanufacturing. Secondly, Neopost needed to think about the upgradeability of the electronic motherboard on the current range. The functional requirement is 32MB whereas the next generation is likely to be 64MB, so to provide the possibility to rework the Printed Circuit Board Assembly (PCBA) the design team opted for a 64MB at the outset.

Environmental Benefits

The key environmental impacts of Neopost's range of franking machines are during the raw material extraction stage (75%). Assuming a product life cycle of five years for a new product, depending on the remanufacturing approach, the life cycle impacts could be reduced by up to 37% when comparing a remanufactured product to a new product. At present, Neopost are achieving reductions of up to 30%.

Economic Benefits

The remanufacturing of products could reduce product costs by up to 20 or 30%, depending on the remanufacturing type. In addition to cost savings, remanufacturing is also a way for Neopost to reduce risks linked to price volatility and the availability of resources.

Social Benefits

Operators from the remanufacturing facility are motivated and proud to work on a project which retains local jobs and also which is one of the key pillars of Neopost's Strategy.

Business Model

Neopost state that many of the design issues they face can be resolved, whereas the management of remanufacturing is a more complex challenge, due to the return of different generations of the same product. Neopost state that it is because of the business model it has (leasing to retain ownership of the carcasses which is driven by extended producer responsibility requirements) that it is in a position to do remanufacturing.

Future Challenges

One of Neopost's key challenges is to be able to effectively anticipate legislation to ensure that its remanufactured goods remain compliant.

5.8 Case Study H

Company: Recover-E
Location: Amersfoort, Netherlands
Product: ICT Equipment (laptops, desktops, tablets, screens)
Type: Foundation
Remanufacturing Maturity: Early-stage
Contact: Jan-Paul Kimmel
E-mail: jan-paul.kimmel@rhdhv.com
Web: http://recover-e.nl/

The Recover-E Foundation is led by Royal Haskoning DHV's sustainability and circular economy consultants and was co-developed in partnership with SiSo, to boost refurbishment of ICT equipment through a shared partnership approach to asset management.

Motivation for Remanufacturing

Electronic waste is the fastest growing waste sector globally. In 2015, more than 245 million laptops were sold worldwide. There is huge potential to optimise value that currently isn't being valorised. Materials embedded in these products can be recaptured and re-used to create a whole new value chain after the first life.

Product Description

Recover-E refurbishes a range of ICT equipment including laptops, mobile phones, tablets and desktops (eg Fig. 10), which are resold to a second user under a two-year warranty.

Fig. 10 Refurbished Lenovo Thinkpad

Design for Remanufacturing

Typical design issues Recover-E see include damage to the hardware including broken buttons and keyboards and aesthetic damage to plastic housings, which drive early product replacement. Recover-E sees durability, modularity and the layout of internal hardware to allow remanufacturable and recyclable components to be separated from each other without damage, to allow more easy separation of valuable materials and working parts, such as hard drives.

Environmental Benefits

Improving management of the processes between initial and second use contributes to a longer life (and use) for the product, unlocking higher value along the entire value chain. By adopting a multi-strategy end of life approach, to combine reuse, remanufacturing and refurbishment Recover-E can extend the life of products, while also ensuring a secure supply of materials at a stable price.

Economic Benefits

The Recover-E approach means reuse of ICT hardware can deliver a higher economic return than recycling alone. Through refurbishing, reselling and maintaining ICT equipment, Recover-E extends the life of these products providing low cost goods to secondary markets. The market potential of Recover-E lies in its focus on managing data relating to ICT equipment, components, parts and materials throughout the whole life cycle. Ultimately, the Recover-E program will expand to provide Life Cycle Analysis (LCA) data on all recovered ICT products, enabling stakeholders in the chain to monitor assets transparently.

Social Benefits

Recover-E works in partnership with The Salvation Army who supports and empowers vulnerable, marginalised members of society by involving them in optimising the logistics chain as part of its reintegration programs. Throughout The Netherlands, the initiative is creating positive impact in many communities, providing opportunities for education and personal development.

Business Models

Recover-E maximise the value of ICT equipment through use contracts within business-to-business markets, through its track-and-trace ICT platform which allows stakeholders to access and track information about finance and materials throughout the product life cycle.

5.9 Case Study I

Company: Philips Healthcare
Location: Best, The Netherlands
Product: Diamond Select Allura Xper FD20/10 Interventional X-ray system
Type: OEM
Remanufacturing Maturity: Experienced
Contact: Nestor Coronado
E-mail: nestor.coronado@philips.com
Web: http://www.philips.nl/healthcare/solutions/refurbished-systems

Philips Healthcare is part of the parent company Royal Philips. Philips Healthcare seeks to improve lives, through meaningful innovations developed in collaboration with clinicians, to improve quality of care and patients' lives (Annual report, 2014). The company is a global leader in the provision of cardiac care, acute care and home healthcare. It sees refurbishment as a means to unlock new business opportunities in innovation and growth.

Motivation for Remanufacturing

Due to the financial effects of healthcare reform, maintaining profitability is a top concern. One solution is to differentiate from competitors with advanced systems and thus increase market share. Doing so can, enhance reputation, and keep patients close to home. But this comes with a price. Today's mandates to manage healthcare costs make total cost of ownership and return-on-investment top concerns. Philips' Diamond Select program meets these requirements, giving you advanced refurbished medical systems at an affordable price. Refurbishment is a win-win across the whole value chain. It is about addressing customer needs and not simply upselling new products.

Product Description

The Diamond Select Allura Xper R7 FD20/10 Interventional X-ray system (Fig.11) is an upgraded system with a maximal reuse of material (around 80%) which has been fully approved and released according to internal and external standards.

Fig. 11 Diamond Select Allura Xper FD20/10 Interventional X-ray system

Design for Remanufacturing

Philip's Healthcare seeks to close material loops by adopting a platform design approach, product upgrading strategies and parts harvesting at the point of refurbishment. A key design approach for Philips Healthcare is designing for reliability in the first place and this is evident in the high residual value of the product. It has developed and approved an upgrade system which is based on material reuse.

Environmental Benefits

Through its system upgrades, Philips Healthcare can reduce material consumption by up to 80%, improving its resource efficiency and reducing overall waste, in essence decoupling its material use from its business activities.

Economic Benefits

Refurbished Systems are sold for 60 to 85% of the equivalent new system price, depending on the generation of the product and the developments of its life cycle. Refurbishment can be strategic from a marketing and market segmentation perspective. In addition, in this case, the system upgrade approach saves costs by up to 50% on the upgrade bill of materials. The upgrades provide a means for new revenue through new sales and service contracts.

Social Benefits

The Refurbished Systems can help healthcare providers to enhance their care capacity to a larger patient base because the capital expenditure is lower or can be minimal if considering business models like leasing, renting or pay per scan. It is about access to the technology and functionality of Philips systems, rather than the ownership of the systems themselves.

Business Models

The product's residual value is capitalized on through a trade-in mechanism offered to clients. Philips sells or leases a range of refurbished good to clients, with a follow-up customer care package and a full warranty. Through refurbishment different value propositions can be offered with different types of technology at different prices. The business proposition centres on making high quality equipment available at an affordable price, for the same warranty as for new equipment.

Future Challenges

In general, refurbishing can benefit from better customer perceptions of refurbished goods. There are also trade barriers that limit the potential for refurbishing; refurbishing requires being able to globally move goods because supply and demand may not be in the same country and this is hindered by the lack of a free market for pre-owned goods. Future material scarcity is also an issue, such as copper, which has medium-term scarcity predictions and helium, which is used as a cooling agent and which is plentiful but difficult to isolate.

5.10 Case Study J

Company Overview

Company: Martela
Location: Helsinki, Finland
Product: Office furniture
Type: OEM Remanufacturer
Remanufacturing Maturity: Mature
Contact: Anne-Maria Peitsalo (Responsibility Specialist)
Phone: +358 10 345 50
E-mail: Anne-Maria.Peitsalo@martela.fi
Web: http://martela.com/

Martela is one of the Nordic leaders in the office interior industry. It strives to offer the best workplaces environments, which has been guiding the company for seventy years. In addition to innovative and ergonomic furniture solutions Martela designs and implements various workplace related services. Martela helps improve the employee wellbeing while at the same time increasing the space use efficiency in workplaces, schools and welfare environments.

Motivation for Remanufacturing

The amount of furniture going to waste is high: it is estimated that in Finland it is about 100,000 tn/year. In 2014 Martela received about 3000tn of used furniture. More than 20000 pieces were sold to new users after cleaning, reupholstering and/or refurbishment. Through remanufacturing, material and energy resources can be saved, but Martela's motivation for remanufacturing is to offer better customer service and win new business.

Product Description

Martela designs and supplies interior solutions (Fig. 12), including chairs, desks, shelves and partition walls, for working environments and public spaces. Martela offer ergonomic solutions for modern working environments - for mobile work and activity based offices. The objective is to provide customers and partners with the best service in the business and high-quality and innovative products. Fast deliveries and an efficient delivery network help attain this objective.

Fig. 12 Martela Furniture Portfolio

Design for Remanufacturing

Martela develops its own designs. The main design objectives include usability, good ergonomics, visually pleasing products. There is no official DfRem process adopted, but the following features support it: easy disassembly and upgradeability, modularity, standardization of components, reusable packaging. Industry standards define the requirements for durability and other technical features, where manufacturability is also taken into account.

Environmental Benefits

The effect of remanufacturing has not been evaluated.

Economic Benefits

For the customer remanufactured products are typically cheaper than new ones but there are also cases when they are more expensive (for example with specific upholstery or when new products are not any more available). For the company, the customers are usually different from the customers of new furniture. Thus new business can be derived.

Social Benefits

Corporate social responsibility means that Martela takes responsibility for the impact that it has to the community, the environment and among other interest groups. Martela takes responsibility for total life cycle of the product: from product design and supply chain to production and customer service, maintenance service during the use time and finally when customer no longer needs the product with product recycling with emphasis in giving a furniture a new life.

Business Models

Martela retrieves used furniture typically when selling new products. The remanufactured products are sold through a specific outlet-channel.

Future Challenges

To perform remanufacturing, sufficient amount of cores need to be available. Currently this is true in Finland, but not in other market areas yet. There are also some challenges in the type of used furniture and demanded furniture.

5.11 Case Study K

Company Overview

Company: AGCO Power
Location: Linnavuori, Nokia, Finland
Product: Diesel engines and equipment
Type: OEM Remanufacturer
Maturity: Mature
Contact: Jarkko Roiha (Sales and Marketing Manager, Aftersales)
Phone: +358 400970604
E-mail: jarkko.roiha@AGCOcorp.com
Web: www.AGCOPOWER.com

AGCO Corporation is an American agricultural equipment manufacturer. Agco Power is the Finnish subsidiary of AGCO Corporation. AGCO is a leading manufacturer and distributor of agricultural equipment and related replacement parts throughout the world. AGCO sell a full range of agricultural equipment, including tractors, combines, self-propelled sprayers, hay tools, forage equipment and implements. AGCO products are recognized in the agricultural equipment industry and are marketed under a number of brands, including: Challenger, Fendt, Massey Ferguson and Valtra.

Motivation for Remanufacturing

AGCO reman engines and components are engineered and remanufactured to provide maximum value and increase uptime in the field for all AGCO customer equipment needs. They are upgraded to the latest OEM engineering specifications, fully tested and ready to install. AGCO Reman parts eliminate uncertainty and prevent complications during rebuilds. AGCO Reman parts are superior to both "rebuilt" and aftermarket alternatives.

- Each part is completely disassembled, cleaned, and inspected
- Their individual components are brought up to the latest OEM specifications, if possible, or replaced with new components. All wear items are also replaced.
- Older cores are brought up to date with the latest engineering specifications, when possible. Doing so provides even better performance on older equipment.

Product Description

AGCO Power division produces diesel engines (Fig. 13), gears and generating sets. The diesel engines are manufactured for use in tractors, combines and sprayers, and are also sold to third parties. The engine division specializes in the manufacturing of off-road engines in the 50-500 horsepower range. The largest number of new engines was manufactured in 2013 (app. 40000 diesel engines). Annually about 1000 engines are remanufactured.

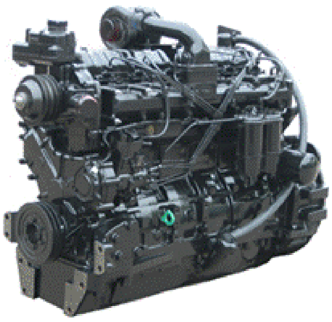

Fig. 13 AGCO diesel engine being remanufactured at Linnavuori Plant.

Design for Remanufacturing

Standardisation and modularisation are the most important factors in the design. In the past, ACGO has partnered with up to 16 engine providers which increased complexity, whereas today the number has decreased to seven. AGCO Power is the only internal engine provider. In the future the number will be decreased to three. The engine blocks are designed with extra working allowance, which allows for remanufacturing and machine-tooling of cylinders.

Environmental Benefits

The remanufacturing process[8] requires 80% less energy and material than manufacturing a new component. The AGCO Power engines division, which specializes in the manufacturing of off-road engines in the 50 to 500 horsepower range, currently complies with Tier II, Tier III and Tier 4i emissions requirements set by European and United States regulatory authorities.

Economic Benefits

- Reduced cost because ownership of equipment is expensive and remanufacturing helps by reducing parts and labour costs for equipment repairs
- Increase uptime through speedy repair time means more time in the field
- Remanufacturing ensures quality as it always brought up to the latest engineering specifications
- Extends service life of older machines
- Otherwise, obsolete parts are kept available
- Warranty and reliability, every remanufactured part with the same warranty as genuine AGCO original equipment parts

Business Models

AGCO Power uses a deposit system. When a customer buys a remanufactured engine he/she pays a deposit. When the used engine (core) is returned the deposit is refunded to the customer.

Future Challenges

In the future one challenge is to be able to respond to customers' increasing standards on delivery times. The remanufacturing process needs to be developed to meet customer service expectations. This will also be visible in sales and marketing, in order to make the decision-making easier for customers. Delivery times at the engine factory times need to be further shortened by two days. In addition, the technology development is difficult to foresee. What is the general business view in 10 years from now? Will the equipment usage behaviour change? Will there be more non-repairable products? If the customers' behaviour changes, then it will also influence AGCO Power.

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[8] *https://www.youtube.com/watch?v=tPomC4BPLmU*

5.12 Case Study L

Company: Fuel Cell Recovery (FCR) Project
Location: United Kingdom
Product: Hydrogen Fuel Cell stack
Type: Project
Maturity: Piloting
Contact: David Stewart
Phone: +44 (0) 2038 23 5650
E-mail: david.stewart@hssmi.org
Web: http://hssmi.org/our-work/circular-value-chains/

Companies involved: Microcab Industries Ltd, High Speed Sustainable Manufacturing Institute Ltd (HSSMI Ltd), MCT Reman Ltd, Env-Aqua Solutions Ltd and Hydrogen London

The aim of the FCR Project is to establish how hydrogen fuel cell stacks (HFCs) in Fuel Cell Electric vehicles (FCEVs) can be recovered once they reach the end of life, so that the optimal value can be recuperated, by extending their service life. The project will lead to the generation of new product designs, process designs, closed loop supply chain designs and business models that facilitate fuel cell remanufacturing.

The consortium for this project consists of five UK-based organisations, each with a stake in a closed loop hydrogen fuel supply chain. The project lead, Microcab, is a lightweight FCEV manufacturer (Fig. 14), committed to offering its newest vehicle through a CE business model which incorporates car sharing, low carbon mobility and remanufacturing. The project manager, the High Speed Sustainable Manufacturing Institute (HSSMI), is a not-for-profit research institute. MCT Reman, are one of the UK's leading powertrain remanufacturers and their interest in the project lies in the impact that the electrification of the automotive industry will have on future remanufacturing. Env-Aqua Solutions Ltd is a recycling consultancy with over 25 years' experience in the electronics and industrial waste treatment and pollution control sector. They are tasked with developing solutions for the recycling of the fuel cell materials. Hydrogen London is part of the Greater London Authority (GLA) and is tasked with supporting the UK's transition towards a Hydrogen economy.

Fig. 14 Microcab vehicle

Motivation for Remanufacturing

This project has two key drivers: the opportunities of a CE and the future impact that HFC technologies will have on the automotive landscape. Due to European and national policies set to reduce CO2 and NOx emissions, vehicle propulsion systems are moving away from traditional combustion engines, towards low carbon hybrid and electric powertrains. As a result, many automotive manufacturers are developing new HFC vehicle technologies. With the increased production and consumption of these new technologies, come new challenges around how to optimally recover the components and materials within them at the end of life. With the growing stringency of the End of Life Vehicle (ELV) directive, coupled with the potential commercial opportunities, it is absolutely critical that automotive manufacturers and producers of these components understand how to do this from the very start[9].

Product Description

A HFC is an electrochemical device that generates electricity through a chemical reaction, a result of hydrogen being fed to a catalyst coated membrane on one side and oxygen on the other, to produce an electrical current. The only emission is water. A cell is made up of multiple layers of parts and coatings to permit this reaction taking place. Multiple cells are then combined together to create a fuel cell stack which allows for an increase in the amount of power output.

Design for Remanufacturing

The team's work has concentrated on the diagnosis, disassembly, replacement and testing of three separate 3kW HFC stacks. Through the development of new processes and equipment, the team has been able to replace faulty cells in a stack, with high performing cells from another stack. This results in a remanufactured stack which matches the performance and specification of the original version. The pilot remanufacturing process has highlighted the need to adapt the product design based on certain guidelines. These include:

- Choice of joining methods, fasteners and part connections – (eg avoiding gaskets attached with strong adhesive)
- Material choice – (lightweighting increases fragility of components, and therefore risk that the parts could break during handling. This risk is compounded when the material chosen is inherently brittle eg flow field plates made of graphite.
- Integration of RFID tags, electronic data logs and sensors – sensors to measure voltage and temperature of the individual cells in order to identify their condition, would allow faults to be picked up before they have a negative knock on effect on other cells, also triggering the remanufacturing operation.
- Tracking history of faults and changes, as well as data about Bills of Materials, known failure modes, test data and original performance and build specifications would be beneficial.

Other aspects of the product design which facilitate the product's remanufacturability, but which are already inherently integrated in fuel cell design include: part standardisation, modularity, and upgradability.

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[9] *When these vehicles reach the end of their life, the automotive industry and fuel cell producers will become accountable for the responsible collection, recovery and disposal of them under the End-of-life Vehicle directive. There is also a significant economic incentive for recovering fuel cells at the end of life. They feat*

ure materials such as platinum and palladium which are expensive, precious metals with finite reserves.

Environmental Benefits

The expected benefits[10] of remanufacturing include:

- reduced reliance on precious and finite raw materials (specifically Platinum Group metals)
- reduction in used products and materials going into waste streams
- reduced energy consumption and CO2 emissions by displacing new production
- accelerating the development of robust fuel cell technology and more eco-friendly transport

Economic Benefits

The expected economic benefits will be realised in the form of:

- materials savings from reusing existing materials compared with buying new
- energy savings compared with producing new
- mitigation of future financial penalties for noncompliance
- offsetting landfill tax costs by recovering retained value within fuel cells
- revenue from selling second life fuel cells

Social Benefits

The expected social benefits will be realised in the form of:

- the creation/retention of skilled and semi-skilled jobs in the recycling and remanufacture industry and will help support jobs in the wider automotive industry
- enabling people with limited financial means to purchase second-hand/renewed products at a fraction of the price of newly manufactured,
- a reduction in carbon generated will help mitigate air and water pollution, improving air quality and hence the health of the population.
- MCT Reman anticipate that, if the project is successful, they could see a potential business revenue growth of 20% for the company with a 10% growth of personnel employed at MCT to support a remanufacturing process for hydrogen fuel cells

Business Models

The work on the relevant business model for Microcab is ongoing.

Future Challenges

Besides the wider challenges associated with HFC vehicles and hydrogen infrastructure development, future challenges relating to their remanufacture lie in the complex development of hybrid manufacturing and remanufacturing lines which are scalable from low to high volumes, which can accommodate a range of different fuel cell types.

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[10] At the time of writing a full LCA is underway and will provide an assessment of the environmental impact of the developed remanufacturing process in relation to new manufacturing and recycling of HFCs.

5.13 Section Summary

This section has described twelve case studies of remanufacturing from six sectors. The cases represent a breadth of stakeholders from the remanufacturing community, including OEMs and independent remanufacturers. This broad representation was deemed important, as despite independent remanufacturers not being able to influence the design of the products they remanufacture, this influences their business activities. In doing so, the cases bring insights to the field of DfRem, highlighting good DfRem guidelines as described by this diversity of stakeholders representing the remanufacturing community, as well as many cases of remanufacturing where DfRem is not integrated at all. The cases represent the perspectives of those remanufacturing actors who have no control over DfRem, on their views on the critical elements of DfRem.

The cases help to bridge the current deficit of DfRem remanufacturing cases in industry as well as broadening the potential for remanufacturing activities by including new technologies that can be suited to remanufacturing (such as in the case of Microcab and partners' innovative approach to remanufacturing FCEVs).

In addition, challenges relevant to DfRem and remanufacturing more broadly are included and this can be used as a springboard for future work in this area. Some cases highlight the important role DfRem can play in improving the efficiency of remanufacturing processes (as described in Ace-Reuse Technology, Neopost, Ricoh cases) or how disclosure of design files (Eg Microcab case) or better product life cycle data (eg KYOCERA case) could benefit and enable remanufacturing uptake. In addition, consideration of the business models gives context the remanufacturing activities and begins to build a picture of the relationship between design and business models in the context of remanufacturing.

Finally, the case studies describe a range of economic opportunities (cost savings, revenue generation, new markets) and environmental benefits (waste reduction, CO2 savings, cleaner production) for remanufacturing within these selected organisations.

The cases are analysed and these themes are mapped out in detail in Section 6.

6 Thematic Analysis

This section provides a cross-case analysis to contribute to the overarching aim of D3.2 which is to map the DfRem landscape. In this body of work, we approach this by defining the distinctive thematic threads and activities, within the sphere of DfRem. In particular this includes a description of the requirements for successful product design practice, a summation of the economic, social and environmental benefits of remanufacturing identified in these case studies, the challenges within DfRem, the role of advanced material in DfRem and the role technological innovation plays in remanufactured goods.

6.1 Design for Remanufacturing

Here we discuss key themes emerging within DfRem, while these are presented as distinct thematic areas there are interrelationships between these and not one stands in isolation.

6.1.1 Collaboration for Information Feedback Loops

Many actors operating within the remanufacturing sector have little control over the design of the products that they remanufacture. In particular, independent remanufacturers describe the problems for remanufacturing when little or no information is available on the product. Even in the cases of OEMs, evident through the interviews and wider discussion within the ERN network, cross-departmental communication between remanufacturing and R&D or product development is a barrier to information flow which can support better design practices for remanufacturing. Experiences of both independent and departmental remanufacturers can be considered to inform future DfRem recommendations. Cross-functional teams and communication is discussed in the innovation literature more broadly and the importance of cross-functional teams and collaboration is also critical in the case of DfRem. Kurilova-Palisaitiene et al (2015) describe the types of information needs for effective remanufacturing including: product design specifications (eg assembly/disassembly instructions, BOM, 3D models); manufacturing specifications (eg manufacturing instructions, process and manufacturing specifications); service specifications (eg repair manuals, training material, spare part catalogue); original part quality assurance (eg user feedback); core quality assurance (eg defect measurement); remanufactured product quality assurance (eg final quality assurance).

The authors go on to recommend the following actions to foster better information flow to support remanufacturing:

- develop standardized data sharing channels,
- establish accessible knowledge exchange platforms,
- increase the data exchange speed through tied collaboration with stakeholders,
- and expand the data ownership in the system of shared values (Kurilova-Palisaitiene et al 2015).

6.1.2 Redesign, Design Briefs and Pilot Studies

Many of the OEMs included in the study have not set out to remanufacture these products at the point of product development, that is the products are not designed for remanufacturing. Companies instead undertake redesign activities. This poses some challenges to defining successful practices in product development and product innovation management with respect to remanufacturing, as it limits the scope of the work to back-casting and interpretation, rather than representing a DfRem process in practice. In addition, a lack of inclusion of DfRem requirements in design briefs limits the agency of designers to adopt DfRem in practice (APSRG, 2014). Moreover, it limits the potential to explore DfRem as a design-driven innovation approach that could conceptualise creative new products suited to remanufacturing practices. This in turn hampers the potential of remanufacturing in general. This could be addressed by facilitating and investing in new product developments tailored towards remanufacturing.

Another reason for this is that in some cases the remanufacturing business activity presented is under development, through for example industry-led pilot studies and feasibility studies, or consortia focused on research and development to support remanufacturing in new sectors (eg Hydrogen Fuel Electric Vehicles). Such activities can give rise to design insights, which are valuable to capture and feed into potential new product development activities. In some of these cases remanufacturing remains limited to redesign within a single product line, with companies then seeking out how to scale and systemise remanufacturing across the organisation. This describes an evolving integration of remanufacturing practices within businesses with varying levels of investment, risk and capabilities depending on the stage of the process a company is at.

6.1.3 Design trade-offs

A recent study, commissioned by the Scottish Government, shows the impacts of the lack of a systems perspective in remanufacturing approach in the automotive sector. Lightweighting through increased use of composite materials makes is increasingly difficult to remanufacture parts and components down the value chain (Zero Waste Scotland, 2015). This is because materials substitution activities compromise the durability of the parts (ibid).

In addition, there might be conflict between DfRem and other Design for (DfX) approaches (Shu & Flowers, 1999). Design that facilitates disassembly for maintenance and recycling can benefit remanufacture (ibid). Nevertheless, remanufacturing often requires disassembly of joints that are not accessed for routine maintenance tasks and the urgency of returning equipment to operation is not as great in remanufacturing as when a product is being maintained. Damage to the part as a result of disassembly or reassembly can also prevent reuse. For example, while a snap fit may provide fast assembly and possibly disassembly and reassembly without introducing a different material, a failed snap fit is difficult to repair and may render the part unusable. On the other hand, disassembly methods destructive to the fastener that do not damage the fastened parts, such as drilling out and replacing a rivet, are acceptable in remanufacture.

Similar issues are seen in the case of Microcab and in the case of Orangebox. Orangebox describes how it seeks to balance between material lightweighting while maintaining product durability and Microcab identify the fragile graphite material used in FCs as a key barrier to efficient remanufactruing. Similar issues have been discussed previously in the literature (Prendeville at al., 2013). In summary, this illustrates how DfRem and material selection for remanufacturing need a product life cycle management approach, to consider such decisions trade-offs along product life cycle.

6.1.4 *Design Guidelines for Remanufacturing*

Section 4 summarised key literature on DfRem guidelines and while this review is not intended to be exhaustive, it did show considerable overlap in the design guidelines identified. Here, these are merged to provide a general set of guidelines relevant to remanufacturing. The design guidelines identified in the literature review and converge with those identified in the cases.

Table 5 Cross case analysis of design guidelines for remanufacturing

	Cases											
Topic	A	B	C	D	E	F	G	H	I	J	K	L
Ease of disassembly (focus on suitable connections, limit variety of tools required, limit fasteners)	■	■	■	■	■		■			■		■
Material selection (eg high value materials incentivize remanufacturing)	■		■	■	■							■
Durable materials/parts; reliability	■	■	■		■	■	■	■	■	■		
Upgradeability / adaptability			■		■		■		■			■
Modular design			■					■	■		■	■
Easy serviceability			■	■	■							
Design for rapid repair			■									
Plastic grade identification					■							
Reuse of high-value components; ; parts harvesting					■				■			
Design for milling and machining						■					■	
Availability of original parts			■			■						
Integration of RFID tags, electronic data logs and sensors												■
Standardization			■								■	■
Easy access to vulnerable/valuable parts							■	■	■			
Small number of parts / designing layouts that segregate recyclable and remanufacturable components							■	■				

6.2 Design for Remanufacturing and Business Models

Selling products through new business models such as integrated product service systems (PSS) is becoming more widespread. One example is a PSS company provides the function of washing clothes instead of the actual washing machine and the customer only pays for the number of laundry loads. PSS is a concept used to obtain a larger share of the market and control a larger share of the product value chain. The focus is on providing the function, not the product, and this means that the provider could put more focus on optimizing the total life cycle cost (Sundin & Lindahl 2008). Known as functional sales, product service systems is a very promising business model for remanufacturing. Nevertheless, in the cases described in Section 5, most firms operate direct sales models through context specific partnerships eg. through a network of dealerships, partnerships between independent and OEMs. Some bases are seen to use rebate systems to incentivize product returns. When the provider has control over the physical products during the use phase, the incentive for cost reduction across the life cycle increases, which can stimulate remanufacturing and in turn influence the design. Revenues from servicing, spare parts and maintenance can be an opportunity for reducing the cost for the use and end-of-life treatment phase. Lee & Sundin (2011) encourage the adoption of PSSs to improve the overall life cycle sustainability of electronic products.

While many of the case companies described do not have any influence on the design of the products, in some cases the interdependency between the business model and the design of the products which they bring to market is evident. In some cases remanufacturing is a mature and strategic business activity and this is reflected in investment in the design of the product (eg RICOH, KYOCERA) as well as design strategy (eg how it positions its product in the market) (eg Philips Healthcare Refurbished Systems). In other cases new regulations stimulate a reverse flow of products (eg Neopost) and therefore the uptake of remanufacturing as a new business activity. However this is not seen to influence the design of the products in any significant way. In other scenarios, the remanufacturing activity is research-driven to evaluate the feasibility (eg Orangebox, Microcab), but the implications for design are clear to the companies, who see the need for more durable product designs through material selection.

For independent remanufacturers, the interplay between the design and business models is indirect because these actors have no agency to affect the designs of the products they remanufacture. Nevertheless, the lack of information available on product designs negatively impacts these actors businesses, as the design is seen to relate to the efficiency of the remanufacturing process and therefore the operational costs for the companies (as in the case of Ace-Reuse). Some manufacturing OEMs try to make it difficult for independent remanufacturing companies to refurbish, or harvest parts and components from OEM cores. In the past, OEM manufacturers have been seen to introduce controversial DfRem strategies to restrict independent remanufacturers from offering competing low-priced printer cartridges (Mass Law Blog, 2014). For example, one OEM´s printer was designed to only operate authorized OEM cartridges. The DfRem strategy strives to restrict the usage of unauthorised remanufactured cartridges, which uses a microcontroller to detect non-OEM cartridges, which if detected then prevents the printer from operating that cartridge. This strategy promoted the sales of the OEM´s own remanufactured cartridges. More recently, Apple were seen to block the use of iPhone6 devices which had been repaired by third parties (Forbes, 2016). Such DfRem conflicts and competition issues limit the potential for remanufacturing in the long-term.

6.3 Design for Remanufacturing and Advanced Materials

The purpose of this section to shed light on the role of DfRem in supporting management of advanced materials and resource efficiency. In line with the market survey, the advanced materials considered in this report largely find use as metals, ceramics and alloys and comprise a particular range of metals termed critical materials. The rationale for this choice follows the concerns of the EU (along with many other developing economies) about the future security of supply of these materials. The term critical materials (for the purposes of this report) concern a range of metal material resources that are selected during product design processes, for a wide range of products. A critical material is a material with a high economic value and which is subject to supply risks. The definition of which materials are critical is given by the EU and the list of materials is updated on a regular basis.

In the context of product design, critical materials are usually 'invisible', as they are an intrinsic constituent of a component that provides a unique performance that the product user highly values. Thus, there are very few product designers with a good understanding of the complexities of the critical materials field (Peck et al, 2015; Peck & Bakker, 2012). Critical materials cannot be easily replaced with less critical substitutes and can be challenging to recycle (Peck et al., 2015). Critical materials can be kept in use using a range of approaches including using circular / closed loop thinking, which includes remanufacturing.

Remanufacturing is perceived as a strategy to retain advanced materials, including critical raw materials, within the European economy. This approach on closing loop (including remanufacturing) has been adopted by the KIC EIT Raw Materials[11], an important EU flagship programme of actions on raw materials (with a focus of critical materials). Critical materials can provide opportunities to significantly reduce environmental impacts during product use and critical material use should not necessarily be avoided. In summary then, there is wider evidence to suggest that remanufacturing can support critical materials management.

In the cases that have been presented, critical materials have not typically been identified as a remanufacturing driver or as a critical materials risk reduction strategy. Nevertheless, in the case of the Microcab consortium, the opportunity to reclaim materials (eg Palladium) is seen as a strategic opportunity. Other respondents did allude to issues around potential commodity material cost increases (such as copper) which can catalyse remanufacturing activities. Nevertheless, this is a wider materials management issue not singularly linked to CRM. Many of the cases presented operate in sectors and sub-sectors relevant for CRM (ICT, Electronics, Automotive[12]) potentially indicating a lack of awareness of CRM issues in general.

Beyond the scope of critical material, most companies have claimed environmental benefits that for resources varied from 50-80%. As remanufacturing focuses on maintaining the most valuable components, that contain most of the critical materials, it seems justified to state that remanufacturing is responsible for similar or larger benefits with respect to critical materials.

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[11] https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/content/strategic-implementation-plan-sip-0

[12] As described in the European Remanufacturing Network Market Survey. http://www.remanufacturing.eu/wp-content/uploads/2016/01/study.pdf

In summary then, while there are likely to be critical material issues relevant to some of the companies profiled, the interview responses didn't identify any cases where this was immediately relevant to the company. In addition, while many of the sectors profiled are subject to critical material supply risks, many of the cases are not in a position to control materials through design decisions or material selection as they are operating independently and are therefore one step removed from these decision-making processes.

6.4 Design for Remanufacturing and Technology Integration

This section explores how design (product design, design strategy) can offer the remanufacturing industry ways to manage products whose technologies are outdated.

Technological progress is inevitable. The interdependencies between technological innovations, future legislative requirements (eg increasingly stringent energy efficiency requirements) and remanufacturing is a complex issue that companies struggle to negotiate. The risks of falling short of future energy efficiency requirements as a result of remanufacturing activities is seen as a key challenge to remanufacturing industries. Through the cases that are presented examples of compensating for potential future efficiency requirements see companies building in higher software specifications within products from the outset (such as in the case of Neopost).

One barrier to the uptake of remanufacturing is the lack of know-how on ways to overcome varying forms of product technological obsolescence that causes inherent risks to the viability of future sales of remanufactured goods. Charter & Gray (2008) suggest that in order to successfully remanufacture, product technology needs to be relatively stable. This is true for many of the cases presented (imaging equipment, engines, furniture). Design for technology integration encompasses both the need to focus remanufacturing activities on products whose technologies are stable and/or which are upgradeable through integration of new software architecture through modularity, product upgrades and platform approaches to the design. In combination with technology roadmaps including technology development paths and timelines (Cunha et al, 2011), these strategies can mitigate against technology obsolescence and reduce business risk. Through such strategies, companies can also address the issue of efficiency degradation in energy-using products, which has to-date limited the potential for energy efficiency gains through remanufacturing (Gutowski et al., 2011).

In addition, in some of the cases discussed, the market requirements for remanufactured goods are such that the latest technologies may not be needed or desired and the geographical location of markets for remanufactured goods (often emerging economies) overcomes the issue of technological innovations. For instance, in the case of Philips, 80% of the market needs are satisfied with refurbished products and markets for remanufactured goods are typically identified in emerging economies. This market opportunity is a means to broaden the uptake of remanufactured goods, beyond the typical long-life high value products described here. For example, Franke et al. (2006) describe the opportunities for OEMs to provide high-quality low-cost remanufactured mobile phones to new developing markets. Kwak & Kim (2013) describe how the combination of product design (specifically adequate upgrades), the target market (customer preferences and competing products) as well as the recovery economics can be used to define both the optimal selling price and product specification to ensure the economic viability of remanufacturing activities. What this means is that remanufactured goods must be brought to market with similar strategic considerations as are incorporated in marketing of newly produced goods and in which design strategy plays an important role. Thus, integrating considerations of product positioning within technology roadmaps can also be beneficial. Sundin & Lindahl (2008) give an example of how to design for easy access in automatic remanufacturing known as the "unit design" used by the designer of single-use cameras. To adapt cameras for the automated remanufacturing process, the company has built in access points into their design to facilitate robotic disassembly of the cameras. These points are not to be changed in between new versions and different models of single-use cameras in order to suit the remanufacturing process.

In addition, Lee & Sundin (2011) identify technology development trend in product development that are in conflict with disassembly automation. Three general product trends that conflict with automatic disassembly: 1) Products are becoming more complex and more heterogeneous; 2) Products are becoming sleeker; 3) Products are using more proprietary joints. Modular, upgrade and platform design approaches can support design solutions for remanufacturing. For example, during new product development, planning should focus on a generic family set of products with the same base technology; then the variations can be designed with more compatibility between models to accommodate upgrades or changes later on. Kerr & Ryan (2001) highlight the benefits of modulation and modular design to facilitate inclusion of technology development in remanufacturing. See section 6.6.1.

Sundin et al (2012) have, through three industrial use cases, explored how these three trends are in conflict with automatic disassembly. Although many manufacturers have adopted design principles such as DfM and DfE, there is still much to improve when it comes to designing for the product's end-of-life processes (ibid). These kinds of adaptations should increase in importance over time, as more and more products and components are remanufactured and/or material recycled (ibid).

In summary then, product design can address the issue of technological obsolescence in remanufactured goods by both:

- Designing in upgradeability through planning for modularity, platform design approaches and part replacement
- Design strategy to facilitate effective market uptake and market positioning through understanding of competing products and customer preferences

6.5 Challenges for Design for Remanufacturing

In order to build a picture of DfRem in industry, it is necessary to understand the broader context of challenges and motivations that stimulate DfRem and the challenges that limit its success. This section summarises the broad set of motivations and challenges companies approaching DfRem face contributing to the overarching WP3 objective to map the drivers for remanufacturing in industry.

Table 6. Summary of Challenges identified in the Cases

	Cases											
Topic	A	B	C	D	E	F	G	H	I	J	K	L
Quality recognition/assurance/certification; user perception	■			■		■			■			
Better standards for DfRem at national and EU level	■											
Foster collaborations between OEMs and independent remanufacturers who have remanufacturing know-how	■											
Dealing with blocking patents and lack of access to design files, Bill of Materials data		■										
Waste transportation limitations (trade-barriers)		■							■			
Anticipating future waste legislation/future compliance issues		■			■	■	■					■
No access to critical product life cycle data (e.g optimal point for remanufacturing / design files)			■									■
Upscaling/automation (amount, diversity, complexity of multi-line products)												■
Balance with technological innovation					■	■	■				■	■
Access to new original parts						■						
Material scarcity									■			
Return of products										■		
Mismatch demanded and offered product										■		
Short delivery times											■	■
Negative perceptions of remanufactured products				■								
Regulatory barriers to the sale of remanufactured goods (moving goods between members states and outside of EU)					■							
Lack broader skillset to bring reman goods to market (such as logistics management, sales and promotion for reman goods)	■											
Utilisation of a high variety of materials and less durable materials											■	■
Lack of within and between company information feedback loops to inform new product development	■											

6.6 Economic, Environmental and Social Benefits of Design for Remanufacturing

The cases described demonstrate a broad set of economic, environmental and social benefits of remanufacturing. In this section we provide a summary of these benefits and in particular benefits from DfRem.

6.6.1 Economic benefits

In general, the economic benefits of DfRem include direct cost savings, which vary from anything between 20%-60% on production costs due to material and energy savings (depending on the type of remanufacturing). This in turn translates to customer benefits (savings from up to 40% on products eg in the case of Faral).

Kerr & Ryan (2001) report on the economic benefits of DfRem. A photocopier OEM shifted away from machine remanufacturing because rapid technological change is reducing the expected life of photocopiers, and hence the economic viability of remanufacturing entire photocopiers. Instead the company facilitate a shift towards parts remanufacturing, and developed modular photocopiers. A popular model has seven modules that contain the majority of moving parts in the photocopier. Each module can be removed and replaced in minutes, making disassembly and remanufacturing faster and easier. Modular copiers also offer greater potential for the continual upgrading of technology and the sharing of components between product lines. A broader set of indirect benefits of DfRem have also been described in the cases and these are described in Table 7.

Table 7. Summary of Economic Benefits identified in the Cases

	Cases											
Topic	A	B	C	D	E	F	G	H	I	J	K	L
Lower production costs (up to 50% cheaper to remanufacture)	■	■				■	■		■	■	■	■
Cost savings for consumers	■	■				■		■	■			
Increased revenue			■									■
Diversifying product portfolios					■							
New market opportunities / revenue					■				■	■		
Satisfying consumers / extends service life of old machines					■						■	
Reduce risk to resource price volatility							■					■
Mitigate future compliance issues / landfill costs												■

6.6.2 *Environmental benefits*

Remanufacturing in general is perceived to be beneficial for the environment. Kerr & Ryan (2001) quantified the life cycle environmental benefits achieved by incorporating design for remanufacturing into photocopiers. They found that remanufacturing can reduce resource consumption and waste generation over the life cycle of a photocopier by up to a factor of 3, with greatest reductions if a product is designed for disassembly and remanufacturing. The savings were quantified using five measurement units; Materials consumption (kg), Energy consumption (MJ) , Water consumption (L),Landfilled waste (kg) and CO2 equivalents (kg). The results also show that products designed for disassembly and remanufacturing can deliver much greater savings than can be achieved through the remanufacturing of a product that was not designed with this intention.

Many independent remanufacturers lack the capacity to undertake such work and therefore are limited in the beneficial claims they can make to their customers. Nevertheless, the companies surveyed communicate a broad set of environmental benefits many of which are supported by LCA studies. These are mapped in Table 8.

Table 8. Summary of Environmental Benefits identified in the Cases

	Cases											
Topic	A	B	C	D	E	F	G	H	I	J	K	L
Waste reduction (diversion from landfill)	X			X		X				X	X	X
Environmental (CO2, energy and others) impact of remanufacturing in comparison with new is up to 80% lower in some cases)		X	X		X	X	X				X	X
Increased material efficiency / Reduced material input requirements (antimony, copper, engineering plastics, commodity metals)			X	X	X	X			X		X	
Cleaner material streams for recycling			X			X						
Reduced energy consumption in-use						X						
Reduced reliance on precious / finite materials												X
Simpler designs foster better recyclability by using a smaller subset of materials'			X									X
Reduced consumables (shipping consumables in the case of Cartridges -- Kyocera)			X									

However, research has shown that remanufacturing is not unambiguously beneficial for the environment (Gutowski et al. 2011). For example, in the case of energy-using products, technological innovation in the form of energy efficiency improvements, typically found in newly produced goods, may outweigh the benefits of remanufacturing devices already on the market (Gutowski, 2011). This in turn demonstrates the importance of adopting design upgrade strategies (eg upgradable firmware) which can overcome these issues.

6.6.3 Social benefits

Finally the benefits of remanufacturing from a social perspective are discussed. Remanufacturing is a labour intensive activity and therefore can contribute to building a skilled workforce, fostering local skilled and semi-skilled jobs. Many of the organisations profiled here require highly technical workforces. So doing, remanufacturing offers the potential to provide opportunities for reskilling, training and recruiting (eg Made in Mayenne). Additional social benefits include the potential to provide high quality lower cost goods to local markets to generate local revenue, as well as retaining local manufacturing skills. Finally, some of the cases describe partnerships with local social enterprises, which can support reintegration programmes (for example).

The research by Sundin et al (2012) highlights the concept of product life cycle thinking and introduces new ways of thinking to cooperate in the value chain. Products should be designed for the automation of certain EoL processes, that can bring an increase in the value of the recovered materials or components and a reduction in the total amount of waste going to the landfill or incinerators. *"From a societal perspective, an increase in remanufactured products being placed on the market can increase the awareness and confidence of the consumers in non-new products made from non-virgin materials. This will increase the market for second-life products and bring about economics of scale, which in turn will alleviate the problem of depletion of resources".*

Table 9. Summary of Social Benefits identified in the Cases

	Cases											
Topic	A	B	C	D	E	F	G	H	I	J	K	L
Develops technically skilled and semi-skilled workforce	■	■				■		■				■
Upskilling and training local workforces			■	■								
Local job-creation					■		■					■
Contributes to cohesive local workforce				■		■		■				
Positive company culture through pro-environmental business activities				■			■					
Market access to high quality goods at good price				■			■		■			■
Corporate social responsibility										■		
Increased population health through localisation of production and/or cleaner production												■

7 Conclusions

This report set out to map the remanufacturing product design landscape, through a literature review in combination with a series of DfRem cases. In this body of work, we approach this by defining the distinctive thematic threads and activities, within the sphere of product DfRem. In particular this includes insights on successful product design practice, a summary of the economic, social environmental benefits of remanufacturing and the challenges and opportunities within DfRem at present. This is supported by a summary list of design guidelines, as well as uncovering key thematic areas within current DfRem activity. The ERN description of work furthermore asks to explore advanced materials and technological innovation with respect to product DfRem and this is discussed in Section 6.

In particular the work illustrates a broad lack of activity within DfRem despite widespread calls for more activity within design to support remanufacturers. This can in part be due to limited perspective on what design can bring to remanufacturing (overly focused on engineering design) with limited creative explorations of how to apply design to develop goods which can then be remanufactured. Moreover, the role of design strategy in successfully bringing remanufactured goods to market is largely overlooked.

While there are potentially a number of reasons for this, in particular the value of design to innovation is often overlooked in general, particularly in engineering-led products. In addition, the remanufacturing sector is largely represented by independent remanufacturers who have no control over product design. In other cases remanufacturing is a peripheral business activity and because of this its potential may not be fully explored or innovation in remanufacturing is not invested in. This highlights the interdependency between the business model and the design of the products which remanufacturing companies bring to market. This lack of investment in design, limits the potential for remanufacturing in the long-term.

Perhaps more significant however is that there appears to be very little promotion or inclusion of the topic of remanufacturing in design higher education. While some activity exists, it is the experience of the ERN network of experts that this is largely unsystematic. This is very likely to contribute to the narrow role design plays within remanufacturing activities today and must be addressed if we are to see creative and inspiring examples of remanufacturing to foster its broader uptake in the long-term.

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Annexe A Interview Questions

Name(s):

Organization:

Other contacts to speak to:

A – <u>Background Information:</u>

1- Key remanufactured products:

2- Stage of remanufacturing in the company:

- ☐ Piloting
- ☐ Experienced
- ☐ Mature

B – <u>For Independent OEMs:</u>

3- Do you collaborate with Original Equipment Manufacturers?

- ☐ Yes
- ☐ No

If yes, how?

C – <u>Barriers and Motivations</u>

4- Key motivations for remanufacturing:

5- Key barriers for remanufacturing:

D – <u>Questions related to the design of the products you remanufacture:</u>

6- Are the products you remanufacture initially designed for remanufacturing?

- ☐ Yes
- ☐ No
- ☐ Don't know

If Yes, do you know what criteria relating to DfRem were defined in the design brief / product design specification:

7- Could you provide an example of a product you remanufacture that is, according to your activity, successfully designed for remanufacturing? Could you explain why and provide visuals support to illustrate?

8- Could you provide an example of a product you remanufacture that is not successfully designed for remanufacturing activities? Could you explain why and provide visuals support to illustrate?

9- According to you and your activity, which design strategies (e.g. reliability, disassembly) are important for remanufacturing?

10- Do you think material selection should be an important aspect to consider during the design of the product you remanufacture? Why and How?

11- Is material scarcity a motivation for your remanufacturing business? Yes/No
   a. If yes, why?

12- Did you undertake any environmental assessments to calculate the potential environmental benefits of your remanufacturing activities? If yes, could you provide us documentation on this study?

13- What are the economic benefits of remanufacturing to your company?

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