European Commission

A report by the partners of:

Remanufacturing Market Study

For Horizon 2020, grant agreement No 645984, November 2015

Remanufacturing Market Study

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645984

Written by: David Parker, Kate Riley, Seigo Robinson, Harry Symington, Jane Tewson (Oakdene Hollins), Kim Jansson (VTT), Shyaam Ramkumar (Circle Economy), David Peck (TU Delft)

Final check by: Katie Deegan (Oakdene Hollins)

Approved by: David Parker (Oakdene Hollins)

Date: October 2015

Reference: EC--09 404 ERN WP2.2.docx

Contact: david.parker@oakdenehollins.co.uk

Contents

Acknowledgements

The partners would like to thank all those who took part in the survey, including participants from:

Abbey Diesel Services Ltd	Ferročrtalič d.o.o.	PRINTek Kft
ACE Re-use Technology BV	Ford Motor Company	Printerland Ltd
Advanced Compressor Engineering Services Ltd	France Cartouche Réemploi	PSS – Steering & Hydraulics Division
AELS	German Imaging Technologies (GIT) Dubai LLC	RD Trading Ltd, trading as RDC
AES Supplies Ireland Ltd	Greenclick	Recoturbo
Agco Power Inc	Harlander.com GmbH & Co KG	Recro SIA
Air France Industries / KLM Engineering & Maintenance	HELLA KGaA Hueck & Co	REFILLCENTER
Alexander Fink HOLEX	Hindle Reman	Rematec
Allstart Ireland	Hitachi Construction Machinery (Europe) NV	RENAULT Choisy-le-Roi
APD Interntional Ltd	HS2 Ltd	RET Reifenerneuerungstechnik GmbH
APRA Europe	Hubbard Hall Inc	Ricoh Nederland BV
Armour SAS – activité Armor Office Printing	I.T Enviro Logic Ltd	Robert Bosch GmbH
ARP Supplies BV	iDoc 1. Hilfe für Mobiltelefone GmbH	Robotif GmbH
Association FME-CWM	Imk automotive GmbH Chemnitz	Rösler Tyre Innovators
ASYSUM S.A.	Intra Business Solutions	Rotor Deconstruction
Atelier 4/5	Inventons Demain	Royo Group
ATP Industries Group Ltd	J&G Renzelmann GmbH	Scandinavian Transmission Service AB
Auto Recycling Nederland	Kentro Melaniou Kastoria	Schmitz + Krieger GmbH
Autocraft Drivetrain Solutions Ltd	Kleen Strike (UK) Ltd	SCM Turbomotive Ltd
Autoelectro	Knorr-Bremse CVS	SDA Im-export BV
Autohaus Baum	Kopierer-Welt GmbH	SEW Eurodrive B.V.
Aviation Cabin Consulting GmbH	Krückels Krankenhausinventar	Siemens Healthcare GmbH – Refurbished Systems
Bond Retail Services Ltd	Lexmark	SKF
B-Tec GmbH & Co KG	Lexmark International	Smartmod GmbH
Büroservice Hübner	Lizarte SA	South East Core Supply
Canon Europe Ltd	LPR Prantzios Konstantinos	Stone Computers Ltd
Carwood Motor Units Ltd	Martela Oyj	Sudden Impact
Clearance Solutions Ltd	Mela GmbH	Tender
CMB France	Melanaki	Tier1Asset A/S
Cottam & Brookes Eng Ltd	Meritor Aftermarket	UBD Cleantech AB
DLL International B.V.	Neopost Industrie	Vector Aerospace
E&U Hetzel GmbH	P. Kotsaridis &SIA EE	Wood Auto Supplies Ltd
ERIKS Industrial Services	Partsupply	Woodcock & Wilson Ltd
Euro-Teli OyP	PartTracker Industrial B.V.	Xander Diesel
Eurotexso Distribution	Philips Healthcare	Zeronet Group Ltd
FARAL	Pôle Eco-conception	ZF Friedrichshafen AG
Federation of Engine Remanufacturers	Pressen HAAS GmbH	

Particular thanks are also due to:

Gregor Schlingschroeder	Automotive Parts Remanufacturers Association (APRA)
Peter Bartel	Automotive Parts Remanufacturers Association (APRA)
Ross Bartley	Bureau of International Recycling (BIR)
Tobias Bahr	European Automobile Manufacturers' Association (ACEA)
Vincent van Dijk	European Toner & Inkjet Remanufacturers Association (ETIRA)
Jean-Pierre Taverne	European Tyres and Rubber Manufacturers' Association (ETRMA)
Niels Klarenbeek	ReMaTec, RAI Amsterdam
Greg Lavery	Rype Office
Jörg Meding	Wolk Aftersales Experts GmbH

Glossary

ACEA	European Automobile Manufacturers' Association
ADS	Aerospace, Defence, Security and Space trade association (UK)
APRA	Automotive Parts Remanufacturers Association
B2B	business-to-business
B2C	business-to-consumer (market)
CAGR	compound annual growth rate
CLEPA	European Association of Automotive Suppliers
CMM	Component Maintenance Manual
CRM	'critical' raw material
CT	computed tomography (scan)
EASA	European Air Safety Authority
ECU	electronic control unit
EEA	European Economic Area
EEE	electrical and electronic equipment
EIP-RM	European Innovation Partnership on Raw Materials
ERN	European Remanufacturing Network
ETIRA	European Toner and Inkjet Remanufacturers Association
ETRMA	European Tyre and Rubber Manufacturers' Association
FIRM	International Federation of Engine Remanufacturers and Rebuilders
HCV	heavy commercial vehicle
GRP	Good Refurbishment Process
HDOR	heavy-duty and off-road equipment
HVAC	heating, ventilation and air conditioning
ICT	information and communication technology
LCV	light commercial vehicle
MRI	magnetic resonance imaging
MRO	maintenance, repair and overhaul (company/business)
OEM	original equipment manufacturer
PERT	program evaluation review technique
PM	parts manufacturer
ROSCO	rolling stock operating company
TOC	train operating company
UNEP	United Nations Environment Programme
USITC	United States' International Trade Commission
VM	vehicle manufacturer
WEEE	waste electrical and electronic equipment
WP	work package

Units

Conventional SI units and prefixes used throughout: {k, kilo, 1,000} {M, mega, 1,000,000} {G, giga, 10^9} {kg, kilogramme, unit mass} {t, metric tonne, 1,000 kg}

Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Author	Editor
1	20/10/15	ERN WP2.2 Market Study –Final Report	SR	KD

1 Executive summary

According to BS8887-Part 2, remanufacturing is an industrial practice of:

> ***"Returning a product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product."***

It is an important component of a resource-efficient manufacturing industry and a key strategy within the circular economy: by keeping components and their embodied material (including 'critical' or 'advanced' materials) in use for longer, significant energy use and emissions to air and water (e.g. CO_2 and SO_2) can be avoided. In addition to its environmental benefits, remanufacturing provides opportunities for the creation of highly skilled jobs and economic growth.

Despite these positives, remanufacturing is an undervalued part of the industrial landscape and an under-recognised, sustainable industry. Activity to promote remanufacturing is currently undertaken on a sector-by-sector basis. In Europe, cross-sectoral activities to facilitate knowledge transfer and promote the industry do not exist in remanufacturing - unlike in the recycling industry. Our major competitors, the USA and China, already have some common vision and strategy for remanufacturing while European remanufacturing could lose competitiveness against these more organised economies. As a result, there is a real need for a European-level solution to encourage remanufacturing throughout Europe.

Accordingly, the ERN project, sponsored under Horizon 2020, has looked to start to address these barriers. This report describes the findings of the first component of the work, namely to estimate the current level of remanufacturing activity within the EU. Using a mixture of methods[1], data has been gathered on remanufacturing across nine key sectors to reveal economic value, numbers employed and approximate carbon benefits. This resource can be used to support further actions at both European and Member State level. The sectors of focus are aerospace, automotive, heavy duty and off-road (HDOR) equipment, electronic and electrical equipment (EEE), machinery and medical equipment, and on smaller sectors such as (office) furniture, rail (rolling stock) and marine.

The table below provides a summary of the findings by sector across the EU.

Sectors	Turnover (€bn)	Firms	Employm't ('000)	Core[2] ('000)	Intensity
Aerospace	12.4	1,000	71	5,160	11.5%
Automotive	7.4	2,363	43	27,286	1.1%
EEE	3.1	2,502	28	87,925	1.1%
Furniture	0.3	147	4	2,173	0.4%
HDOR	4.1	581	31	7,390	2.9%
Machinery	1.0	513	6	1,010	0.7%
Marine	0.1	7	1	83	0.3%
Medical equipment	1.0	60	7	1,005	2.8%
Rail	0.3	30	3	374	1.1%
Total	**29.8**	**7,204**	**192**	**132,405**	**1.9%**

[1] On-line survey, direct phoning, use of meta-studies and top-down analysis

[2] Core: a used part intended to become a remanufactured product

In summary, the activity generates around €30bn in turnover and employs around 190,000 people. These are substantial numbers but represent an intensity (ratio of remanufacturing to new manufacturing) of only 1.9%. Both intensity and overall value lag the US experience. It is, therefore, apparent that there is substantial headroom for growth, given the right interventions and framework conditions.

The four key regions, estimated to account for some 70 % of remanufacturing value in Europe, are Germany, the UK & Ireland, France and Italy. A fuller overview is provided in the table below. It shows that Germany undertakes most remanufacturing by a significant margin, making up almost a third of European remanufacturing turnover. It has a strong position in aerospace, automotive and HDOR sectors. This position mirrors Germany's status as a manufacturing powerhouse, particularly as it has strong automotive and HDOR capabilities. Remanufacturing in France and in the UK & Ireland, similar in size to each other, is estimated to be around half that in Germany. Italy's remanufacturing industry is slightly smaller than expected considering the size of its manufacturing industry. This is partly due to the distribution of the aerospace sector across Europe: Germany, France and the UK are major global aerospace maintenance, repair and overhaul hubs. There is also reportedly slightly less remanufacturing in Italy's automotive sector potentially due to cultural preferences.

Turnover	Benelux[1]	Central[2]	Eastern[3]	France	Germany	Italy	Medi-terranean[4]	Nordic[5]	UK & Ireland	Total
Aerospace	389	399	513	2,311	3,814	1,127	816	368	2,698	**12,436**
Automotive	395	652	692	754	2,370	699	790	273	766	**7,393**
EEE	111	230	578	355	646	592	311	106	190	**3,118**
Furniture	10	16	52	24	66	66	23	18	34	**310**
HDOR	160	227	343	633	1,108	541	380	242	509	**4,142**
Machinery	44	45	81	108	336	199	70	53	90	**1,026**
Marine	11	2	15	3	11	8	13	5	6	**76**
Medical equipment	36	70	104	112	316	61	68	83	121	**971**
Rail	11	46	41	22	61	39	48	27	49	**343**
Total	**1,167**	**1,687**	**2,420**	**4,322**	**8,728**	**3,333**	**2,519**	**1,173**	**4,463**	**29,813**

Notes: [1] *Benelux: Belgium, Luxembourg, Netherlands*
[2] *Central (excluding Germany): Austria, Czech Republic, Slovenia*
[3] *Eastern: Bulgaria, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovakia*
[4] *Mediterranean (excluding Italy): Croatia, Cyprus, Greece, Malta, Portugal, Spain*
[5] *Nordic: Denmark, Finland, Sweden*

The survey element of this work has also considered motives and barriers for remanufacturing. Amongst the top motives for remanufacturers are **higher profit margins**, **environmental responsibility**, **strategic advantage** and **increasing market share**. These all point to an encouraging view of the future of the remanufacturing industry from those within the business. Further motives cited through the survey and discussions include securing spare parts supply, potential to lower product prices, enabling alternative business models, reduced resource security risk, customer pressure, product warranties, asset and brand protection, and reduced lead times.

Top barriers include **customer recognition**, **volume/availability of 'core'** (a used part intended to become a remanufactured product), **quality of core** and **high labour costs**. Other barriers included legal ambiguity over remanufacturing in different jurisdictions particularly around trans-national shipments, lack of sales channels (linked to customer recognition), lack of product knowledge including third party product technical information, lack of technology, low cost new product competition, skills shortages, poor design for remanufacturing, rapid evolution of technology base and lack of remediation techniques.

Despite these barriers, with supportive policies and industry investment, 'stretch' and 'transformational' targets for remanufacturing can be envisaged. Within these scenarios, we can expect that by 2030 EU remanufacturing could attain an annual value of ¬€70bn and ¬€100bn with the associated employment of ~450,000 and almost 600,000 respectively.

2 Introduction

2.1 Remanufacturing and the Grand Societal Challenges

The manufacturing sector is the largest employer and the greatest contributor to GDP in industrialized nations (in EU-27, 34 million people contributing about 14.5 % of total GDP[3]) and so can be considered an important driver of wellbeing and prosperity. It is also a major consumer of material and energy as well as a significant source of waste (about 14 % of the 2,652 million tonnes of waste generated in EU-27 countries in 2008[4]).

The issue of resource constraint has never been as critical as it is today due to rapidly increasing consumption of energy and material resources in industrialized and developing countries. Today's most significant challenge is to develop closed loop manufacturing systems which not only ensure economic and environmental sustainability but also satisfy consumers' needs and create high-skill jobs in current and future societies.

The EC working paper *Roadmap to a Resource Efficient Europe*[5] published in 2011 outlines resource conservation and resource management in the product lifecycle as key approaches to deal with this problem. More recently, the *Manifesto for a Resource Efficient Europe*[6] published in December 2012, states:

> *"…in a world with growing pressures on resources and the environment, the EU has no choice but to go for the transition to a resource-efficient and ultimately regenerative circular economy as our future jobs and competitiveness, as a major importer of resources, are dependent on our ability to get more added value, and achieve overall decoupling, through a systemic change in the use and recovery of resources in the economy."*

The European Innovation Partnership on Raw Materials (EIP-RM) has the aim of contributing to the 2020 objectives of the EU's Industrial Policy[7] and the objectives of the flagship initiatives *Innovation Union*[8] and *Resource Efficient Europe* by ensuring the sustainable supply of raw materials to the European economy whilst increasing benefits for society as a whole. One proven way to achieve this aim is by expanding the remanufacturing sector.

The EIP-RM supports this by proposing to achieve the objective by reducing import dependency and promoting production and exports by improving supply conditions from the EU, diversifying raw materials sourcing and improving resource efficiency.

Importantly, recent years have seen an increase in the diversity of materials used in EU manufacturing. Securing reliable and undistorted access to certain raw materials is of growing concern within the EU. At the heart of this concern are the raw materials which are 'critical' for the EU's economy. These critical raw materials have a high economic importance to the EU combined with a high risk associated with their supply.

---

[3] *Europe in figures* - Eurostat yearbook, 2010. ISBN 978-92-79-14884-2, European Union 2010

[4] Eurostat pocketbooks - *Energy, transport and environment indicators*, 2010 edition; ISBN 978-92-79-16303-6, European Union 2011

[5] *Roadmap to a Resource Efficient Europe*, Sept 2011. Accessed at: http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf

[6] *Manifesto for a Resource Efficient Europe*, Dec 2012. Accessed at: http://europa.eu/rapid/press-release_MEMO-12-989_en.htm

[7] http://ec.europa.eu/enterprise/policies/industrial-competitiveness/industrial-policy/index_en.htm

[8] http://ec.europa.eu/research/innovation-union/index_en.cfm

Remanufacturing is an important component of a resource-efficient manufacturing industry. By keeping components and their embodied material (including 'critical' or 'advanced' materials) in use for longer, significant energy use and emissions to air and water (e.g. CO_2 and SO_2) can be avoided. In addition to its environmental benefits, remanufacturing provides opportunities for the creation of highly skilled jobs and economic growth.

Despite these positives, remanufacturing is an undervalued part of the industrial landscape and an under-recognised, sustainable industry. Activity to promote remanufacturing is currently undertaken on a sector-by-sector basis. In Europe, cross-sectoral activities to facilitate knowledge transfer and promote the industry do not exist in remanufacturing - unlike in the recycling industry. Our major competitors, the USA and China, already have a common vision and strategy for remanufacturing within their industrial landscapes European remanufacturing could lose competitiveness against these more organised economies. As a result, there is a real need for a European-level solution to encourage remanufacturing throughout Europe.

2.1.1 The industrial challenges within remanufacturing

In the project partners' long experience within remanufacturing research we have found many different driving forces[9] and challenges[10] faced by remanufacturing companies. These are hurdles that manufacturers need to overcome to start remanufacturing or to keep remanufacturing profitably. These challenges relate to the three areas we have chosen to study within this network:

- **business models**[11] - without a viable business case, remanufacturing would not take place;
- **product design**[12] - product design plays a significant role in determining the ease with which a product can be remanufactured; and
- **remanufacturing process technologies**[13] – process technologies can be developed to increase the efficiency of remanufacturing operations. However, the experience gained needs to be collected systematically and disseminated effectively to European industry.

Underpinning these efforts is the need for a robust understanding of the remanufacturing industry, its key sectors and the value it provides from economic, social and environmental perspectives. This report is the first to present a comprehensive review of this European remanufacturing landscape.

2.2 Remanufacturing defined

Given the complexities associated with surveying across Member States, it is particularly important that the term 'remanufacturing' is well defined in language that is portable across Member States. Even with a definition in place, it is equally important to recognise that terminology and practice varies across different sectors. An inflexible definition could

---

[9] See e.g. Östlin J., Sundin E. and Björkman M. (2008) *Business Drivers for Remanufacturing*, in the Proceedings of 15th CIRP International Conference on Life Cycle Engineering, ISBN: 1877040673, The University of New South Wales, Sydney, Australia, 17-19 March, pp 581-586

[10] See e.g. Lundmark P., Sundin E. and Björkman M. (2009) *Industrial Challenges within the Remanufacturing System*, Proceedings of Swedish Production Symposium, ISBN: 978-91-633-6006-0, Dec 2-3, Göteborg, Sweden, pp 132-138

[11] See e.g. Sundin E. and Bras B. (2005) *Making Functional Sales Environmentally and Economically Beneficial through Product Remanufacturing*. Journal of Cleaner Production, Vol.13, Issue 9, pp 913-925

[12] See e.g. Hatcher, G.D., Ijomah, W.L., Windmill, J.F.C. (2011) *Design for remanufacture: a literature review and future research needs*, Journal of Cleaner Production, 19, pp.2004-2014.

[13] See e.g. Seifert S., Butzer S., Westermann H-H., Steinhilper R.: *Managing Complexity in Remanufacturing*, Lecture Notes in Engineering and Computer Science: Proceedings of The World Congress on Engineering 2013. WCE 2013, 3-5 July 2013, S.: 647-652, London, UK

alienate potential network members by virtue of linguistic understanding or because it excludes activities which embrace the principles if not exact practices of remanufacturing.

2.2.1 Essential attributes of remanufacturing

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. The performance after remanufacture is expected to be at least the same as the original performance specification ('like new') or better, and the remanufactured product generally comes with a warranty.

Numerous definitions have been offered, many of which include common features. An extensive review is not provided here but may be found in *An Analysis of the Spectrum of Re-use.*[14] The only definition which has recognition as a national standard is that provided by the British Standards Institution's BS 8887-2:2009 Terms and Definitions, as part of the 'MADE' series of standards (Design for Manufacture, Assembly, Disassembly and End-of-life processing[15]). This definition drew upon practitioner experience, and two of the partners in the European Remanufacturing Network (the Centre for Remanufacturing & Reuse and the University of Strathclyde) participated in drafting, consulting on and editing the Standard.

The BS 8887-2 definition states that remanufacturing is the process of:

> ***"Returning a product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product."***

Notes accompany this text, drawing in features of other definitions, including that:

- Manufacturing effort involves dismantling the product, restoring and replacing components and testing individual parts and whole product to ensure it fits within the original design specifications.
- Performance after remanufacture is expected to be at least that of the original performance specification.
- Subsequent warranty is generally at least equal to that of the new product.
- The remanufactured product can be considered the same as a new product by the customer.

However, in essence, BS 8887-2 is an outcome-oriented standard in that it focuses on the product produced, customer expectations and guarantees of performance or longevity. Such a standard sits well with original equipment remanufacturers since the liabilities reflect directly on their brand, and there is an implicit assumption that the processes supporting both original manufacture and remanufacture are informed by the same engineering knowledge. It is consistent with the approach advocated by Lund in his report *The Database of Remanufacturers*[16] when explaining the use of the term 'like-new':

> *"From the viewpoint of the producer, this represents the remanufacturer's intent, its claim for the product, and its ability to live up to that claim. Starting with cores that are likely to have a variety of defects, the remanufacturer must produce a flow of products that uniformly meet the like-new standard. From the customer's*

[14] http://www.remanufacturing.org.uk/pdf/story/1p297.pdf

[15] http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030182997

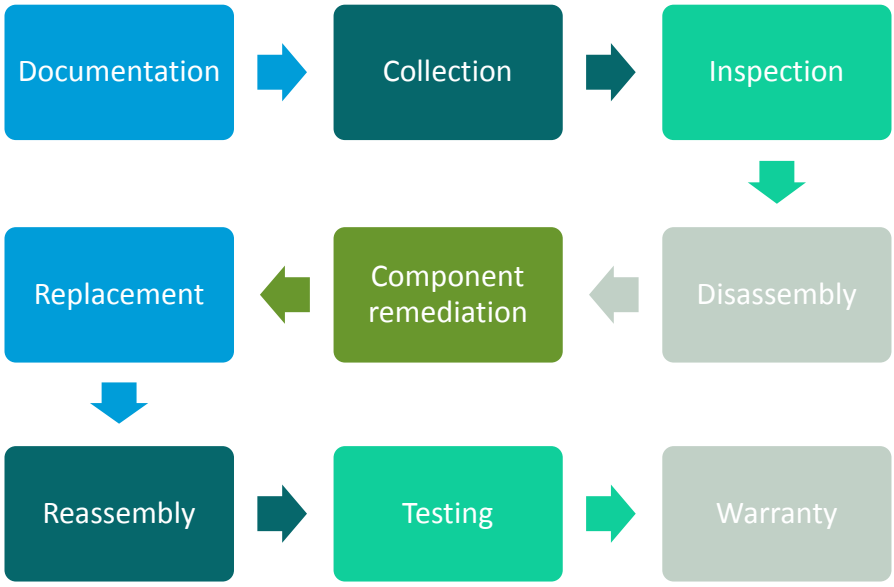
[16] Lund, R.T. (2012) *The Database of remanufacturers*, http://www.bu.edu/reman/The Remanufacturing Database.pdf

viewpoint, the like-new term represents the customer's expectation for the product sold as remanufactured."

However, an alternative process-oriented standard has other benefits. Specifying process steps to remanufacture at least lays the basis for a common approach by remanufacturers which – other factors being equal – might lead to a similar production output. This is particularly relevant for independent agents who do not necessarily have access to original designs, and hence need processes to substantiate their engineering credibility - as is the case with other quality-oriented standards.

Therefore, for the purposes of this work, we have also described a typical set of informational, logistical and manufacturing processes which together might constitute an idealised remanufacturing process, as depicted in Figure 1. As a side benefit this description creates a useful model when asking companies whether they are indeed remanufacturers, as some firms are can be unaware that they carry out remanufacturing.

Figure 1: A generic remanufacturing process



ACEA, APRA Europe, CLEPA and FIRM[17] use a common definition of a remanufactured part which captures very similar concepts to those discussed above:

> *"A remanufactured part fulfils a function which is at least equivalent compared to the original part. It is restored from an existing part (core), using standardized industrial processes in line with specific technical specifications. A remanufactured part is given the same warranty as a new part and it clearly identifies the part as a remanufactured part and states the remanufacturer."*

While this reflects the view of the automotive industry and there may be sector-specific nuances, the definition is mostly general enough to have wider applicability in other product sectors. A useful flyer with further details is provided on APRA Europe's website.[18]

While these definitions presented are well aligned, lack of a globally accepted definition for remanufacturing can hamper the uptake of remanufacturing. The lack of definition can create barriers to international trade, as products and core (a used part intended to become a remanufactured product) are sometimes considered as waste, rather than potentially high value inputs into a (re-)manufacturing process. Consumer perception of remanufactured products could also be affected by this lack of definition.

2.2.2 Terms and practices related to remanufacturing

It has already been acknowledged that both terminology and practice in this area may differ slightly according to product or sector; this is not surprising. Remanufacturing originates in the domain of valuable, typically large, engineered, complex, durable goods and we are attempting to map the practice into very different product and manufacturing domains. What is practical and cost-effective to achieve depends on the balance of design features, inherent value, product dispersion, product emotional attachment, technological evolution and trade-off of material and labour costs. This is particularly true for consumer goods.

The study must therefore be sensitive to these differences and must not unnecessarily exclude activities which have a clear intent to extend product life whilst offering a similarly extended performance expectation and guarantee to the user.

Briefly, and for comparative purposes, we offer descriptions of terms related to remanufacturing and which form common practice in life extension activities (Table 1). These terms can be considered as specific loops within the circular economy (see Section 2.2.5 for further details).

[17] The European Automobile Manufacturers' Association, the European Automotive Parts Remanufacturers Association, the European Association of Automotive Suppliers, and the International Federation of Engine Remanufacturers and Rebuilders

[18] http://www.apra-europe.org/dateien/News/News2014/Reman_Flyer_Web.pdf

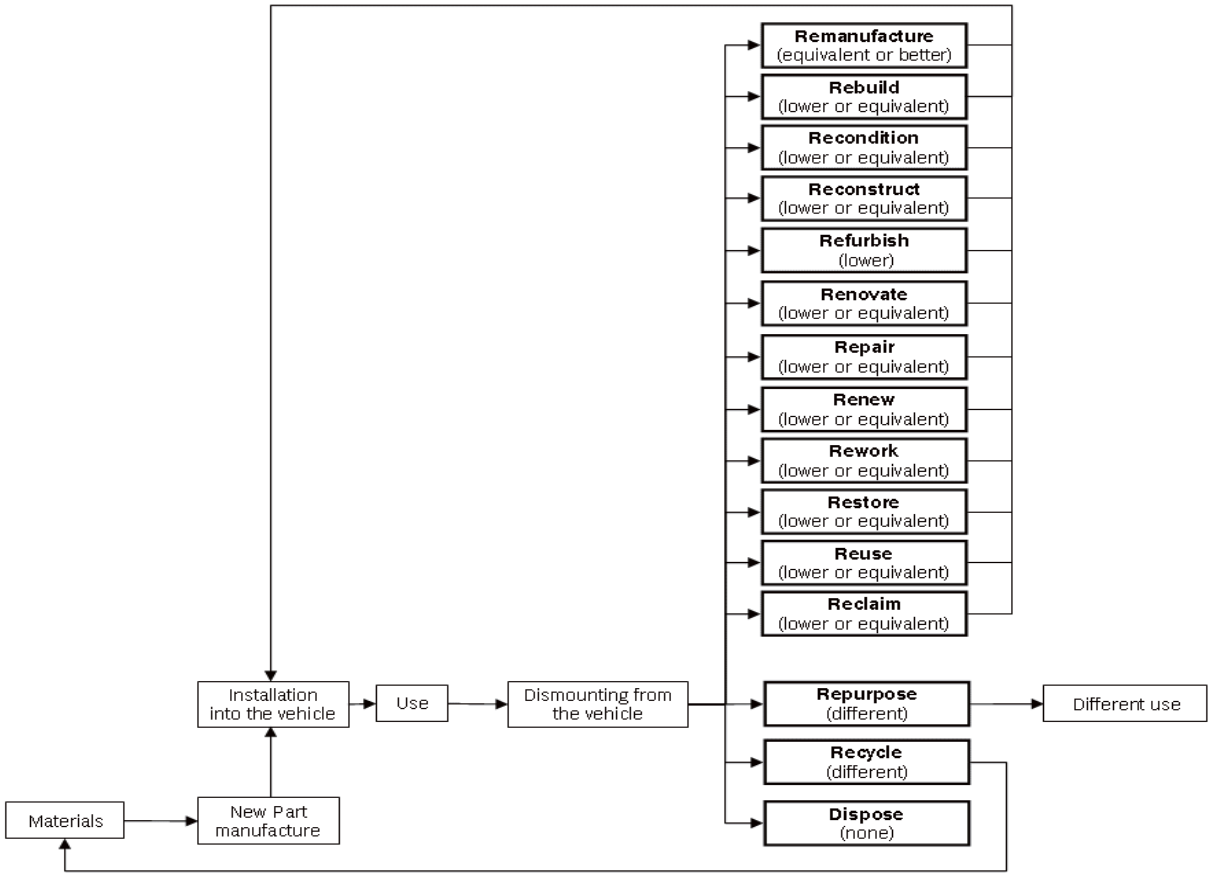
Table 1: Terms related to remanufacturing

Term	Definition	Reference
Recondition	The potential adjustment to components bringing an item back to working order, though not necessarily to an 'as new' state.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
	Return a used product to a satisfactory working condition by rebuilding or repairing major components that are close to failure, even where there are no reported or apparent faults in those components.	BS 8887-2: 2009
	Notes • Generally less expensive than remanufacture but more than necessary for repair. • Performance after reconditioning is expected to perform its intended role but overall is likely to be inferior to that of the original model. • Subsequent warranty is generally less than new or a remanufactured product.	
Refurbish	The largely aesthetic improvement of a product which may involve making it look like new, with limited improvements to functionality.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
Repair	Fixing a fault but with no guarantee on the product as a whole.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
	Returning a faulty or broken product or component back to a useable state.	BS 8887-2: 2009
	Fixing what is broken or worn.	Lund, n.d. *The Database of Remanufacturers* http://www.bu.edu/reman/The Remanufacturing Database.pdf
	Notes • Repair may use remanufactured or reconditioned parts. • Minimum manufacturing effort required to address the specified fault. • Subsequent warranty is generally less than that of newly manufactured, reconditioned or remanufactured and may only apply to the replaced component.	
Re-use	The simple reuse of a product with no modifications.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
	Operation by which a product or its components are put back into use for the same purpose at end of life.	BS 8887-2: 2009
Recycle	Extracting a product's raw materials to use in new products. This is a good option for products which are easily constructed and have minimal numbers of components.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
	Shredding or disassembling products to recover materials value.	Lund, n.d. *The Database of Remanufacturers* http://www.bu.edu/reman/The Remanufacturing Database.pdf
	Process waste materials for the original purpose or for other purposes, excluding energy recovery.	BS 8887-2: 2009

2.2.3 Sectoral and international remanufacturing practices

We need to be sensitive to the fact that use of these terms may vary by sector and that they are presented from the perspective of the English language. Use in other languages may be equally nuanced. A full review of use across all sectors is not appropriate, but an illustration of the way a multitude of terms exist and have been rationalised within one sector is provided by APRA in its document, *Remanufacturing Terminology: Remanufacturing Term Guideline*.[19] Here, one diagram neatly encapsulates the variety of terms and their implied rigour compared to new (Figure 2) in the automotive sector.

Figure 2: The potential lifecycle(s) of a product and its materials



Source: APRA Europe (2012) Remanufacturing Terminology: Remanufacturing Term Guideline. Note, the words in parenthesis indicate inferred quality relative to the new product.

A further APRA Europe document presents comparative terminology across a number of Member States (Table 2) which could provide the basis for conversations in other sectors - although we are still reliant on the interpretation of researchers.[20]

[19] APRA (2012) *Remanufacturing Terminology: Remanufacturing Term Guideline* at http://www.apra-europe.org/dateien/downloads/Reman_Term_Guideline_2012-03-06.pdf

[20] APRA (?) *APRA's Remanufacturing Translation Matrix* at http://www.apra-europe.org/dateien/downloads/Reman_Terms_and_Definitions_Translations_Final.pdf

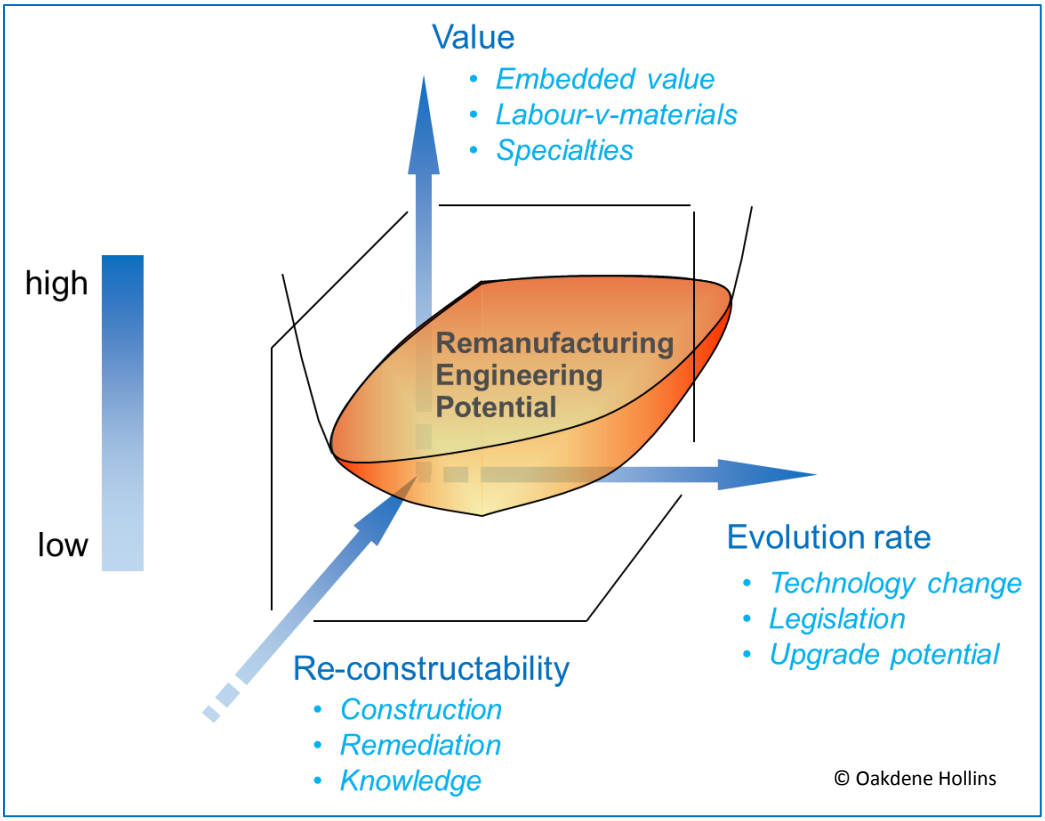
Table 2: Comparative remanufacturing terms in the automotive sector

EN	core	deposit / refund	rebuild	recondition	reconstruct	recycle	refurbish	re-manufacture	renew	repair	restore	reuse
CZ	použitý díl	záloha	obnovit	renovovat	rekonstruovat	recyklovat	modernizovat	opravit	obnovit	opravit	restaurovat	opětně použít
DA	ombytter (bx)	pant	gen-opbygge	istandsætte	genopbygge	genbruge	renovere	renovere	fornye	reparere	restaurere	genanvende
NE	schroot-deel	statiegeld / terugbetaling	renoveren	herstellen	reconstrueren	recycleren	opknappen	herfabricage	vernieuwen	reparatie	terugbrengen	hergebruik
EE	korpus	pant	korrastada	restaurerimine	rekonstrueerima	korduvkasutami	värskendama	taastamine / tehases	uuendama	remontima	restaureerida	uuesti kasutama
FI	runko	pantti	kunnostaa	kunnostaa	jälleenrakennus	ne kierrättää	ehostaa	tehdaskunnostus	uudistaa	korjata	entisöidä	käyttää uudelleen
FR	vieille matière (carcasse)	consigne	rénover	reconditionner	reconstruite	recycler	remettre à neuf	refabriquer	rénover	réparer	restaurer	réutiliser
DE	altteil	pfand	wieder-aufbauen	wieder-herstellen	wieder-aufbauen	recyceln	aufpolieren	(serien) instandsetzen (refabrikation)	erneuern	reparieren, erneuern	restaurieren	wieder-verwenden
IT	carcassa	deposito / cauzione	ris-costruzione	ricondizionare	riscostruire	riciclare	rinnovare	regenerato	riprendere	riparare	ripristinare	riutilizzare
LI	korpusas	depozitas	atstatyti	restauruoti	perkonstruoti	perdirbti	renovuoti	perdaryti	atnaujinti	suremontuoti	atkurti	panaudoti iš naujo
NO	bytte	pant	gjenn-oppbygge	renovere	gjenn-oppbygge	resirkulere	overhale	reprodusere	fornye	reparere	restaurere	brukes på nytt
PL	rdzeń	depozyt / kaucja	odbudowa	remontować	rekonstruować	utylizować	odnawiać	regeneracja fabryczna	odnawiać	naprawa	od-restaurowywać	ponownie użyć
PT	peça usada	depósito/ reembols	reconstruir	recondicionar	reformar	reciclar	polir / limpar	remanufaturar	renovar	reparar	restaurar	reutilizar
SK	použitý diel	o záloha	obnoviť	renovovať	rekonštruovať	recyklovať	modernizovať	opraviť	obnoviť	opraviť	zreštaurovať	znova použiť
ES	pieza usada	depósito / reembolso	reconstruir	reacondicionar	reconstruir	reciclar	pulir	remanufacturar	renovar	reparar	restaurar	reutilizar
SE	stomme	pant	renovera	renovera	åter-uppbyggning	cirkulera	sminka	fabrics-renoverad	förnya	reparera	restaurera	använda på nytt

2.2.4 *Remanufacturing overview*

Remanufacturing occurs across a wide range of industrial sectors, but is particularly attractive to industries that produce capital-intensive, durable products with relatively long product life cycles. These include: aerospace, automotive, electrical and electronic equipment, furniture, heavy duty and off road equipment, machinery, marine, medical devices and rail (rolling stock). However, these factors alone are not enough to enable remanufacturing to take place. The economic viability of remanufacture can depend on a number of factors including: how dispersed the product is; how easy it is to locate and retrieve; the ease with which it can be disassembled, diagnosed and remediated; the rate of technology and product performance change; knowledge and skills related to manufacturing; and legislative changes. The interplay of the effects of these factors creates a 'feasible space', summarised in Figure 3.

Figure 3: Remanufacturing attributes - feasibility space



The production of remanufactured goods depends upon the supply of end-of-life finished goods for disassembly and remanufacture. The length and complexity of the remanufacturing process varies, with companies performing one or a number of different operations: storage and transport, disassembly, cleaning, inspection, trading of components, replacing worn parts, product restoration, testing and distribution.

The individual sectors with the greatest number of remanufacturing firms include electrical and electronic equipment (EEE), motor vehicle parts, and aerospace.

In general, the remanufacturing businesses can be broadly divided between original equipment manufacturers (OEMs) and non-OEMs. OEM remanufacturers manufacture their own products, and then have the capability to collect them at end of life and the facility to remanufacture. Non-OEM remanufacturers typically source core at the end of life either

directly or in some cases through brokers. They can also be distributor-type organisations selling OEM products and also providing repair, refurbishment and remanufacturing services. In some sectors, this distinction between OEMs and non-OEMs is more nuanced, with a set of component manufacturers (for example, Bosch in the automotive components sector) that manufacture components to feed into OEMs directly or to sell into the aftermarket for parts.

2.2.5 *Remanufacturing within the circular economy*

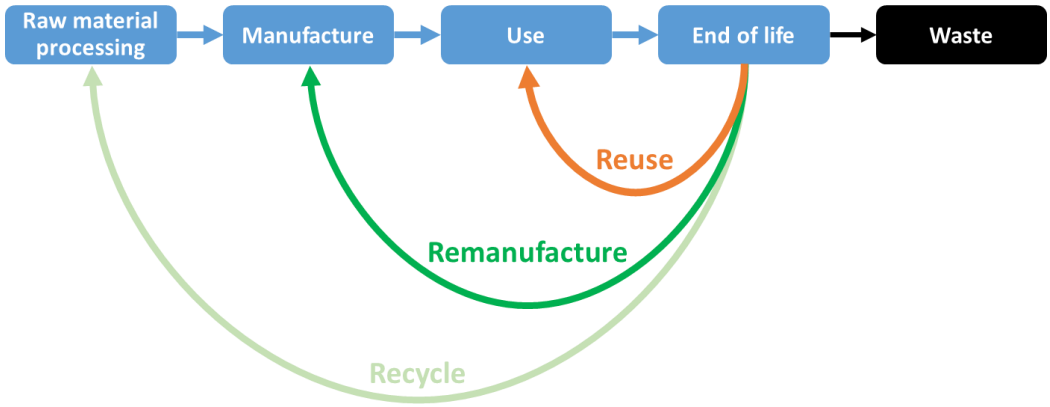
The Ellen MacArthur Foundation defines the circular economy as an economy that is:

> *"Restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles."*[21]

The circular economy is an alternative to a traditional 'linear' economy that extracts resources and makes products that are disposed of after use. The circular economy approach is to keep resources in use for as long as possible, extracting maximum value from them during use, then recovering and regenerating them at the end of each service life.

Remanufacturing typically applies to complex manufactured products that possess significant embedded material, energy and labour resources; therefore it fits well as a key strategy within the circular economy and represents an important component of a resource-efficient manufacturing industry. Remanufacturing can be considered as a 'loop' of the circular economy, where products return to a manufacturing setting where most of the value can be recovered by suitable remediation techniques.[22]

Figure 4: Remanufacturing in context with the circular economy



By keeping components and their embodied material in use for longer, large environmental benefits can be realised; for example, the remanufacturing of automotive components yields some 88 % materials savings compared to using a new product, with an associated 53 % decrease in CO_2 emitted and 56 % lower energy requirement.[23] Further, remanufacturing has the ability to keep advanced materials, including those termed as critical raw materials (materials with high economic value and supply risk), within the economy. It also provides opportunities to create high skill jobs and economic growth; and yet, despite all these

---

[21] http://www.ellenmacarthurfoundation.org/circular-economy

[22] http://www.zerowastescotland.org.uk/sites/files/zws/Remanufacturing Study - Full Report - March 2015_0.pdf

[23] *Remanufacturing as best practice of the Circular Economy*, APRA Europe: http://www.apra-europe.org/dateien/News/News2015/APRA_Position_Paper.pdf

benefits, remanufacturing remains an undervalued and under-recognised part of the industrial landscape.

2.3 Objectives and scope of the project

2.3.1 Objectives

Stakeholders in the European remanufacturing industry have previously highlighted the need for an evidence-base on the current size, benefits and potential growth of the industry.[24] The roles of legislation and standards are also pertinent for regulating and promoting genuine remanufacturing activities.

The purpose of this study has been to map the current remanufacturing landscape across Europe for the first time, and to quantify the current size and structure of the European remanufacturing industry in key market sectors - including the value, employment and key drivers and barriers affecting the industry. This evidence-base will be used to inform industry and policymakers on the current state of remanufacturing across the EU.

The specific aims and objectives of this market study were as follows:

- To identify sources of existing market data on remanufacturing in Europe.
- To quantify the current size and structure of the European remanufacturing industry, in key market sectors (e.g. aerospace, automotive components).
- To quantify the current social (number of jobs), economic (turnover) and environmental (CO_2 reductions and displaced tonnages) benefits of remanufacturing in Europe.
- To quantify the estimated social, economic and environmental potential of increased remanufacturing in Europe, and to identify particular areas for growth.
- To look at the markets for advanced materials and to identify where remanufacturing provides opportunities.
- To identify region-specific contextual factors that may influence the uptake and development of remanufacturing.

More widely, the formation of a European Remanufacturing Network (ERN) would provide resources for collecting and disseminating information on these topics. In support of this, exemplars of remanufacturing business models, design and processes that already exist in the European remanufacturing industry will be collated. The formation of the ERN provides a platform for collaborative networking from which good practice can be disseminated. As a complement to the ERN, the project will establish a European Remanufacturing Council (ERC) - a group of organisations large and small from a variety of sectors representing the coordinated voice of the European remanufacturing industry to policy-makers and wider stakeholders.

2.3.2 Scope

During project scoping, see Section 2.4.2, nine sector categories were identified as areas where significant remanufacturing activities might be occurring. These sectors are addressed in detail in the following chapters:

Chapter 5: Aerospace industry [Oakdene Hollins]
Chapter 6: Automotive (including components, engines, tyre retreads) [Oakdene Hollins]

[24] Remanufacturing workshop held in London in December 2013 coordinated by Oakdene Hollins.

Chapter 7: EEE (including consumer electronics (ICT and mobile electronics), ink and toner cartridges, and white goods) [Oakdene Hollins]
Chapter 8: Furniture (including office furniture) [Circle Economy]
Chapter 9: Heavy duty and off road equipment [Oakdene Hollins]
Chapter 10: Machinery (including pumps, machine tools and food processing machinery) [Oakdene Hollins]
Chapter 11: Marine industry [VTT]
Chapter 12: Medical equipment [Oakdene Hollins]
Chapter 13: Rail industry [VTT]

2.4 Approach

Much of the information presented in this report was based on the analysis of primary data collected and its application to macroeconomic data sources such as Eurostat. The primary data was collected via a market survey of remanufacturing actors and sampling the wider manufacturing industry to understand the proportion of manufacturing organisations that perform remanufacturing.

The market survey of remanufacturing actors involved:

- Identifying companies for survey – companies in the target sectors and countries were identified through trade associations, academic institutions, desk-based research, partner contacts, Steering Group contacts, contacts database and calls for support (newsletters, conferences, ERN website and mailing lists).
- Designing a questionnaire/semi-structured interviews – a list of questions was compiled and included questions to gather detail on remanufacturing organisations e.g. size of firms, sectors they participate in, type of remanufacturer (OEM, contractor, third party) barriers and motivations to participating in remanufacturing. The survey was offered online in eight European languages. A copy of the survey can be found in Annexe B.
- Collecting market information – identified companies were contacted via email and/or telephone. Responses to the questionnaire/interviews were collected either by online survey, telephone interviews, email or from company visits.

Through the various communication routes, it is estimated over 20,000 contacts were made aware of the survey, although it is likely that there was some double counting and that some contacts represented the same organisations. In most cases, these contacts were sent at least one reminder of the survey. This approach yielded 206 responses from remanufacturing actors across Europe.

Sampling the manufacturing firms involved the following activities:

- Identifying companies for sampling – similar to above, with a focus on developing wider lists of manufacturing firms in the sectors of interest.
- Testing for remanufacturing activity - this was generally done through a cold-calling campaign for each sector, supplemented where appropriate by desk research.
- The focus on the sample was not an in-depth set of questions as with the formal market survey above; instead it was to confirm the following pieces of information:
    - Whether the firm performed remanufacturing activities: in a significant number of cases a description of what constitutes remanufacturing was required to distinguish between firms that provided repair, refurbishment and/or reconditioning activities from those that provided remanufacturing.

- Where remanufacturing occurred, how much of the business this represented in terms of turnover (€) and/or number employees.
- What type of organisation it was: OEM vs non-OEM.

- Where possible, further information was gathered (e.g. estimates of number of similar firms) to provide further input into the analysis.

Over 1,300 companies were reviewed in this phase of work as a basis for understanding the subset of manufacturing and repair and maintenance organisations that remanufacture.

2.4.1 Analysis

Analysis included the following activities:

- Identifying and reviewing existing data sources, including Eurostat and information held by trade associations. This formed the basis of the project scoping step described in further detail in Section 2.4.2.
- Collating raw data, generating graphs and tables of key results, and anonymising the results.
- Extrapolating the data gathered during both the survey and sampling exercise to estimate the size of the remanufacturing industry for the whole of Europe.
- Scaling up the data collated for environmental impact of remanufactured versus new products to the size of the European remanufacturing industry.
- Estimating the overall potential for remanufacturing in Europe through assumptions on differing levels of remanufacturing rates.

2.4.2 Scoping study results

This section provides an overview of the scoping stage, which comprised two main elements:

- Identifying what data on the European remanufacturing market already exists.
- Identifying what market sectors should be explored in the full market study.

Industry associations were approached to determine what, if any, market data on remanufacturing they collect on the behalf of their members. Other information sources were collated to see what market data exists on the remanufacturing industry in Europe. The scoping study also identified target sectors for remanufacturing, i.e. those in which significant remanufacturing activities might be expected to have a large impact. The sectors identified were:

1. Aerospace.
2. Automotive (including tyres, engines, components).
3. EEE (including ink and toner cartridges, consumer electronics (ICT and mobile electronics), white goods).
4. Furniture/office furniture.
5. Heavy duty and off road equipment.
6. Machinery (including pumps, machine tools, energy, food, vending machines).
7. Marine industry.
8. Medical equipment.
9. Rail industry.

Within the Eurostat Structural Business Statistics, data are publicly available for ‘repair’ ‘maintenance’ or ‘retreading’ activities for a number of sector categories including retreading of tyres, machinery and equipment, motor vehicle, ICT/electronics and other

household goods. In most instances, with the possible exception of repair of aerospace, we do not believe that the quality of the final products matches that provided by remanufacturing. In other cases, 'hidden' remanufacturing by OEMs is not captured in the data but is incorporated within wider manufacturing production. However, the data for repair activities can provide an upper estimate of remanufacturing activities by non-OEMs and thus be useful later for extrapolating the survey data collected.

A variety of other potentially useful data sources were uncovered during engagement with remanufacturing actors or during the scoping study, including:

- Market studies for particular countries e.g. UK by the Centre for Remanufacturing & Reuse (CRR) and USA by the US International Trade Commission (USITC).
- High-level sector information from industry associations in aerospace (ADS), automotive (APRA, CLEPA, FIRM), tyres (ETRMA) and toner/printer cartridges (ETIRA).[25]
- Other useful background documents, such as those by the CRR, Ellen MacArthur Foundation or United Nations Environment Programme.

In conclusion, the scoping study revealed that some interesting and useful market data sources exist for remanufacturing in Europe, although overwhelmingly few are detailed or provide any breakdown by sector or by geographic region. The coverage of the data is also patchy, and it is not always clear whether the economic activities reported are *bone fide* remanufacturing or simply repair activities. Nonetheless, these sources were useful in helping to triangulate and extrapolate the data collected during the full market survey.

Encouragingly, a number of the industry associations were supportive towards this project, and offered support in disseminating the market survey and collecting data from their membership across Europe. The full market survey was launched at the end of April 2015. See *Annexe B* for a copy of the survey.

2.5 Global remanufacturing landscape

The following sections present a compiled view of individual national remanufacturing markets where it appears in literature. Only two countries are known to have conducted and published holistic reviews of their remanufacturing landscape, namely USA and UK.

2.5.1 Brazil

Remanufacturing in Brazil is mainly focused on aerospace, motor vehicle parts, heavy duty and off-road (HDOR) equipment, and information technology (IT) products. The repair and remanufacturing industry consists of thousands of small firms, mostly employing 20 or fewer workers. However, domestic remanufacturers also include OEMs that remanufacture and sell products that they originally produced and independent firms that purchase used goods on the open market or receive them from specific customers and remanufacture them.[26]

There are over 2,000 engine remanufacturers in Brazil, 60 % of which employ fewer than six workers. The remainder are SMEs employing between 20 and 60 workers. However, several large multinational firms account for the majority of remanufacturing activity. Motor vehicle

[25] Aerospace, Defence, Security and Space trade association, Automotive Parts Remanufacturers Association, European Association of Automotive Suppliers, European Tyre and Rubber Manufacturers' Association, European Toner and Inkjet Remanufacturers Association

[26] *Remanufactured goods: An overview of the US and Global Markets and Trade* 2012. USITC. Accessible from http://www.usitc.gov/publications/332/pub4356.pdf

parts producers ZF Sachs Automotive, Eaton Corp., and Siemens account for three quarters of the total value of Brazil's remanufactured engines and parts.[26]

Brazil's economic growth and increase in infrastructure development, construction, mining, and energy exploration has driven demand for heavy duty equipment and remanufactured parts in the country. Equipment producers in Brazil include multinational OEMs such as Caterpillar, Cummins, Komatsu, and Odebrecht. These firms remanufacture diesel engines and provide services in the equipment, motor vehicle and industrial machinery sectors. For example, Komatsu is a major producer of remanufactured diesel engines and parts, as well as construction and industrial machinery.

Remanufacturing in Brazil's IT products sector is primarily of printer cartridges. There are around 18,000 firms that manufacture or repair printer cartridges, and remanufacturers reportedly make up about 25 % of the number of firms in the broader printer cartridge industry.[26]

Imports of remanufactured goods are allowed into Brazil provided that the remanufacturing has been performed by the original manufacturer and has the same warranty as an equivalent new product. Remanufacturers located in Brazil are limited to remanufacturing domestically sourced products, which are subject to additional requirements. For example, it is reported that engine serial numbers are linked to vehicle registration, and engines must be de-registered by the vehicle owner before they can be remanufactured. In 2011, Brazil proposed regulation that would prohibit the import of remanufactured medical devices altogether, limiting domestic remanufacturing to used medical equipment originally produced in Brazil or imported 'as new'.[26]

2.5.2 China

Statistics on Chinese remanufacturing production, foreign trade, and employment are largely unavailable as the remanufacturing sector was largely unestablished before 2008. In 2003, a series of laws were enacted which addressed pollution, recycling and energy conservation, ending with a law[27] which expanded the application of remanufacturing. In 2008, China's National Development and Reform Commission (NDRC) and the Ministry of Industry and Information Technology (MIIT) established two pilot programs allowing limited remanufacturing by 'approved' firms in the automotive parts, industrial machinery and electrical equipment sectors.[31]

In the automotive parts sector, the pilot program authorises the remanufacture of engines, transmissions, generators, starters, drive shafts, compressors, oil pumps, water pumps and other components. Only 15 remanufacturers were approved for the pilot program. In 2009, China reportedly remanufactured around 110,000 engines, 60,000 transmissions, and a million starter motors.

In 2009, the MIIT established a pilot program which allowed the controlled remanufacture of construction machinery; industrial, electrical, and mechanical equipment; machine tools; mining machinery; railway locomotives and equipment; marine equipment; office equipment and IT products. 60 remanufacturers were approved for this pilot.[31]

In 2010, the NDRC and 11 other ministries and agencies issued a guidance document to promote the development of China's remanufacturing industry.[28] It listed the industries and

[27] The Law of the People's Republic of China on Circular Economy Promotion stipulated that the term 'reusing' included remanufacturing.

[28] NDRC, *Guidelines for Promoting the Development*, May 31, 2010

products that should be promoted, established broad goals for remanufacturing, noted the major challenges, and presented a strategic road map for implementation. Further guidance in September 2011 aimed at expanding the number of industries approved for remanufacturing and sought to ensure that pilot projects achieved tangible results.[29]

Beyond this central government encouragement, the landscape is somewhat complex with seemingly overlapping authorities and contradictory regulations. The aforementioned pilot programmes are closed and it is unclear how a new business can be classified as an approved remanufacturer now. These issues are thought to have hampered industry growth.

Although outside the scope of the remanufacturing pilot programs, tyre retreading is a well-established industry with reportedly over 1,000 retreaders, but only a few producing more than 100,000 retreaded tyres annually, and only one producing more than 300.[29]

Barriers

- **A lack of an official definition** is seen as a significant barrier because regulators find it confusing to deal with firms seeking approval for their operations.
- **Collection of core** can be difficult due to import constraints on certain parts, and regulations regarding dismantling and requirement to melt down certain components.
- **Import bans** on used goods to be remanufactured domestically. Remanufactured mechanical and electronic products are considered 'used' products for import purposes and are either prohibited, restricted or freely imported, depending upon the product. Thus automotive parts and HDOR remanufacturers selling directly into the Chinese market depend for core on domestic supply of used goods. Import of remanufactured products is considered effectively impossible. Linking back to the official definition, China's customs service does not have a separate classification for remanufactured goods, making it difficult to apply the correct import duty.[29]
- **Tax burdens** have also been cited as potentially restrictive for remanufacturing
- Pilot programmes rules **prohibit remanufacturing** within the OEM warranty period.

2.5.3 Denmark

A recent review[30] found the scope of remanufacturing in Denmark was limited. The potential for remanufacturing was estimated at around DKK 2.3 billion or a little over €300 million based on the assumption that Danish industries could accomplish remanufacturing at the level of the US in the seven sectors presented in Table 3.

Table 3: The value of products potentially remanufactured in Denmark (2014)

Industry	Intensity (reman / prod'n)	Production (DKK million)	Investment (DKK million)	Employ-ment (FTE)	Exports (DKK million)	Imports (DKK million)
Metals	0.9 %	439	18	318	104	184
Electronics	0.4 %	126	18	65	26	126
Electrical equipment	0.9 %	163	10	83	46	130
Machinery	0.9 %	1,280	63	544	317	833

[29] *Remanufactured goods: An overview of the US and Global Markets and Trade* 2012. Accessible from http://www.usitc.gov/publications/332/pub4356.pdf

[30] *Remanufacturing in Denmark* (2015), Incentive, viewed at https://groenomstilling.erhvervsstyrelsen.dk/sites/default/files/media/remanufactoring_incentive_2015.pdf

Transport vehicle industry	1.0 %	147	7	80	38	300
Furniture & other manufacturing	0.9 %	136	12	86	38	138
Total	**0.9 %**	**2,289**	**127**	**1,177**	**569**	**1,712**

Source: Remanufacturing in Denmark (2015), p5

Notes: The intensity shows the share of the total production being remanufactured. Only sectors that remanufacture are shown. Investment, exports and imports are calculated based on standard production in the industries and are not based specifically on remanufacturing.
The assessment is subject to uncertainty but gives an indication of the scope.

Barriers

The following barriers to remanufacturing were identified through interviews:

- Companies
  - **Logistics chain:** Costly and complicated collection of cores.
  - **Compliance with quality requirements:** Costly to ensure the quality of remanufactured products
  - **Long-term investment:** Remanufacturing requires cost intensive R&D with a long payback period that can be too risky for some companies.
  - **Too much transparency:** Remanufacturing requires cooperation between suppliers and customers, as well as an open value chain. It can give competitors an advantage and increase espionage.
  - **Sales vs leasing:** To counter customers' scepticism of remanufactured products, some companies lease their products to the customers. The inability to lease some product types was seem to be a potential barrier.
- Legislation and accounting
  - **International trade:** International laws may restrict or prevent the transport of remanufactured products into or out of the country.
- Demand
  - **Perception of quality:** companies are concerned that customers will perceive remanufactured products as being of lower quality than new products.
  - **Limitations in tenders:** Several companies highlighted that Danish authorities do not demand remanufactured products in public procurement.
- Structural
  - **Rapid evolution rate:** Some products change so fast that new products are significantly different from old products, thereby making it difficult or impossible to remanufacture old products.
  - **High wages**: These make remanufacturing very expensive in Denmark.

2.5.4 India

Remanufacturing in India is underdeveloped, and repair is more common.

Most of the remanufactured IT products in India are printer cartridges, although the definition of 'remanufacture' can be somewhat variable. More than 30,000 businesses reportedly engage in some form of cartridge refilling or remanufacturing, but it is said that the sector is largely unregulated, quality varies, and counterfeiting common, and it is thought that only about 70 firms remanufacture printer cartridges under reputable brands.

The Indian market for printer cartridges is estimated at roughly US$250 million annually; genuinely remanufactured cartridges are thought to account for less than 10 % of this.[31]

In the HDOR sector, Volvo began remanufacturing construction equipment at its facility in Bangalore for the domestic market. Cummins operates two separate remanufacturing facilities—one for exports and the other for the domestic market.[31]

The country prohibits imports of used goods to be remanufactured in India and sold in the domestic market, but does allow imports of goods for remanufacture and subsequent export. Imports of most used capital goods (e.g. reconditioned spare parts or components) intended for the domestic market are prohibited unless it can be shown they retain 80 % of the residual value of the original products. Imports of used computers and laptops are banned completely.[31]

Although India's foreign trade policy document does not define a 'remanufactured' good, imports of remanufactured goods are subject to licensing. Only the specific remanufactured parts listed on the import license may be imported. This restriction, and the long approval times needed to obtain a new license, hampers the ability of importers to either import more or change the product mix of import shipments in response to evolving demand.[31]

2.5.5 Japan

Japan has a relatively well established remanufacturing sector albeit estimates for the size of the remanufacturing industry by sector is not well characterised. Remanufacturing is estimated at up to €3.8 billion (500 billion Yen) with the automotive sector believed to be a little more than €800 million (109 billion Yen). Retread tyres, photocopiers, and toner cartridges make up €150 million, €110 million and €230 million respectively (20, 15 and 30 billion Yen respectively).[32] The Japanese government has promoted the reduction of pollution and waste generation, for example through the 3Rs initiative to reduce waste generation, re-use parts and recycle used products.[33] Remanufacturing is thus seen as a waste reduction strategy and has been adopted by a number of industry sectors.

Japan is home to several large photocopier manufacturers (Fuji Xerox, Ricoh and Canon) that have expanded their activities to include remanufacturing. The companies collaborate to collect returned units and have invested in design for remanufacturing principles. However, Fuji Xerox – unlike the other manufacturers – reportedly also uses remanufactured components in its new products.[34]

Single-use cameras is also a well-developed remanufacturing sector in Japan. Fuji Film developed a fully automated remanufacturing line for processing returned cameras in 1998. Again, key elements of success in the sector include collaboration between OEMs to get a high core return rate, and design for remanufacturing.[34]

Remanufacturing in the automotive sector and printer cartridge sector is predominantly led by independent remanufacturers rather than OEMs. Remanufacturing in the automotive

---

[31] *Remanufactured goods: An overview of the US and Global Markets and Trade* 2012. Accessible from http://www.usitc.gov/publications/332/pub4356.pdf

[32] Conference proceedings from International Remanufacturing Conference, 2015, Seoul. Presented by Dr Mitsutaka Matsumoto, National Institute of Advanced Industrial Science and technology (AIST)

[33] Ramstetter, E. *Remanufacturing and the 3Rs in Japan: Lessons for Thailand*, Thammasat Economic Journal, Vol. 30, No. 4, Dec 2012

[34] Matsumoto, M. & Umeda, Y., *An analysis of remanufacturing practices in Japan*, Journal of Remanufacturing, 2011 1:2

sector is likely to be a growth area (though from a relatively low base), as the average age of passenger vehicles in Japan increases and the repair industry is deregulated.[35]

Remanufacturing of heavy duty and construction equipment, for example by Hitachi Construction Machinery and Komatsu, is another active sector in Japan.[36]

2.5.6 Korea

Remanufacturing in Korea is a significant industry and focused primarily in the automotive parts and printer cartridge sectors with some activity in heavy duty equipment, IT products, medical devices, and defence sectors. In 2011, the Korean government identified that remanufacturing could foster sustainable growth in 'green' industries, create employment and stabilise prices in the country.[37] The government has encouraged remanufacturing growth through the Ministry of Trade, Industry and Energy (MOTIE) and has sought promotional policies from around the world to support its domestic industry.

Estimates suggest that the automotive sector represents some 80% of the industry and is worth about €550 million (670 billion Korean Won) while the ink and toner cartridge sector represents much of the rest (17%) and is worth €120 million (145 billion Korean Won). The value of the industry has grown by 11% in the last five years. While the value has increased, the number of firms and employment has decreased from around 1,500 firms down to 1,100 and 11,000 employees down to 7,300.[38]

The market for remanufactured HDOR equipment is reportedly small, partly because Korean construction firms contract out repair activities to independent suppliers rather than relying on OEMs to remanufacture OEM-branded equipment.[37]

2.5.7 Malaysia

Significant remanufacturing sectors in Malaysia include aerospace, motor vehicle parts, ICT equipment and ink & toner cartridges.

Maintenance repair and overhaul of engines, airframes and other aerospace components is an important sector, with the market valued at €730 million (RM3.4 billion). There are currently drives to increase this activity to turn Malaysia into a hub for South East Asia. There are no institutional barriers preventing this activity. The most significant barrier to continuing growth is a lack of skills in the workforce and the required investment in test equipment.[39]

There is a remanufacturing industry which feeds into the domestic aftermarket for automotive components. Most core is imported from Japan and Europe even though there are some restrictions on the import of used 'safety-critical' components such as brakes. The market for remanufactured components was previously estimated to be €6.5 million per year.[40] An in-depth review by the CRR found the market to be significantly larger, estimated

---

[35] US Department of Commerce, *US Commercial Service Automotive Resource Guide, A reference for U.S. Exporters*, Third Edition, 2014

[36] APEC, US AID, *Remanufacturing Resource Guide*, 2013

[37] *Remanufactured goods: An overview of the US and Global Markets and Trade* 2012. Accessible from http://www.usitc.gov/publications/332/pub4356.pdf

[38] Conference proceedings from International Remanufacturing Conference, 2015, Seoul. Presented by Dr Hong-Yoon Kang, Center for Resources Information & Management at the Korea Institute of Industrial Technology

[39] *Remanufacturing in Malaysia, 2015*, CRR for Nathan Associates Inc. for review by the United States Agency for International Development. http://www.ncapec.org/docs/USAID Study on Malaysian Remanufacturing.pdf

[40] http://www.apec.org/~/media/Files/Groups/MAG/20131120_APEC-RemanResourceGuide_Sep2013.pdf

to be approximately €45-75 million (RM207-345 million) with the potential to double should the profile of the US remanufacturing industry be replicated.[39]

The market for remanufactured ICT equipment is estimated at €23 million (RM109 million). Core is sourced both domestically and internationally with remanufacturing performed by both OEM and third-party independent remanufacturers. The sector sometimes suffers from association with remanufactured / refurbished equipment sold with illegal pirated software.

Estimated at €15 million (RM73 million), there is an active ink and toner cartridges remanufacturing industry consisting of small players with generally fewer than 25 employees. Remanufactured cartridges do not seem to be imported: empty cartridges are imported and remanufactured and used domestically. As in the ICT sector, there are issues with illegal practices; in this case selling remanufactured cartridges as 'new' cartridges.

2.5.8 Mexico

Goods remanufactured in Mexico include consumer electronics, IT products, and automotive parts. There are 60 known remanufacturers in Mexico. No specific laws regulate remanufacturing as an industrial activity; however, in 2008, Mexico implemented the *Three Rs* initiative[41] to promote sustainability and to reduce waste in industrial activities.[40]

2.5.9 Singapore

In Singapore, remanufacturing occurs in the HDOR equipment, automotive parts, medical devices, electrical apparatus and marine equipment remanufacturing sectors. The government neither distinguishes between new, remanufactured or used goods nor has specific labelling requirements for remanufactured goods. Used goods to be remanufactured can be freely imported, and remanufactured products are sold both domestically and exported to ASEAN countries and Australia.[42]**Error! Bookmark not defined.**

In 2011, Caterpillar began remanufacturing equipment for trucks and mining work including transmissions, drives, and torque converters, to serve the regional mining industry.[43] 80 % of Caterpillar's remanufactured products are exported to Indonesia, the remainder to Australia. Tru-Marine (a remanufacturer of turbocharger components used in marine, power plant, and locomotive applications)[42] and Ark (remanufacturer of marine compressors, pumps and other components) have also begun remanufacturing.

Although Singapore does not specifically collect data on domestic remanufacturing production or trade, the government is committed to establishing a remanufacturing base to increase value-added manufacturing activities. In 2011, the government launched the Advanced Remanufacturing and Technology Center (ARTC), an R&D centre that works with local universities and remanufacturers to develop remanufacturing technologies for the aerospace, motor vehicle parts, marine, and HDOR equipment sectors. The ARTC has partnered with a handful of SMEs and larger multinational companies, including Boeing, Rolls-Royce and Siemens.[42]

---

[41] Reduce, Reuse and Recycle

[42] *Remanufactured goods: An overview of the US and Global Markets and Trade* 2012. Accessible from http://www.usitc.gov/publications/332/pub4356.pdf

[43] Caterpillar Inc., *Caterpillar Announces Opening of New Singapore Remanufacturing Facility* May 24, 2011.

2.5.10 United Kingdom

A 2004 study by Oakdene Hollins estimated remanufactured goods production in the UK at £4.9 billion in 2002.[44] It was estimated that 44,300 full-time jobs exist because of remanufacturing activities in the UK. In 2002, aerospace remanufacturing accounted for 40 % (£2 billion) of the total value of remanufacturing carried out in the UK, followed by the machinery and automotive sectors which each accounted for 11 % (£530 million).

In a 2009 update to the 2004 study, the total value of remanufacturing, refurbishment and reuse in the UK was estimated to be £2.4 billion (with carbon savings[45] of 10 million tonnes of CO_2e).[46] The apparent decline in the value of remanufacturing since the 2004 report is partially attributable to a higher granularity of the 2009 survey but mainly a result of the exclusion of the aerospace sector (~£2 billion) in the more recent report.

Of the remanufacturing-type activity identified in the UK in the 2009 report, proper remanufacturing accounted for approximately half of the total £2.4 billion value, with refurbishment and reuse contributing around a quarter each. The sector showing the highest intensity of remanufacturing was found to be the ink and toner cartridges sector. Outside this sector the highest intensity of remanufacturing was found in sectors which are associated with mechanical or powered machinery. Of the total value identified in these sectors, 30% was associated with remanufacturing activities.

Barriers

Barriers to growth in remanufacturing in the UK were identified to be:

- Declining UK manufacturing base.
- Availability of low cost products.
- Cost of labour.
- Low awareness of remanufacturing amongst purchasers.
- Increased incidence of lower quality products which has reduced the quality and quantity of core available, further increasing costs and complexity of remanufacturing.
- Shift in favour of refurbishment – economic pressures.
- Longer product lifetimes.
- Complexity of business operations.
- Economic recession.

2.5.11 United States

A wide-ranging remanufacturing review was commissioned by the USITC and published in 2012[47] with a focus on international trade of US-produced remanufactured goods. The report defined remanufacturing as an industrial process that restores end-of-life goods to original working ('like new') condition. Remanufacturing is well-developed in the USA, occurring across a diverse range of industry sectors, but it is most prevalent in sectors making capital-intensive, durable products that have relatively long product life cycles. This is in line with the 'feasible space' in Figure 3.

---

[44] Parker, D. (2004) *Remanufacturing in the UK*, Oakdene Hollins

[45] The effect of greenhouse gas emissions is often measured as the equivalent effect of emissions of carbon dioxide (CO_2e)

[46] Chapman A.C. et al. (2009) *Remanufacturing in the UK*, Oakdene Hollins and Centre for Remanufacturing & Reuse

[47] *Remanufactured goods: An overview of the US and Global Markets and Trade* 2012. USITC

The remanufacturing-intensive sectors that account for most of the remanufacturing activity in the USA include (in alphabetical order): aerospace, automotive components, consumer products, electrical apparatus, HDOR equipment, IT products, locomotives, machinery, medical devices, office furniture, restaurant equipment, and retreaded tyres (Table 4).

According to the USITC report, the USA is the largest remanufacturer in the world: between 2009 and 2011 the value of US remanufactured production grew by 15 % to at least US$43 billion, supporting 180,000 full-time US jobs. 63 % of total US remanufactured production values and 48 % of remanufacturing-associated employment stemmed from the aerospace, HDOR and automotive sectors. In the USA, SMEs were estimated to be responsible for a quarter of production (US$11 billion), 17 % of exports and 36 % of employment. The EU is estimated to have received 37 % (US$105 million) of US Foreign Direct Investment for remanufacturing activities.

Table 4: US remanufacturing statistics, 2011

Sector[a]	Production (US$ m)	Investment (US$ m)	Employed ('000 FTE)	Exports (US$ m)	Imports (US$ m)	Intensity (%)[b]
Aerospace	13,046	90	35.2	2,590	1,870	2.6
Automotive parts	6,212	106	30.7	582	1,482	1.1
Consumer products	659	5	7.6	21	360	0.1
HDOR equipment	7,771	163	20.8	2,452	1,489	3.8
IT products	2,682	18	15.4	260	2,756	0.4
Machinery	5,795	711	26.8	1,349	268	1.0
Medical devices	1,463	31	4.1	488	111	0.5
Retreaded tyres	1,399	24	4.9	19	11	2.9
All other[c]	3,974	68	23.0	225	41	1.3
Wholesalers[d]		8	10.9	3,752	1,874	
Total	**43,000**	**1,223**	**179.5**	**11,736**	**10,263**	**2.0**

Derived from: Remanufactured goods: An overview of the US and Global Markets and Trade 2012. USITC

Notes: [a] *Sector ranked by production value*

[b] *Total value of shipments of remanufactured goods as a % of total sector sales*

[c] *Includes remanufactured electrical apparatus, locomotives, office furniture, restaurant equipment*

[d] *Wholesalers do not produce remanufactured goods, but sell or export/import them*

The USITC report focused on international trade, particularly exports, and found that Canada, the EU and Mexico were the leading destinations for US exports of remanufactured goods. The value of exports of remanufactured goods from the USA was estimated to be US$11.7 billion in 2011.

The report found that trade in remanufactured goods is strongly affected by regulatory barriers in foreign markets, and by price and availability of core (

Table 5). An absence of an accepted legal definition was found to exacerbate the issue, with customs authorities treating remanufactured goods and core as used products which are often prohibited.

The challenge of moving core across borders resulted in attempts to source core in foreign markets – also difficult due to price and availability. Cheap new products and consumer perceptions around price and quality were also seen as key challenges.

Table 5: Factors cited by US remanufacturers as important in determining their ability to compete domestically and globally

Sector (ranked by production value)	The US market	Foreign markets
Aerospace	Availability of skilled workers Availability of core Labour costs	Regulatory barriers in foreign markets Licensing or certification requirements Transportation costs
Automotive parts	Labour costs Transportation costs Availability of core	High price of core Cost of compliance with products' environmental standards Licensing or certification requirements
Consumer products	Availability of low-cost new products Customer preference for new products Declining demand for reman goods	Lack of knowledge of foreign markets Transportation costs Lack of distribution/marketing channels
HDOR equipment	Transportation costs Environmental regulations Availability of core	Foreign market tariffs Transportation costs Regulatory barriers in foreign markets
IT products	High price of core Customer preference for new products Availability of low-cost new products	Transportation costs Lack of knowledge of foreign markets Foreign market tariffs
Machinery	Availability of skilled workers Healthcare costs Unfavourable tax treatment	High price of core Transportation costs Regulatory barriers in foreign markets
Medical devices	Unfavourable tax treatment Availability of core Healthcare costs	Transportation costs Regulatory barriers in foreign markets Lack of distribution/marketing channels
Retreaded tyres	Availability of core Energy costs Unfavourable tax treatment	(a)
All other[b]	Healthcare costs Availability of core Unfavourable tax treatment	Transportation costs Foreign market tariffs Lack of distribution/marketing channels
Wholesalers	Transportation costs Energy costs Labour costs	Regulatory barriers in foreign markets Transportation costs High price of core

Derived from: Remanufactured goods: An overview of the US and Global Markets and Trade 2012. USITC
Notes: a Neither foreign markets nor factors reported by respondents
b Includes electric apparatus, locomotives, office furniture, restaurant equipment

2.5.12 Trends in developing nations

According to a recent UNEP report (2013):[48]

> *"Remanufacturing offers potential for new national business ventures within developing countries and new export opportunities. Given the minimal financial and material input into production, remanufacturing services provide lower prices to consumers, typically in the order of 30 to 40 % less than comparable new products."*

The report goes on to state that:

> *"Another advantage of remanufactured goods is that they can meet the criteria for new goods without additional quality and safety requirements that sometimes apply to refurbished goods. Indeed, in the 2011 Asia-Pacific*

[48] United Nations Environment Programme (2013) *Green economy and trade – trends, challenges and opportunities*, viewed at http://www.unep.org/greeneconomy/Portals/88/GETReport/pdf/FullReport.pdf

Economic Cooperation (APEC) Ministerial Meeting, 11 countries including Australia, Japan, Singapore and the United States, agreed in principle to refrain from implementing import restrictions on remanufactured goods, and to apply the same trade measures to such products as they would to new goods."

The report assesses that trade in remanufactured products is growing in many developing countries. African companies, for example, are seeking to market their remanufactured goods inside and outside Africa. It quotes the examples of *EbTech Solutions* in Kenya which advertises and offers remanufactured toner cartridges at 60 % of the price of new toners, and the company ships the goods in Eastern Africa; and *ICC Toner*, an Egyptian-US joint venture, which remanufactures cartridges in Egypt for export to the USA. ICT remanufacturing is reputed to be buoyant in Nigeria.

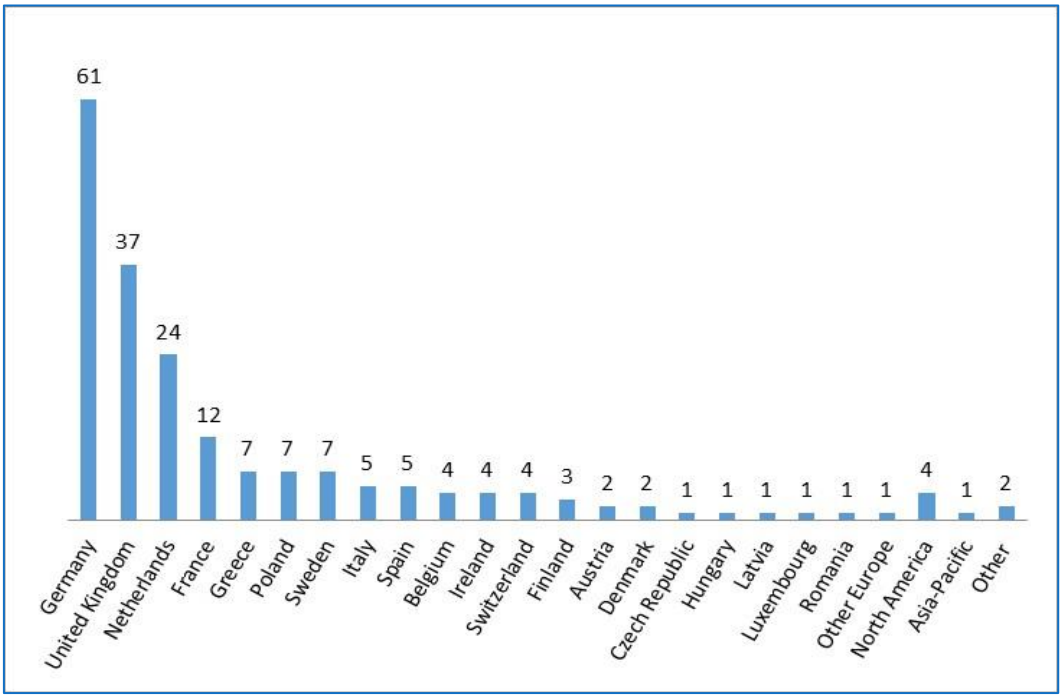
3 Survey responses

3.1 Survey participants

The survey questionnaire, a copy of which can be found in *Annexe B*, was distributed electronically to an estimated 20,000+ contacts that were identified as very likely to be remanufacturing actors. 206 responses to the questionnaire were received; a response rate of 1 %. Of these responses, 181 had completed all the questions while 25 questionnaires were returned not entirely complete.

The first questions in the survey were designed to identify the type of companies represented by the respondents. 197 individuals responded to the question on where their headquarters are based. The most responses were received from those whose company is headquartered in Germany (31 %), the UK (19 %) and the Netherlands (12 %). While Germany and the UK are large remanufacturing markets, this response from the Netherlands is believed to be disproportionately high because two of the eight project partners are based there and they were able to elicit more responses from local networks. There was also significant dissemination of the survey at ReMaTec 2015 in Amsterdam, the world's largest remanufacturing event, and thus a higher likelihood that more remanufacturing actors from the Netherlands heard about and responded to the survey.

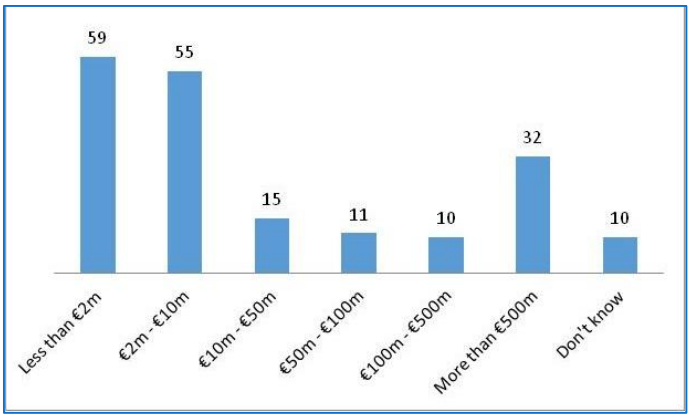
Figure 5: Number of responses to the question "Where is your company headquartered?"



192 company representatives provided information on their turnover in the EU (Figure 6), including 10 respondents who said they 'didn't know'. Of the respondents that knew, 63 % stated their company's EU turnover is below €10 million, 20 % that it is between €10 million and €500 million, and 17 % that it is greater than €500 million. Based on this, 71 % of the respondents represent small and medium-sized enterprises (SMEs) as per the EU

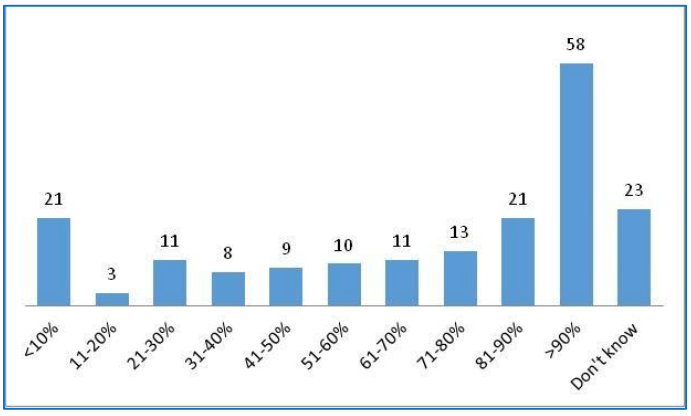
definition[49]; 32 % are in the Micro (≤€2m) category, 30 % in the Small (≤€10m) category and 8 % in the Medium (≤€50m) category (sum does not match due to rounding). This suggests that the structure of the remanufacturing industry is characterised by a skew toward a significant number of smaller non-OEMs, with a relatively small proportion of larger firms (€10m to €500m). It is likely that the 17 % of firms with a turnover greater than €500 million represent OEMs that also remanufacture i.e. remanufacturing will only be associated with a small minority of the company's revenues.

Figure 6: The EU turnover of companies (number of responses)



We received 188 responses to the question regarding what proportion of the overall global business turnover is located within the EU (Figure 7). Excluding the 23 respondents who stated that they did not know, 13 % of the participants reported EU turnover was less than one tenth of the company's global turnover, while 48 % reported that over 80 % of the company's business took place in the EU.

Figure 7: The share of company turnover originating in the EU (number of responses)

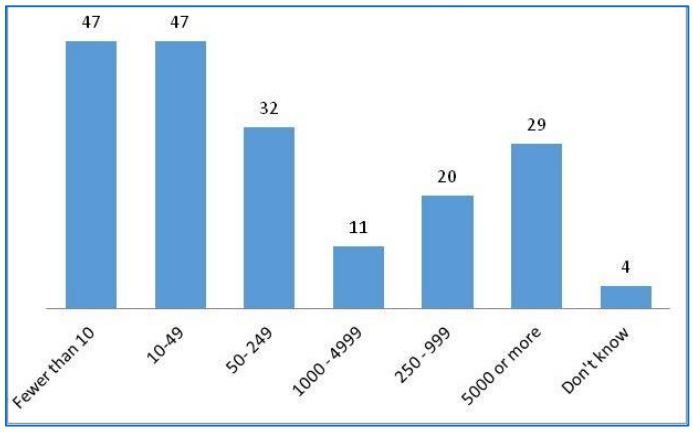


190 respondents answered the question of how many EU-based employees the company employed (Figure 8), including four who said they 'didn't know'. Mirroring the answer to the

[49] EU SME definition: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/index_en.htm

question regarding company turnover, a majority of firms (67 % of those who knew the answer to this question) are in the SME category[50]; Large Enterprises which employ over 5,000 people made up 16 % of responses.

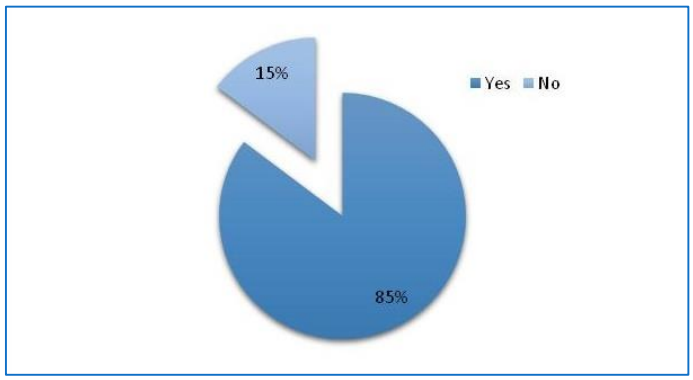
Figure 8: The number of EU employees per company (number of responses)



3.2 Survey results

Having established the type of companies represented by the respondents to the survey, the extent of their involvement in remanufacturing was probed. Firstly, we established whether the companies were involved in remanufacturing at all. Of the 190 respondents who answered this question, 162 (85 %) said that their company does undertake remanufacturing activity; the others generally represented research, promotional or consulting organisations with remanufacturing interests (Figure 9).

Figure 9: Share of respondents whose company is involved in remanufacturing activity



186 people responded to the question on what kind of remanufacturer they consider themselves to be, although 13 (7 %) of these did not know how to classify themselves and 14 % thought they were better described by a different definition than those presented as options. A summary of the other respondents is included in Table 6.

[50] We take the employment aspect of the EC definition of a SME, i.e. fewer than 250 employees

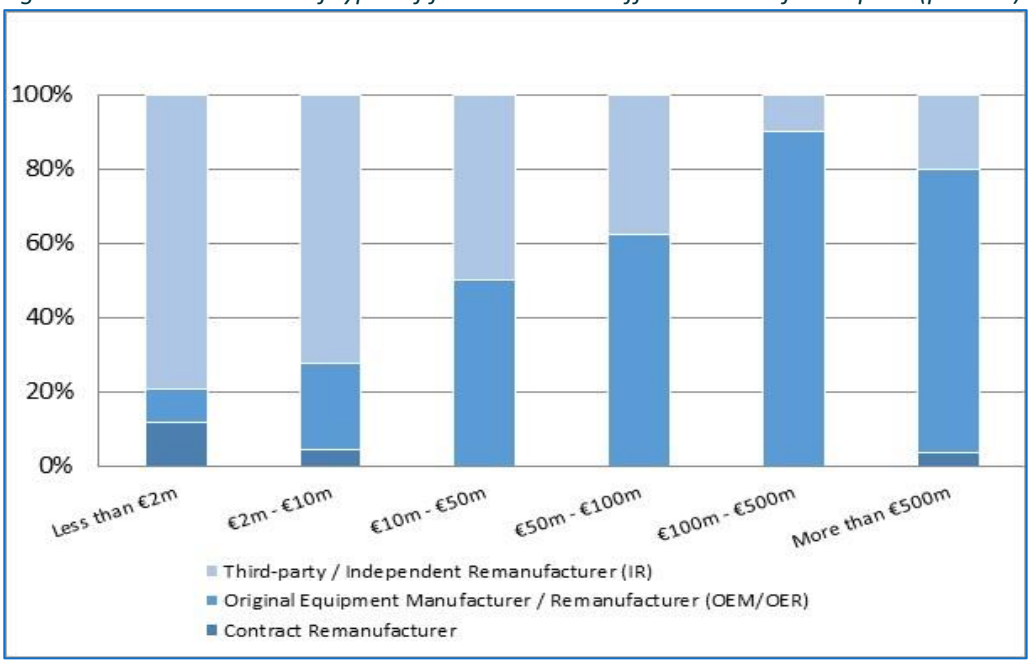
Table 6: Summary of responses to question regarding remanufacturer type

Type of remanufacturer	No. of respondents	Share (excluding those who answered 'don't know')
Contract remanufacturer	7	4 %
OEM/OER	63	36 %
Third-party / Independent remanufacturer (IR)	79	46 %
Other*	24	14 %

46 % told us that their business is a third-party or independent remanufacturer. Typically these businesses are the SMEs identified in Figure 6. 36 % of those who picked a category stated that their firm is an original equipment manufacturer or remanufacturer (OEM or OER). It is of note that only a very small proportion (4 %) identified themselves as a contract remanufacturer which validates the idea that the remanufacturing industry can be broadly classified into two categories i.e. OEMs and non-OEMs. Historically, remanufacturing has been described as having the three categories presented above as in the survey question; however this may be a legacy of a narrower past focus on the automotive remanufacturing industry where this nuance is valid. With a more holistic view of the wider remanufacturing industry, it seems that this distinction is less relevant.

Reviewing the size of firm against the perspective of firm type (Figure 10) supports the premise that, as the firms get bigger, the proportion of third-party / independent remanufacturer decreases.

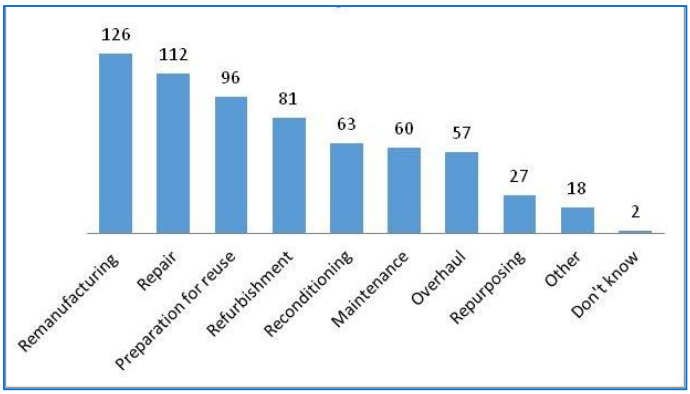
Figure 10: The distribution of types of firm across the different sizes of enterprise (percent)



We then focused on what remanufacturing-type activities were being carried out by the companies. With multiple responses allowed per respondent, the total number of remanufacturing-type activities reported was 642 via 188 respondents (Figure 11); as an example a company could perform remanufacturing, preparation for reuse, refurbishment and repair activities and would therefore have reported four options. Note that differences in how common each term is in the sectors surveyed and that the exact-meaning of these terms is also sector- or actor-specific. This makes further detailed analysis of the responses

to this question statistically unreliable. However, remanufacturing was cited by two thirds of respondents (125 of 188) to this question and represented 20 % of all activity reported, confirming that the term is used (if not necessarily always correctly). Including overhaul and reconditioning (words often used synonymously with remanufacturing), this accounted for responses from 84% of respondents (157 of 188).

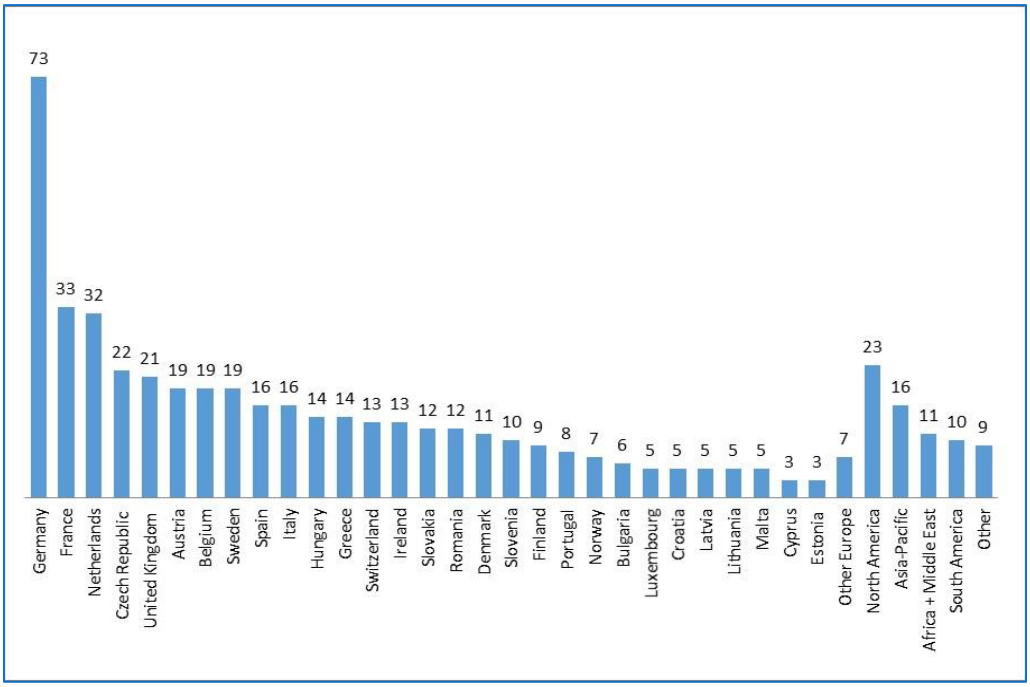
Figure 11: The type of remanufacturing activities respondents identified their companies to be undertaking (number of responses; multiple responses were allowed)



The respondents were asked to specify in which countries these remanufacturing activities were taking place. Multiple answers were allowed and 506 responses were received (Figure 12). 73 respondents said their firm is active in Germany (14 % of the total carrying out remanufacturing); a similar number are active in France and the Netherlands with a little over 6% of responses each. North America, the Czech Republic and the UK represented the next most active with around 4% of responses each. The top ten was rounded out by Austria, Belgium, Sweden, Spain and Italy.

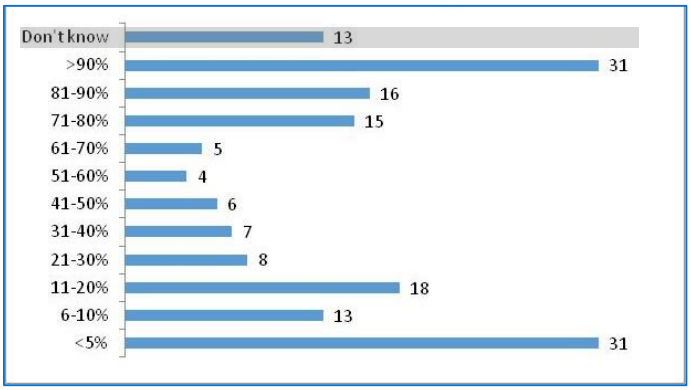
Not too surprisingly, Germany has a dominant position in remanufacturing for European remanufacturers with France and UK also expectedly being significant markets. In terms of slightly unexpected results, is the Netherlands and Czech Republic being relatively high up on the list while Italy is a little lower than could be expected based on its manufacturing base. We have previously described the over representation in the sample of the Netherlands, nonetheless it shows that there is a significant market there. The Czech Republic is also likely to represent significant remanufacturing activity based partly on its lower wage costs versus Western Europe and therefore enabling remanufacturing to occur. Italy's lower remanufacturing activity may partly be due to a reduced amount of aerospace and automotive remanufacturing compared to its peers (DE, FR, UK), strict rules on the movement of core and manufacturing activity focused in less intensive remanufacturing sectors like machinery.

Figure 12: Geographical distribution of remanufacturing activity (number of responses; multiple responses were allowed)



To assess the value that the companies which responded gained from remanufacturing activities, we asked them to estimate what percentage of their turnover relates to remanufacturing. To this question we received 167 answers, though this includes 13 respondents who said they 'didn't know' (Figure 13). Of those that knew, 28 % reported that under 10 % of their business related to remanufacturing, whereas 20 % stated that their remanufacturing turnover accounted for over 90 % of the total, or 40% with over 70% of their business.

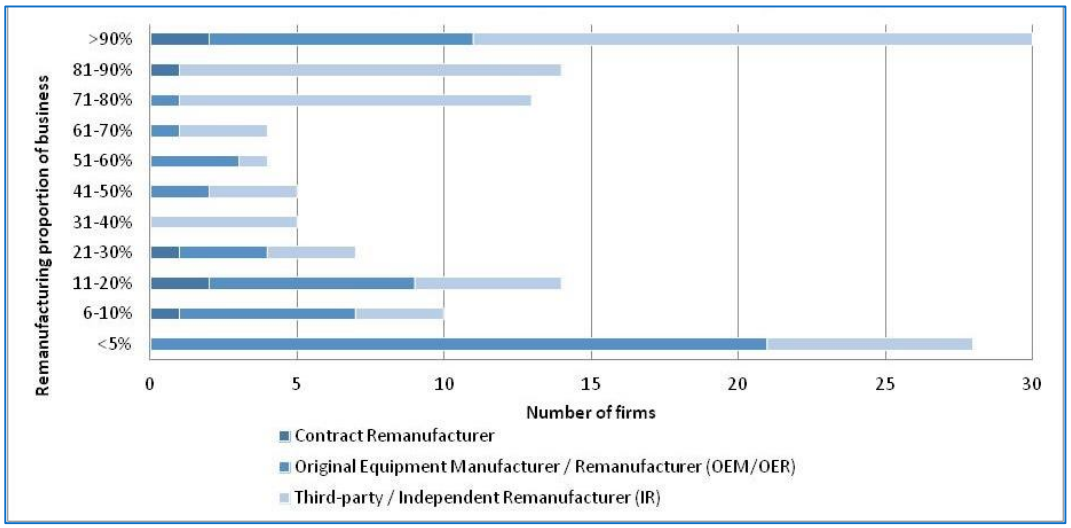
Figure 13: Percentage of turnover related to remanufacturing (number of responses)



A more nuanced view of Figure 13 is presented in Figure 14, which shows the proportion of business by firm type. This shows that non-OEMs tend to have a higher proportion of their business in remanufacturing activities. Some three quarters of respondents with <5% of their business related to remanufacturing were OEMs. Another way to view this is that 40 %

of OEMs in this sample have less than 5 % of their business in remanufacturing – this is not altogether surprising as the OEM's primary business is to manufacture a product rather than remanufacture it. This effect is in fact even more pronounced on detailed review of the few OEM companies that responded that over 90 % of their business is in remanufacturing – these include very large OEMs that have responded to the survey as the local remanufacturing subsidiary rather than the overall parent company meaning that the response does not represent the wider manufacturing company e.g. a large vehicle manufacturer. Therefore this approach by respondents has somewhat masked the fact that most OEMs have only small proportions of their businesses in remanufacturing.

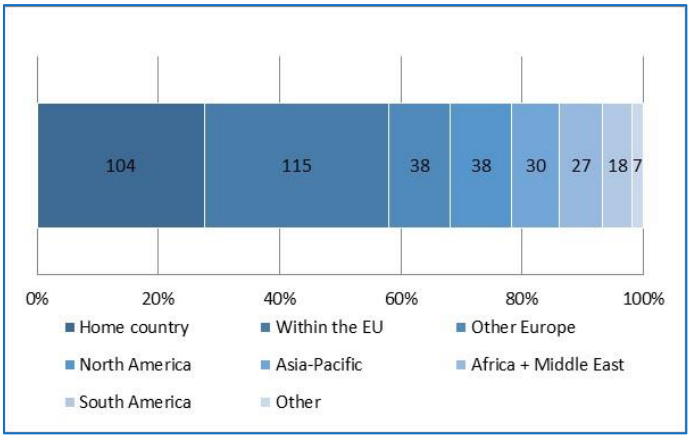
Figure 14: Remanufacturing percentage of business by firm type (number of responses)



One point to highlight here is that there seems to be two clear peaks: over 40 % (of those that knew) responded that remanufacturing activities made up more than 70 % of their business and 40 % stated manufacturing made up less than 20 % of their business. This seems to support the characterisation that the remanufacturing industry is comprised of third party / independent firms that consider remanufacturing as their core business, while OEMs are keen to consolidate and grow their remanufacturing businesses as part of their portfolio. This may be more nuanced in the automotive sector where there are major first tier suppliers / aftermarket components suppliers that may see themselves as distinct contractors rather than OEMs (or see themselves in multiple roles).

When asked where the major geographical markets for their remanufactured products were, the respondents informed us that they market their remanufactured products in a total of 377 markets (Figure 15). Multiple responses were allowed to this question. 28 % of the businesses represented in this sample produce remanufactured products for the domestic market whilst slightly more (31 %) market these products across other countries in the EU. Markets for extra-EU regions were as expected, with North America and Asia leading, Asia and Middle East and South America being smaller markets.

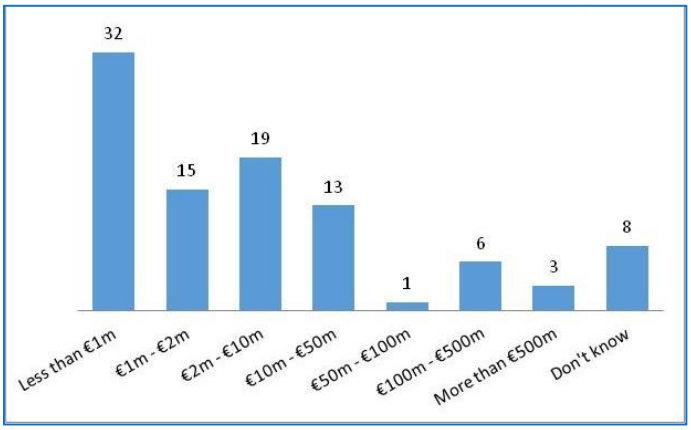
Figure 15: Major geographical markets for remanufactured products (number of responses; multiple responses were allowed)



We also asked respondents to identify approximately their annual turnover as a result of remanufacturing activities. To this question we had 97 responses (Figure 16). This is a low response rate considering that 162 respondents were involved in remanufacturing. This may suggest that remanufacturing is not run as a stand-alone business but takes place within an existing business line, thus does not have a clear / reported turnover associated with it.

53 % of those who knew the amount reported that their company turnover is under €2 million; 87 % of those who knew reported turnover to be less than €50 million. Using the EC definition, these companies' can be categorised as SME remanufacturers (as viewed as a stand-alone business). At the other end of the spectrum, turnover of greater than €100 million from remanufacturing was reported by 10 % of respondents (excluding those who said they 'didn't know').

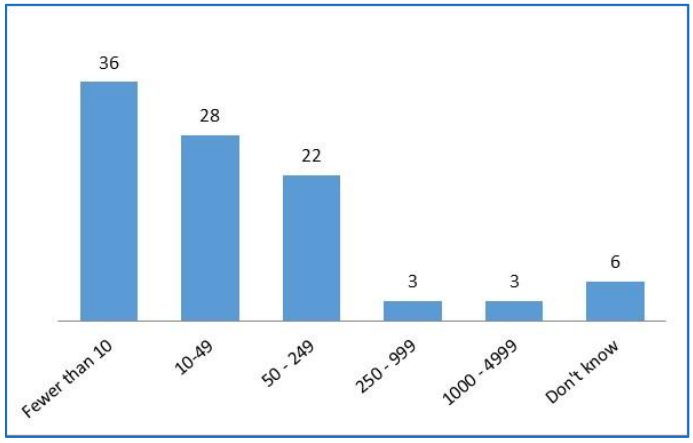
Figure 16: Annual turnover from remanufacturing-related activities (number of responses)



98 people responded about the number of employees that are involved in remanufacturing type activities in the company they represent. Unsurprisingly similar to the turnover profile, 93 % of respondents who knew this figure stated that there were fewer than 250 employees (the cut-off for SMEs) working in the remanufacturing part of their business. 6 % of respondents did not know the answer to this question.

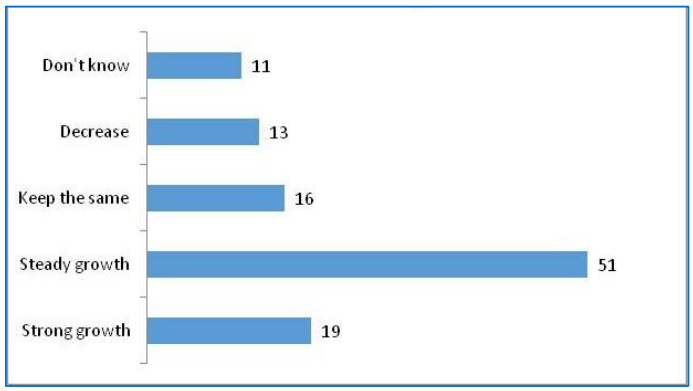
This seems to confirm that European remanufacturing, at least from the point of view of number of firms, is largely based in SMEs. With SMEs representing 85 % of new jobs and providing two-thirds of the total private sector employment in the EU over the last five years[51], it may point to remanufacturing being a useful policy tool for employment growth within the high skill arena.

Figure 17: The employment supported by remanufacturing activities (number of responses)



To the question of what changes are expected in the market for respondents' remanufactured products over the next 5-10 years, we received 110 responses (Figure 18). A strong majority of 71 % of the respondents (excluding those who did not know) expect steady or strong growth in the next 5-10 years. 13 % of respondents thought that their market would decline in the near future and 15 % foresaw no change. Those within the industry are therefore generally positive of the growth prospects of remanufacturing.

Figure 18: How the market for remanufactured products will change in the short-to-medium term (number of responses)



A sectoral analysis of the above responses, including information from other sources, points to the following sector growth profiles.

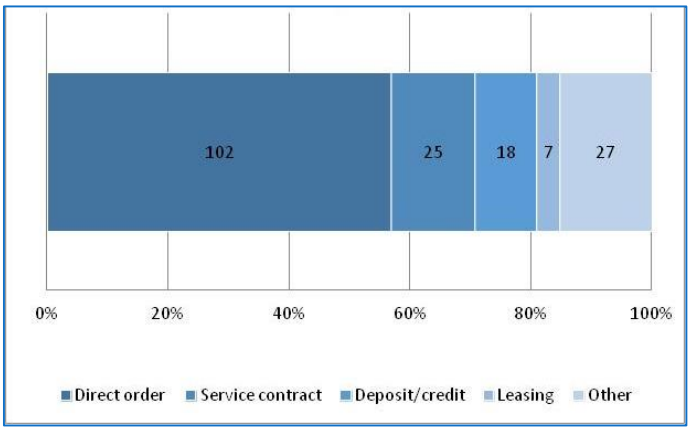
[51] http://ec.europa.eu/growth/smes/ accessed October 2015.

Table 7: Growth profile of remanufacturing intensive sectors

Growth profile	Sectors
Low	HDOR, Ink+toner cartridges, Machinery, Marine, Tyre retreading
Steady	Aerospace, Automotive, Rail
High	EEE (ex. ink+toner cartridges), Furniture, Medical equipment

Respondents were asked to classify their business model by choosing from a list including: direct order, service contract, deposit/credit, leasing or other. Of the 179 respondents to this question, 57 % assessed that their company's remanufacturing business relied on direct orders, while 14 % classified their business model as service contract and 10 % as deposit/ credit (Figure 19). 'Direct order' increases to over two thirds of responses if we omit the 'Other' group, which contained several comments that would not traditionally be considered as a business model e.g. non-profit.

Figure 19: Business models of the companies of the respondents (number of responses)



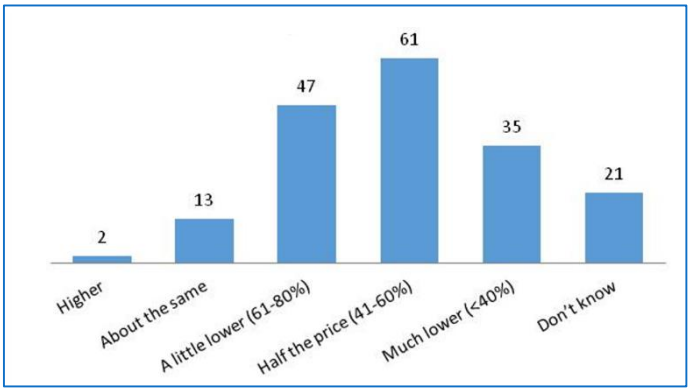
A deeper look at the survey information suggested that no particular sectors were associated with specific models apart from perhaps aerospace that had a tendency toward service contracts. Considering the long history of remanufacturing-type activities in aerospace, it might be argued that this sector is potentially more sophisticated in its understanding of remanufacturing than other sectors. It may therefore be that the service contract business model is the most appropriate for remanufacturing as it ensures performance for the customer by moving this risk to the manufacturer, with customer concern around product quality effectively become irrelevant allowing the remanufacturer to deliver the most cost-effective approach and still deliver the appropriate performance.

This fits well with circular economy thinking around servitisation of products - selling performance rather than product - for example Philips and Turntoo providing light (a service) rather than lightbulbs (a product) at Schiphol airport. This servitisation forces Philips to develop lighting fixtures with serviceability and remanufacture i.e. replacement of individual components specifically in mind. Philips has therefore designed and innovated to a solution that makes it economical for this model to work.

Beyond the three models highlighted above (direct order, service contract, deposit/credit) *leasing* was reported by only 4% of responses. Notably, most of these were focused around the EEE sector, or more specifically electronics: ICT+mobile and Ink+toner cartridges.

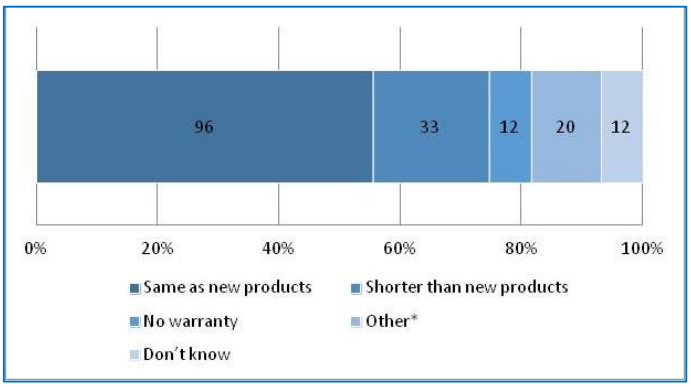
179 responded about the pricing of how their remanufactured product compares to the price of comparable new products. Two said that their products command a higher-than-new price, but 91 % of respondents (excluding 'Don't know') said their remanufactured products sell for a price lower than that of a new product, with over 60% saying that the price realised was no more than 60% of a new product. This clearly poses a barrier and an opportunity to further remanufacturing growth; if consumers recognised that the products are indeed as good as new and were willing to pay a similar price to a new product, the industry turnover could be roughly 50% bigger without any more remanufacturing activity.

Figure 20: The answers given to the question of what the price of their remanufactured product is compared to a comparable new product (number of responses)



173 answered the question about what kind of warranty is offered on their remanufactured products, as summarised in Figure 21. This highlights an issue around a lack of understanding of the term remanufacturing, with some 7 % of those that knew responding that they provided no warranty, a key tenet of remanufactured products.

Figure 21: Types of warranties offered on remanufactured products (number of responses)



To end the survey, the respondents were asked how important various drivers (motives) and barriers are to remanufacturing. The motives and barriers were rated on a scale of 1 (unimportant) to 4 (very important) by the respondents. Figure 22 charts the drivers that respondents considered quite or very important.

Interestingly, three of the top four most important reasons were 'Company profitability', 'Strategic advantage', and 'Increase market share'. This highlights a positive market view of

remanufacturing by those closest to it, showing that it is viewed as a growing and key segment of manufacturing. The fourth was 'Environmental responsibility', which suggests that remanufacturing is not only seen as an economic opportunity but that there is also a good understanding of the benefits associated with remanufacturing and linkages to the circular economy. The fifth ranked motive was Secure spare parts supply which is an integral enabler for a remanufacturing type business. At least 70% of respondents highlighted these five motives.

A little less important as motives were Customer pressure, Product warranties, and Asset brand protection. These focus less on market conditions but more around customer assurance and engagement that setup up the preconditions for remanufacturing.

Notably, Government legislation and Secure government subsidies were not cited often as important motivation for remanufacturing, suggesting either that there is little legislation / subsidies to promote remanufacturing g and/or that other factors like Company profitability far outweigh the policy levers.

Figure 22: Motives rated as 'quite' or 'very' important (percentage of respondents)

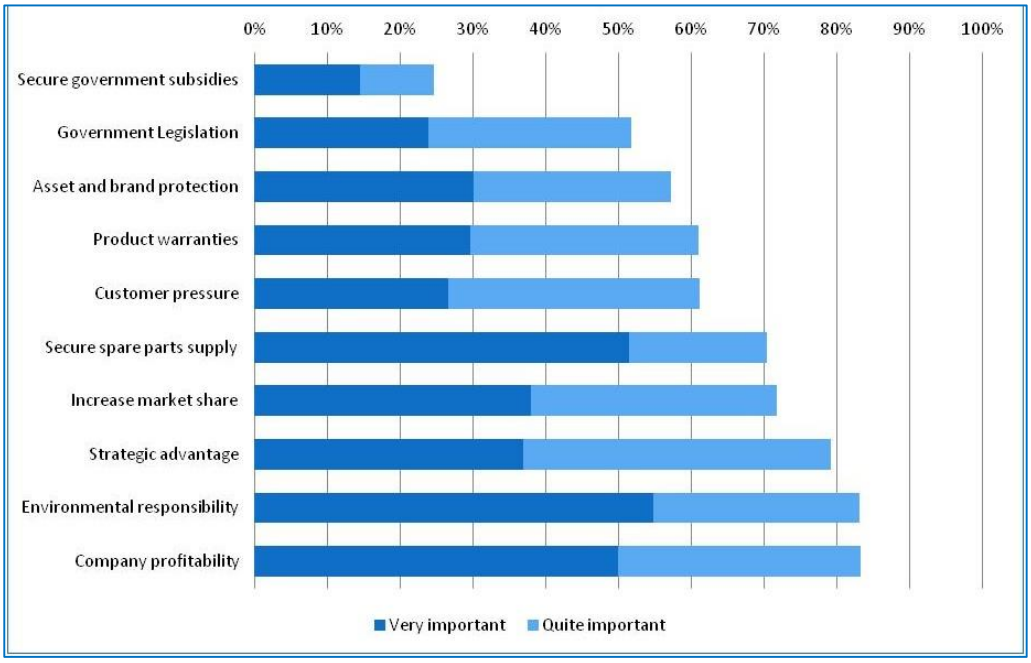
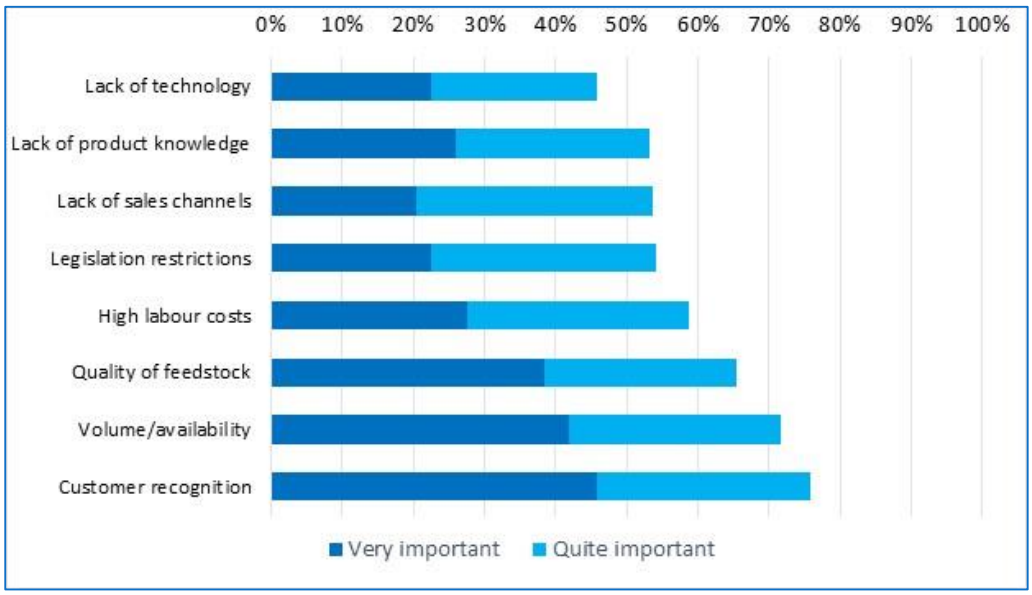


Figure 23: Barriers seen as 'quite' or 'very' important (Percentage of respondents)



The most significant barrier identified was 'Customer recognition'. This underlines the need for customers not only to be aware of remanufactured products and their environmental benefits, but also to have an understanding of the workmanship that goes into a quality remanufactured product and hence to pay accordingly. Without it, the economics of remanufacturing could be undermined, or there will only be niche markets for specific cost-effective products to be remanufactured and the remainder of end-of-life products will be lost to recycling or landfill. This concept is linked to the fourth most important barrier, 'High labour costs'. If remanufactured products could be sold for higher prices, either remanufacturing could occur in high wage areas e.g. Western Europe or, more likely, remanufacturing which currently occurs in emerging markets could move to Europe. The latter point is supported anecdotally by remanufacturers that remanufacture in Middle East and North Africa that would be able to move activity to Europe if wages were lower or that prices of remanufactured goods were higher. Further work would be required to quantify the volume and associated value of this structural industry change, but it is certainly an issue for several remanufacturers we spoke with.

Beyond 'Customer recognition', access to core (i.e. 'Volume/availability') was the next most important, highlighting the need for improved reverse logistics capabilities across the industry. 'Quality of feedstock' was seen as next important; while access to core is clearly important it is undermined if the available core is damaged or in poor condition. An example of this is in the business-to-consumer (B2C) printer cartridge market where there are a lack of facilities to support recovery of high quality core. Where facilities do exist, core is often co-collected rather than through a bespoke cartridge collection facility, meaning the core can be contaminated by foreign materials such as liquids.

3.3 Comments on remanufacturing

Assembled below are paraphrased comments, received predominantly via the survey but also through engagement with remanufacturers.

3.3.1 Motives and barriers

- A clear definition of waste and understanding by customs officials is required.

- Every country seems to develop different rules on what is allowed to be imported or exported. There is no single repository available on this and, with a centralised remanufacturing centre, it is very hard to keep up with the uneven legislative landscape.
- Many countries outside the EU have either import restrictions for remanufactured products or export restrictions for core.
- Transboundary shipments of waste and the interpretation of extended producer responsibility (EPR) different nation by nation.
- International trade barriers / import bans for recycled parts/ restrictions in cross-border repatriation of used parts are all barriers.
- High taxes can make remanufacturing prohibitive in some cases.
- The End of Life Vehicle (ELV) Directive[52] motivates dismantlers to focus on direct resale of components; often products that could be remanufactured end up in scrap. A significant barrier also is that dismantlers work on ELVs up to 25 years of age, meaning the parts are not very valuable.

3.3.2 *Policy measures to support remanufacturing*

The following **economic** measures to support remanufacturing were proposed:

- Grants to support remanufacturing.
- Tax relief for customers who buy remanufactured products e.g. reduce VAT due to the environmental gain.
- Tax or environmental subsidies like those subsidies for renewable energy.
- Tax allowances to encourage leasing.
- Grants and certification advice.
- Funding to support established remanufacturers.
- Loans for investment.
- Loans for products that remain in use through remanufacture.

The following **market** measures to support remanufacturing were proposed:

- Make it mandatory to sell remanufactured product as a percentage of sales of the aftermarket.
- Create a voluntary code of practice or stewardship scheme run by a competent body.
- Reclassify core as a commodity, rather than scrap, for trade and customs purposes.
- Introduce genuine EPR for EEE[53] (i.e. down to product level recovery rather than for generic recovery of all WEEE[53]) for material-only recycling.
- Obligate repair and remanufacturing with appropriate guidelines.
- Create a simple program for specifying the Intrastat reporting required for used parts.
- Encourage take-back by OEMs and thus promote design for remanufacture - most large OEMs are not interested as it is not seen as core business.
- Clearly label product as remanufactured.
- Eliminate non-innovative OEM patents which are designed to cut out remanufacturing rather than protecting innovation.
- Protect remanufacturing as an industry, via WEEE or similar efforts.

---

[52] The Directive on End-of Life Vehicles 2000/53/EC aims to reduce of waste arising from passenger cars (M1) and light commercial vehicles (N1) at end-of-life. The Directive covers aspects during the life cycle of a vehicle and aspects related to waste treatment operations.

[53] EEE = electrical and electronic equipment; WEEE = waste EEE

- Cut or tackle tariffs on products from the Far East which infringe intellectual property.
- Ensure access to spare parts for third party remanufacturers.
- Create apprenticeships or college courses specific aimed at remanufacturing.
- Create EU-funded technical courses for remanufacturing.

The following measures on **movement** were proposed to support remanufacturing:

- Allow free movements of goods across borders (in and out) for remanufacturing and refurbishment purposes. Only a centralised approach to remanufacturing can be made profitable; thus the collection of core in a central location is required, requiring free movement of core. If remanufacturers are forced to run local operations, more potential core will go to scrap.
- Improve Customs clearance / reduce bureaucracy.

The following measures on **consumer demand** were proposed to support remanufacturing:

- Educate retailers of the benefits of reuse.
- Create universally-developed and accepted standards on remanufacturing.
- Motivate customers to demand remanufactured goods through retailers' reporting of corporate social responsibility in annual reports.
- Give support in advertising remanufacturing.
- Governments to lead by example and use locally-produced remanufactured products and/or source products based on product emissions.
- Encourage public sector procurement of equipment remanufactured to specified quality standards.
- Incorporate remanufacturing quotas in green procurement.
- Increase the number of procurement tenders in which price does not score higher than the environmental score.
- Promote existing standards (e.g. PAS 141[54]) to raise public awareness.
- Create national and sector targets for remanufacturing.
- Encourage meaningful application of Article 4 of the recast WEEE Directive[55]

[54] Publicly Available Specification (PAS) 141 is a process management specification for the re-use of used and waste electrical and electronic equipment (UEEE and WEEE)

[55] The WEEE Directive is the EC Directive 2012/19/EU on waste electrical and electronic equipment. It sets collection, recycling and recovery targets for electrical goods.

4 Overview of European remanufacturing

4.1 Industry sector overview

This section provides an overview of the European remanufacturing sector, including information on the size and scope of remanufacturing; turnover, employment, amount of processed core; remanufacturing intensity (i.e. remanufacturing as a proportion of the relevant manufacturing) and repair activities. This chapter aggregates and summarises information presented in subsequent chapters of the report.

The remanufacturing industry comprises a diverse set of sectors, each with its own challenges, which share some clear underlying similarities - particularly around customer recognition of remanufactured goods, volume / quality of core, and access to core.

4.2 Market size

The market survey has sought to collect data from remanufacturers across Europe, with particular focus on those sectors where the majority of remanufacturing activity resides (in descending order of value): aerospace, automotive, heavy duty and off-road (HDOR) equipment, EEE, machinery and medical equipment, and on smaller sectors such as (office) furniture, rail (rolling stock) and marine. The wider market sampling provided information on the proportion of the sector that relates to remanufacturing. Together they provided a view of the remanufacturing landscape across Europe.

Table 8: Summary of market size of remanufacturing activities by sector

Sectors	Turnover (€bn)	Firms	Employm't ('000)	Core ('000)	Intensity
Aerospace	12.4	1,000	71	5,160	11.5%
Automotive	7.4	2,363	43	27,286	1.1%
EEE	3.1	2,502	28	87,925	1.1%
Furniture	0.3	147	4	2,173	0.4%
HDOR	4.1	581	31	7,390	2.9%
Machinery	1.0	513	6	1,010	0.7%
Marine	0.1	7	1	83	0.3%
Medical equipment	1.0	60	7	1,005	2.8%
Rail	0.3	30	3	374	1.1%
Total	29.8	7,204	192	132,405	1.9%

The value for all manufactured products in the above remanufacturing-intensive sectors is €1.5 trillion. Remanufacturing makes up a small share of European manufacturing output, accounting for an estimated 1.9 % of total production value in these sectors – the remanufacturing 'intensity'. However, despite the relative small size of the activity, it is seen as a key part of company strategy and a potential differentiator for businesses, as discussed in Section 3.2. Remanufacturing is viewed favourably for its potential to decrease raw material risk, reduce environmental burden, grow market share and increase profitability.

The aerospace (42 %), automotive components (25 %) and HDOR (14 %) sectors are estimated to be the largest in terms of production value and make up some 80 % of the European remanufacturing industry. They generally represent the more established remanufacturing sectors, focused on heavy metal fabricated products. Aerospace remanufacturing is spurred on by the continuing growth in air travel combined with an aging

aircraft fleet that requires continuous maintenance and overhaul services. While there may be better prospect for continuing growth in the automotive sector than in HDOR, these two sectors share similarities and some firms perform activities in both. Therefore our analysis may suffer slightly from 'leakage' between automotive and HDOR. An analysis by Fernand Weiland in 2012 concluded that the combined markets were €10.5 billion[56]; our analysis gives a not dissimilar combined figure of €11.5 billion for 2015, equivalent to a CAGR[57] of 3 % between 2012 and 2015.

Outside these key sectors, the sectors more focused on electronics (EEE and medical equipment) represent growth areas due to an underlying trend in most sectors that electronics are being integrated into more and more product systems. This presents both a potential barrier and an opportunity: there is an increased need for electronics skills in the remanufacturing industry to be able to unlock this potential market value which could not be serviced without the appropriate electronics capability. For example, we heard in our discussions with automotive engine remanufacturers that some work requests were having to be turned down due to the lack of ability to service the electronics interfaces.

The four key regions estimated to account for some 70 % of remanufacturing value in Europe are Germany, the UK (& Ireland), France and Italy. Table 9 shows that Germany undertakes most remanufacturing by a significant margin, making up almost a third of the European market. It has a strong position in aerospace, automotive and HDOR sectors. This position mirrors Germany's status as a manufacturing powerhouse, particularly as it has strong automotive and HDOR capabilities. Remanufacturing in France and in the UK & Ireland are similar in size to each other, and is estimated to be around half that in Germany. Italy's remanufacturing industry is slightly smaller than expected considering the size of its manufacturing industry. This is partly due to the distribution of the aerospace sector across Europe: Germany, France and the UK are major global aerospace maintenance, repair and overhaul hubs. There is also reportedly less remanufacturing in Italy's automotive sector perhaps due to cultural preferences.

[56] *Remanufacturing of Heavy Duty Vehicle Components*, Fernand J.Weiland

[57] CAGR = compound annual growth rate i.e. average year-on-year growth %

Table 9: Summary of market size of remanufacturing activities by region (turnover, €m)

Turnover	Benelux[1]	Central[2]	Eastern[3]	France	Germany	Italy	Medi-terranean[4]	Nordic[5]	UK & Ireland	Total
Aerospace	389	399	513	2,311	3,814	1,127	816	368	2,698	**12,436**
Automotive	395	652	692	754	2,370	699	790	273	766	**7,393**
EEE	111	230	578	355	646	592	311	106	190	**3,118**
Furniture	10	16	52	24	66	66	23	18	34	**310**
HDOR	160	227	343	633	1,108	541	380	242	509	**4,142**
Machinery	44	45	81	108	336	199	70	53	90	**1,026**
Marine	11	2	15	3	11	8	13	5	6	**76**
Medical equipment	36	70	104	112	316	61	68	83	121	**971**
Rail	11	46	41	22	61	39	48	27	49	**343**
Total	**1,167**	**1,687**	**2,420**	**4,322**	**8,728**	**3,333**	**2,519**	**1,173**	**4,463**	**29,813**

Notes: [1] Benelux: Belgium, Luxembourg, Netherlands
[2] Central (excluding Germany): Austria, Czech Republic, Slovenia
[3] Eastern: Bulgaria, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovakia
[4] Mediterranean (excluding Italy): Croatia, Cyprus, Greece, Malta, Portugal, Spain
[5] Nordic: Denmark, Finland, Sweden

4.3 Environmental benefits

Remanufacturing has significant environmental benefits by averting CO_2e emissions and diverting large amounts of product away from landfill. A high proportion of the worked material of a remanufactured good - typically up to 80 % - is retained from the original core product. This is associated with a similar retention of embedded energy and savings of emissions. Note a key distinction between recycling and remanufacturing in that the former only recovers material while the latter recovers products i.e. more value is retained.

It is notoriously difficult to perform comparative life cycle assessments for manufactured vs remanufactured goods, due to difficulties in defining the exact boundaries for assessment. We are faced with further difficulties with the range of sectors and product types represented within the sectors covered in this report. We have taken a pragmatic approach to the problem by using representative products to characterise sectors in terms of embedded material and CO_2e emissions. This approach uses information - where available - on life cycle assessments comparing new and remanufactured products, and where not available uses proxies of products from similar sectors. Beyond this, we have taken a conservative approach in some sectors where there was limited information; for example, assuming a manufactured product is equivalent to the same mass of its base steel material. Therefore the associated emissions for the production of that amount of steel is quoted, which omits any further embedded energy / emissions required to craft the material into the appropriate form and function. This method is consistent with the *Remanufacturing in the UK* report, 2009, Centre for Remanufacturing & Reuse.

Table 10 presents the estimated savings of material and CO_2e due to remanufacturing in Europe. HDOR and automotive sectors are seen to be major contributors to savings, but note that calculations for aerospace used the slightly more conservative approach to materials and emissions averted based on the steel amount, as no impact information was available. A landfill saving of 2.3 million tonnes and a CO_2e saving of 8.3 million tonnes is clearly a very significant positive environmental benefit.

Table 10: Summary of remanufacturing material and equivalent CO_2 savings

Sectors	Materials ('000 t)	CO_2e ('000 t)
Aerospace	136	356
Automotive	902	3,298
EEE	150	177
Furniture	76	131
Heavy duty and off road equipment	855	3,458
Machinery	35	393
Marine	15	40
Medical equipment	22	58
Rail	69	344
Total	**2,260**	**8,255**

As a rough comparison to highlight the scale of these figures, the mass of material saved annually by European remanufacturing is equivalent to the mass of all new registered passenger cars in the UK in 2013[58], or all registered passenger cars in Slovakia. The annual CO_2e savings is roughly equivalent to the emissions generated by all cars in Belgium.[59]

[58] The Eurostat/ITF/UNECE Common Questionnaire on Inland Transport; based on assumption of 1,200 kg per automobile

[59] Based on 5.493 million cars in 2013 (Eurostat) at 130g/km and 12,000 km per year

We are aware of only one other previous estimate for CO_2e savings by European remanufacturing, which gave a figure of 2.38 million tonnes.[56] We do not have details of the methodology but, considering the imprecise nature of carbon footprint analyses especially considering the wide scope of sectors and product types, it does provide reassurance that European remanufacturing is indeed providing a benefit of many millions of tonnes of CO_2e.

4.4 Societal benefits

Remanufacturing has significant scope to create highly skilled jobs. As Figure 24 highlights, a very genericised review of an income statement (in effect a 'per product' view) for both a manufacturer and a remanufacturer highlights that, while the manufacturer may be able to generate higher revenue for a given number of products sold, it has significantly higher costs from procuring all the raw materials (and paying for the risk associated with component supply chains) when compared to a remanufacturer. However, the manufacturer will need fewer employees per unit when compared to a remanufacturer as the work requirement is higher for remanufacturing considering all the inspection, disassembly, remediation, reassembly, testing and other associated activities required. Therefore fixed costs will be proportionately higher for a remanufacturer. Subtracting the costs from turnover results in a similar profit level for both companies – crucially, with an **increased number of highly skilled employees in remanufacturing**. Further, if customer perception of remanufactured goods could be improved with commensurate increase in revenue per product, the profit per product could be increased.

Figure 24: Manufacturer versus remanufacturer income statement comparison

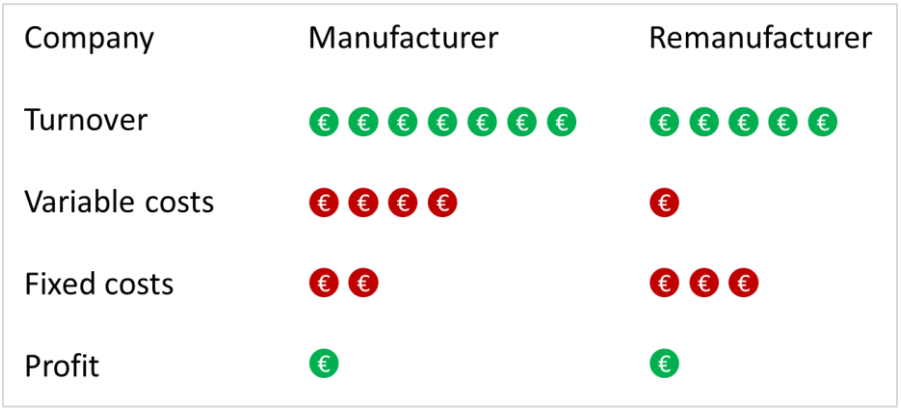


Table 11 overleaf presents the estimated employment in remanufacturing across Europe by region and by sector. The total number of jobs across Europe is estimated to be in the region of 192,000, with aerospace, automotive and HDOR accounting for nearly 80 % of this.

Table 11: Remanufacturing employment across Europe

Employment	Benelux	Central	Eastern	France	Germany	Italy	Mediterranean	Nordic	UK & Ireland	Total
Aerospace	2,110	4,630	10,780	9,010	17,370	4,390	6,990	3,030	12,220	70,530
Automotive	1,990	4,210	6,940	5,280	10,440	4,890	4,570	2,040	3,090	43,450
Consumer products	590	2,670	8,190	2,200	4,040	4,340	3,150	700	1,680	27,560
Furniture	80	230	1,200	190	550	520	300	140	350	3,560
Heavy duty and off road equipment	1,520	1,670	3,440	5,810	6,380	5,050	2,300	1,760	2,960	30,890
Machinery	310	240	710	680	1,630	1,260	420	320	290	5,860
Marine	120	20	250	40	70	90	110	40	40	780
Medical equipment	230	770	1,560	650	2,030	350	520	440	490	7,040
Rail	120	340	490	220	350	400	340	220	300	2,780
Total	7,070	14,780	33,560	24,080	42,860	21,290	18,700	8,690	21,420	192,450

Notes: [1]*Benelux: Belgium, Luxembourg, Netherlands*
[2]*Central (excluding Germany): Austria, Czech Republic, Slovenia*
[3]*Eastern: Bulgaria, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovakia*
[4]*Mediterranean (excluding Italy): Croatia, Cyprus, Greece, Malta, Portugal, Spain*
[5]*Nordic: Denmark, Finland, Sweden*

4.5 Potential of the European remanufacturing industry

This section estimates the size of the future European remanufacturing industry i.e. the potential out to 2030. This has been done on a scenario basis to demonstrate the breadth of potential for the industry. The three scenarios presented reflect different degrees of market development based on increasingly positive perspectives for the remanufacturing industry.

The three scenarios presented are:

- **Base case:** assumes approximate current growth rates through to 2030 for the remanufacturing intensive sectors discussed in this report. An increased understanding of remanufacturing value both from manufacturers and from consumers support continuing growth resisting some of the downward pressure exerted on the wider manufacturing industry in Europe. This does not incorporate any step-change in the remanufacturing industry, rather just positive organic growth for the industry.
- **Stretch case:** a scenario where the value of remanufacturing from the perspectives of creating high skill jobs and environmental benefits is well understood by policy makers, industry and consumers alike. Remanufacturing is thus incorporated as an important strategy within a wider circular economy plan for the EU. Appropriate policies and promotional activities to foster growth in the remanufacturing industry are adopted resulting in a higher intensity of remanufacturing as a proportion of manufacturing.
- **Transformation case:** a scenario where remanufacturing becomes a key strategic pillar for the EU, taking much of the investment and effort away from lower level waste hierarchy activities (Recycle, Recovery and Disposal) and focus on remanufacturing and reuse activities. This would be done based on the belief that remanufacturing and reuse would create significant numbers of high skilled jobs, ability to avert waste to landfill and associated greenhouse gas emissions. The significant effort results in very significantly increased intensity of remanufacturing as a proportion of manufacturing by 2030.

The base assumptions and methodology were tested with industry experts as a reasonable approach to estimating the future potential of the remanufacturing industry in Europe. The potential is presented through the following assumptions for the three scenarios:

- **Base case:** based on assumptions of remanufacturing sectors growing under the following conditions:
  - **Low [0.5% p.a.]:** Heavy Duty and Off Road, Machinery, Marine
  - **Steady [3% p.a.]:** Aerospace, Automotive, Rail
  - **High [5% p.a.]:** EEE, Furniture, Medical Equipment
- **Stretch:** taking the 2030 scenario further, with appropriate policies and promotional activities to improve remanufacturing, through the increase of sector intensities (i.e. the proportion of manufacturing sales that is attributable to remanufacturing) in the following manner:

- **Intensity increase of 25%:** Heavy Duty and Off Road, Machinery, Marine
- **Intensity increase of 50%:** Aerospace, Automotive, Rail
- **Intensity increase of 100%:** EEE, Furniture, Medical Equipment

- **Transformation:** taking the Stretch scenario further with investment, strong policy support and large scale promotional activities to embed remanufacturing into manufacturing. The intensities by sector is assumed to therefore follow the following profile:
  - **Intensity increase of 50%:** Heavy Duty and Off Road, Machinery, Marine
  - **Intensity increase of 100%:** Aerospace, Automotive, Rail
  - **Intensity increase of 200%:** EEE, Furniture, Medical Equipment

A scaling quotient for employment of 0.85 was used to capture the fact that as the scale of remanufacturing activities increase, the number of employees to produce the same amount of value (or products) should decrease due to efficiency improvements. This is equivalent to requiring 80% more employees for a doubling i.e. 100% increase in production. For a trebling of production i.e. 200% increase in production, the increase in employees required is 154%.

With the parameters described above, the Base Case scenario would yield a production value of €46 billion, employing some 300,000 people and averting 16 million tonnes of carbon dioxide equivalent. This is a little over a 50% increase in remanufacturing from today's levels.

The Stretch scenario yields more than double today's levels with a value of €73 billion, employing 450,000 and averting 16 million tonnes of carbon dioxide equivalent.

In the Transformation scenario by 2030, the value of European remanufacturing would be close to €100 billion employing over half a million people and averting some 21 million tonnes of carbon dioxide equivalent.

In terms of net jobs created, which corrects for displaced manufacturing jobs due to remanufacturing jobs, the Stretch scenario would yield nearly 34,000 net new jobs while the Transformation scenario would be close to 65,000 extra jobs relative to the 2030 Base case. Compared to 2015, this is equivalent to 144,000 and 175,000 jobs respectively.

Table 12: Future potential of EU remanufacturing industry

	Turnover			Employment			CO2e (kte)			Net Employment		
Sectors	**Base case**	**Stretch**	**Transformation**	**Base case**	**Stretch**	**Transformation**	**Base case**	**Stretch**	**Transformation**	**Base case**	**Stretch**	**Transformation**
Aerospace	19.4	29.1	38.7	110	155	198	555	832	1,110	-	12.6	24.1
Automotive	11.5	17.3	23.0	68	95	122	5,137	7,706	10,275	-	9.7	18.6
EEE	6.5	13.0	19.4	57	103	145	369	737	1,106	-	3.1	5.8
Furniture	0.6	1.3	1.9	7	13	19	273	546	818	-	1.3	2.4
HDOR	4.5	5.6	6.7	33	40	47	3,726	4,658	5,590	-	3.5	6.9
Machinery	1.1	1.4	1.7	6	8	9	423	529	635	-	0.3	0.5
Marine	0.1	0.2	0.2	1	2	2	62	94	125	-	0.2	0.3
Medical equipment	2.0	4.0	6.1	15	26	37	120	240	360	-	2.3	4.2
Rail	0.5	0.8	1.1	4	6	8	537	805	1,073	-	0.7	1.4
Total	46.3	72.6	98.9	302	449	587	11,202	16,147	21,091	-	33.7	64.4

4.6 EU region specific contextual factors

The European Commission has issued several mandatory Directives that have implications for remanufacturing. EC Directives such as the Waste Framework Directive notionally encourage the development and growth of remanufacturing industries in Europe.[60] The Directive on End-of-Life Vehicles (the ELV Directive) provides guidance for harmonizing end-of-life regulations for motor vehicles among EU Member States.[61] The stated goals of the ELV Directive are to minimize the impact of end-of-life vehicles on the environment, to conserve energy, and to ensure the smooth operation of the internal market and avoid distortions of competition in the EU. The ELV Directive sets targets for reuse, recycling, and recovery. As more EU members comply with the Directive and intra-EU standards are established, the ELV Directive is likely to lead to an expanded use of remanufactured motor vehicle parts in the EU.

Similarly, the EU's Directive on Waste Electrical and Electronic Equipment (the WEEE Directive) sets targets for waste recovery, recycling, and reuse for certain electrical and electronic devices, and establishes that producers are responsible for financing the management of waste from their products.[62] The effects of the WEEE Directive on remanufacturers will vary: it may encourage reuse, including remanufacturing, but remanufacturers that are OEMs must also bear the costs of compliance as original producers of equipment covered by the Directive.

There are also restrictive policies such at the EU's Restriction of the Use of Certain Hazardous Substances (RoHS) Directive which regulates the use and amount of certain substances (such as lead) in electric and electronic components in the EU market. The RoHS Directive is of particular importance to the IT sector because IT products are likely to contain substances that are restricted under the Directive. The Directive is intended to ensure that used electronic components do not contain substances that may damage human health or the environment. However, this has reportedly driven up costs (and/or reduced the recovery of components i.e. reduced the 'circularity' of products) for some EU remanufacturers by prohibiting the reuse of components containing these substances.

4.7 Factors affecting European remanufacturing activities

4.7.1 Drivers

- **Volatility of supply:** A growing global population and increased urbanisation (70 % of the global population will live in urban areas in 2050) will increase demand for land, materials, water and energy. As a result, resources will be subject to greater competition, with potential disruption in their supply. In most cases, prices will rise and may become more volatile. Companies and nations that learn how to manufacture their products with less of these inputs will be more resilient to these effects.
- **Climate change and the increased vulnerability of global supply chains:** Climate change will have a range of impacts including rising sea levels and extreme weather events. EU manufacturers will be affected by challenges such as the disruption of their international supply chains.

---

[60] See EC Directive 2008/98/EC available from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN

[61] See EC Directive 2000/53/EC available at http://eur-lex.europa.eu/resource.html?uri=cellar:02fa83cf-bf28-4afc-8f9f-eb201bd61813.0005.02/DOC_1&format=PDF

[62] See EC Directive 2012/19/EU available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:197:0038:0071:en:PDF

- **Greater use of regulation, potential 'pricing of the environment':** Regulation is likely to focus increasingly on promoting resource productivity. For example, the aforementioned WEEE Directive aims to divert electrical equipment waste away from landfill. The Waste Framework Directive already places obligations on Member States to have in place, *inter alia*, waste prevention plans, and to adopt the waste hierarchy to prioritise 'higher actions' (remanufacturing is a waste prevention measure, though this is poorly promoted). Over the period to 2050, national and international responses are likely also to include tougher environmental standards for products and new ways to price natural resources and ecosystem services.
- **Consumer pull for eco-products:** Consumer demand for sustainable products which use less energy and fewer materials is growing, although it is not clear how far and fast demand will change, including willingness to pay. Unilever's pledge to double turnover while reducing its environmental impact[63], and Marks & Spencer's Plan A to go 'beyond compliance' on the environment, are examples of corporate responses.
- **Making robust products for 'collaborative consumption':** ICT-based systems are facilitating new business models based on shared use of assets. This shifts the business model from ownership to access, motivates manufacturers to provide robust products, and allows the creation of new service-based revenue streams.
- **Emergence of a 'circular economy' in which end-of-life products are reused, remanufactured and recycled:** Resource scarcity and higher costs for energy and waste disposal will shift manufacturing value creation to new models:

    - **reuse**: redeploying a product without the need for refurbishment
    - **remanufacturing**: returning a product to at least its original performance with a warranty that is at least equivalent to that of the newly manufactured product
    - **cascaded use**: using a product for a lower value purpose, for example turning used clothes into pillow stuffing or redeploying computers within a business for less demanding applications
    - **recycling**: extracting the raw materials and using them for new products
    - **recovery**: re-using materials for a low value purpose such as road base or combustion to produce heat.[64]

4.7.2 Motives

The following incentives to remanufacturing were identified:

- **Economic**: Remanufacturers benefit from the greater profit margins associated with service-based rather than 'make and sell' businesses; for example, product service systems promote remanufacturing rather than replacement.
- **Cost savings**: Remanufactured product is usually lower cost than new product. The cost differential varies from sector to sector and also within product lines but the survey showed over two thirds of remanufactured product sells for between 41 % and 80 % of the cost of a new product.
- **Access to used product**: Many remanufacturing businesses are supply-constrained, and increasing collection rates will enable remanufacturing to grow.
- **Reduced lead times**: Remanufactured products can have reduced lead times, minimising disruption due to failure of key systems.

---

[63] https://www.unilever.com/sustainable-living/the-sustainable-living-plan/our-strategy/

[64] https://www.gov.uk/government/publications/future-of-manufacturing/future-of-manufacturing-a-new-era-of-opportunity-and-challenge-for-the-uk-summary-report

- **Alternative businesses models**: These include rental- and service-based offerings which tend to lead to better relationships with customers and a more skilled and adaptable workforce. This can also lead to a reconfiguration of the supply chain to service the new business model.
- **A reduced risk of resource insecurity**: By keeping products 'whole', remanufacturing reduces risks associated with long supply chains.
- **Environmental legislation**: The ELV Directive poses a problem for recycling but could become an opportunity for remanufacturers - since January 2015, 95 % of a vehicle's material must be reused or recovered.

4.7.3 Barriers

The barriers to uptake of remanufactured products can be divided into those affecting remanufacturers and those affecting consumers/procurers. Those affecting remanufacturers include:

- **Lack of technical information on third party products**: The knowledge necessary to remanufacture products effectively is not readily available to non- OEMs.
- **Legal ambiguity**: Lack of clarity over what remanufacturing entails. There is no clear guidance on the use of remanufactured components in new products or whether remanufactured products need to be declared as 'second-hand'. Also, there are issues over the effect on remanufactured products of legislation such as: the WEEE Directive, the Waste Framework Directive, the ELV Directive, the Sales of Goods Act, the REACH Regulation, the RoHS Directive and the Energy Using Products Directive.
- **Definition of waste**: Ambiguity over whether the activities undertaken during remanufacturing are considered 'waste processing' may affect remanufacturers. For example, the requirement to control and process products that are legally considered waste adds additional administrative and compliance costs to a business. There is a business risk where regulatory guidance is not provided.
- **Competition from lower cost products**: This is widely cited as an issue across several remanufacturing sectors. The sale of anecdotally inferior products undercuts the market for remanufactured products.
- **Lack of technically skilled engineers**: Skills shortages affect the industry - as they do in the manufacturing sector.
- **Poor design for remanufacturing**: Particularly where remanufacturing is not embedded within the OEM culture, remanufacturing can sometimes be inhibited by poor design.
- **Technology shifts**: As advances in materials and electronics occur, remanufacturers also need to make advances in their processing technologies to ensure that the end product matches the performance of new products. This includes energy efficiency, new materials and the incorporation of more electric/electronic systems into traditionally mechanical-based products.
- **Reverse logistic costs**: The transport of large or bulky items can be a significant cost which may prevent remanufacture of certain goods or prevent the remanufacture of goods in certain sparsely populated areas.
- **Cost and availability of storage space:** Storing large volumes of reused components is a large expense on remanufacturers.
- **A lack of remediation techniques**: In some sectors, technological advances in remediation are needed to ensure that remanufactured products match the performance of new products.

5 Aerospace

5.1 Description of sector

5.1.1 Definition of aerospace sector

The European aerospace industry encompasses activities including the design, development and production of civil and military aircraft, aero engines, helicopters, unmanned aerial vehicles and their associated systems, parts and equipment.[65] The sector is characterised by some of the most durable, long-lived products covered in this report. Civil aircraft typically have a lifespan of 25 years or more and can have their life prolonged further by conversion to a freight aircraft. Military aircraft have longer life cycles; military transport aircraft may have a life span of 30 years or longer.[66] The physical life-limiting factor for aircraft is the number of cycles of pressurization and depressurization of the fuselage (one cycle per flight) which affects the durability of the fuselage structure. Hence, long haul aircraft have a longer life span than short haul, which make more cycles/flights per day. Operating costs are another factor that can affect the in-use life of an aircraft.

Maintenance, repair and overhaul (MRO) activities make up an important part of the aerospace sector. The focus of this chapter is on civil aeronautics, which excludes activities relating to space and those sectors relating to land and naval defence equipment.[65] However, if the available data sources do not allow them to be adequately differentiated, the highly interdependent civil and military aviation sub-sectors are considered together.

5.1.2 Structure of aerospace sector

The aerospace remanufacturing businesses in Europe are broadly made up of OEMs and non-OEMs. This latter group consists of a wide range of companies including large subsidiaries of civil airline operators, such as Lufthansa Technik (Germany), Air France KLM Maintenance and Engineering (France and the Netherlands) and British Airways Maintenance and Engineering (UK). Specialist independent operators are also active in this area. These companies are termed 'MROs' and carry out maintenance, repair and overhaul activities in the aerospace industry including aircraft servicing and maintenance checks.

Many of the large independent third-party MROs began life as an in-house MRO operation for national or other airlines. The business model typically involves creating joint venture companies in EU states with low labour costs (or even outside the EU), and signing long-term risk-sharing agreements with airlines. For example, Lufthansa Technik has bases in Bulgaria, Ireland, Malta and Hungary.[67] The larger of these MROs carry out overhaul work in-house, while smaller operators tend to carry out more specialised tasks, generally subcontracted out by the MROs. The major European MROs often have global reach. Lufthansa, for example, employs 26,000 people in 30 operating subsidiaries and affiliates worldwide.[68]

Though traditional MROs currently control the largest share of the maintenance, repair and overhaul market, including remanufacturing, OEMs are increasingly offering service-based purchasing agreements, which are in direct competition with the service contracts offered by

---

[65] European Commission, *Annual Analyses of the EU Air Transport Market 2011*, Final Report 2013: http://ec.europa.eu/transport/modes/air/internal_market/observatory_market/doc/annual-2011.pdf.

[66] A national aviation organisation in Germany

[67] http://www.lufthansa-technik.com/lufthansa-technik-sofia

[68] http://www.lufthansa-technik.com/facts-and-figures and http://www.lufthansa-technik.com/locations

the MROs. The OEMs Airbus and Boeing, which both offer these types of products, can thus be considered as MRO integrators. Boeing *GoldCare* is an integrated service providing asset management, engineering, maintenance and support for airline customers; available for the 787, Next Generation 737 and the 747-400 with the intended introduction of similar packages for the 777 and 747-8123. Airbus has a similar product named *Flight Hour Services* which is modular in the sense that an airline can select the level of support it needs to complement its own maintenance, repair and overhaul capability, or defer all maintenance to Airbus and its service partners under a *Tailored Support Package*.[69]

5.2 The European aerospace remanufacturing landscape

The term 'remanufacture' is not commonly used in the European aerospace sector.[70] Remanufacturing in the aerospace sector entails following European Air Safety Authority (EASA) regulated specific procedures set out in the Component Maintenance Manual (CMM).[71] Other terminology used in the aerospace sector when referring to a remanufacturing process includes 'overhaul', 'repair', 'reconditioning', 'repurposing' and 'refurbishing'.

The role of remanufacture is to keep an aircraft 'airworthy'. Airworthy is a legal term defined and enforced in Europe by EASA, and in the USA by the Federal Aviation Authority. Similar rules are set by national authorities for military aircraft. Broadly, 'remanufacturing' in the aerospace sector is any activity that keeps an aircraft airworthy and therefore effectively indistinguishable to the end consumer. This covers a wide range of services that include the maintenance, repair and overhaul of used components, the manufacture and integration of new parts, and the enhancement of performance to keep up-to-date with advances in technologies. Strictly, warranties are generally not offered but operators must nevertheless abide by strict rules governing the sector and guarantee service levels during a contract period, thus in effect providing a performance guarantee for the customer i.e. abides by the 'as-new' principle of remanufacturing.

The remanufacturing process involves the removal of a unit from an aircraft to a workshop, disassembly, inspection, repair and replacement of parts, reassembly and return to the aircraft once it is tested according to strict CMM procedures. It is difficult to define exactly what constitutes a remanufacturing process in the aerospace sector but, in general, most remanufacturing activity takes place when work is described as being 'repair' or 'overhaul' rather than 'servicing'.

In the aerospace sector the term 'rotables' describes products and service systems that embed remanufacturing and maintenance across operators from a shared pool of components. Rotables are distinct from 'repairables' and 'consumables' in that they can be overhauled or remanufactured. One industry expert suggested that a significant portion of the original product would need to be replaced for the product to be considered remanufactured. Given the strict safety and quality regulations that govern the aerospace industry, 'remanufacture', 'overhaul' and often even 'repair' amount to the same thing.[72]

---

[69] European Commission, *Annual Analyses of the EU Air Transport Market 2011*, Final Report 2013: http://ec.europa.eu/transport/modes/air/internal_market/observatory_market/doc/annual-2011.pdf.

[70] *Remanufacturing in the UK, 2009*, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf.

[71] EASA has jurisdiction over airworthiness approvals for aircraft, engines, propellers and parts in Europe. EASA works with National Aviation Authorities (NAAs) of the EU in the interest of aviation standardisation. EASA sets policy for aeronautical repair stations (Part-145 organisations) in Europe and issues repair station certificates.

[72] An independent operator in the UK

Firms that remediate aircraft cabins strip and remanufacture the interior trim and seats, repairing damaged aluminium and composite parts as required, and call this type of activity 'repurposing'. Engines, airframes, hydraulics and avionics all require remanufacture, in this case referred to as 'overhaul', after a set number of operating hours or cycles to return them to an airworthy condition. Aircraft may also undergo a 'refit', when older models - of military aircraft in particular - are remanufactured to incorporate the most up-to-date technology - such as weaponry and detection systems. Thus aircraft refits are also effectively another example of remanufacturing in the aerospace industry.

It is the role of MROs to prolong the life of aircraft and their components by conducting airworthy repairs on the constituent parts and to keep costs down for their customers, the aircraft carriers. Only companies approved or certified as Part-145 organisations by EASA can remanufacture aircraft components or perform remanufacturing activities in the EU. MROs may have EASA approval to remanufacture or make a range of repairs to many different parts, or they may be a smaller operator that has approval to remanufacture or repair only a single part.

The maintenance, repair and overhaul sector can be split into the four categories of engine, airframe and component overhaul and repair, and line maintenance, as described in more detail below. Although remanufacturing takes place across all these categories it is concentrated in engine overhaul, followed by airframe and component remanufacturing. The systems and components of aircraft that are remanufactured include the engine, airframe, avionics, hydraulics and interiors, brakes, auxiliary power units, fuel systems, flight controls, thrust reversers, landing gear and electrics.

5.2.1 Engine overhaul

Engine overhaul or remanufacture is largely contracted out to the OEMs that originally manufactured the engines. Their control of the intellectual property relating to the engines enables them to capture a greater share of the aftermarket, though some specialist engine overhaul MROs (such as MTU and Vector Aerospace) also provide this service. Leading EU aircraft engine OEMs are Rolls-Royce (UK) followed by SNECMA and its subsidiary Turbomeca (both in France). Airlines that have their own in-house engine overhaul service and major component systems include Lufthansa Technik (Germany) and Air France KLM Engineering (France and the Netherlands). In addition, US-based engine manufacturer Pratt & Whitney has an aircraft engine maintenance and repair facility in Ireland. Given that aircraft can move easily from one region to another, suppliers are increasingly competing on a global basis.

5.2.2 Airframe heavy maintenance

For airframe heavy maintenance the aircraft is taken out of service and placed in a hangar where structural and airframe components are inspected, as required by the aircraft maintenance plan, and repairs made where necessary. This regularly scheduled 'heavy' maintenance check is also known as 'base' maintenance.

MROs affiliated to airlines dominate remanufacturing in the airframe segment of the market, which tends to be based on service contracts, with the remainder performed by independent third-party contractors.[73] Lufthansa Technik and Air France KLM Engineering are examples of third-party airline subsidiaries which began life as in-house airline engineering departments.

[73] USITC *Remanufactured goods: An overview of the US and Global Industries, markets and Trade*, 2012: http://www.usitc.gov/publications/332/pub4356.pdf

Each performs remanufacturing activities for its parent airlines and other airline operators. SR Technics became a separate company within the Swissair group and eventually outlived its parent to become a separate third-party supplier. Some airlines, such as British Airways, conduct most of their remanufacturing in-house.

5.2.3 Component overhaul and repair

As with engines, component overhaul and repair work is carried out in an overhaul shop, where components are inspected, repaired and tested. The scope of these activities is wide because of the vast range of different components, functions and technologies involved - from large structural parts, such as landing gear, to the advanced electronics on the flight deck.

Component remanufacturing is largely outsourced to independent third-party operators. The component remanufacturing segment is therefore more fragmented than the engine overhaul sector, with many more independent third-party operators involved. OEMs, airline operators and their subsidiaries, and independent suppliers remanufacture aircraft components. The share of the activities between these types of firms is more evenly split than for engine and airframe remanufacturing.[73] Larger fleet operators tend to be supported by larger organisations and OEMs, but smaller fleets can be maintained by SMEs that can also provide remanufacturing of obsolete items that are no longer supported by the OEM.

5.2.4 Line maintenance

Aircraft require some small-scale maintenance in-between flights while on the concourse at airports. This is called 'line' maintenance and is not generally associated with remanufacturing activities.

5.3 Market size/survey data

The addressable aerospace sector as mapped to Eurostat codes identified a total market value within the EU of €107.8 billion. This includes new manufacturing and repair type activity. The value is based on a summation of two Eurostat Group codes, which include 20 product codes, reported in the Eurostat database (see Table 39 in Annexe A for a list and description of the group codes considered in this report to represent the aerospace sector).

Table 13 shows the total value of remanufacturing for the aerospace sector in the EU is estimated at €12.4 billion. This represents 42 % of the total value of European remanufacturing turnover across the key sectors surveyed in this report. The major remanufacturing regions, which together make up over 70 % of the market in the aerospace sector in the EU are Germany, followed by the UK (&Ireland) and France. Germany accounts for the largest fraction of remanufacturing in Europe (31 %), followed by the UK & Ireland (22 %), France (19 %), Italy (9 %) and the Mediterranean area (7%).[74] The European aerospace remanufacturing sector employs approximately 70,000 people across 1,000 firms.

Table 13: Remanufacturing landscape for the aerospace sector

[74] ERN market survey data

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	390	400	510	2,310	3,810	1,130	820	370	2,700	**12,440**
Employ-ment	2,100	4,600	10,800	9,000	17,400	4,400	7,000	3,000	12,200	**70,500**
# Core ('000)	160	170	210	960	1,580	470	340	150	1,120	**5,160**

Note: see Table 9 for definitions of regions

Remanufacturing is well established in the aerospace sector. Of our sample of 74 repair stations, 70 % reported being involved remanufacturing-type repair and overhaul activities. Among these firms, the proportion of business turnover that was related to remanufacturing was lower for OEMs (24 %) than for non-OEM operators (68 %). OEMs have an interest in selling new products as well as remanufacturing, while specialised repair stations tend to focus on airworthy repairs to prolong a component's life to keep the costs down for their customers.[75] The aerospace maintenance, repair and overhaul market is highly competitive, and fairly cyclical in that the large OEMs may go through stages of taking maintenance programmes in-house.[76] OEMs and airline-affiliated MROs are supported in their remanufacturing activities by independent MROs and SMEs that tend to specialise in the repair and overhaul of specific aircraft components.[77] Germany has the largest number of registered Part-145 licensed repair stations (489[78]); then the UK (375[79]) and France (289[80]).

According to the European Commission's *Annual Analyses of the EU Air Transport Market 2013*[81], the European maintenance, repair and overhaul sector is expected to grow at an annual average rate of 2.9 % to 2024. Organisations in the aerospace sector surveyed for this study also reported steady growth over the next 5-10 years.

Within the major European aerospace remanufacturing hubs, Germany, the UK, France, Italy and Spain have a disproportionate share of the market for service contracts, particularly multinational companies and MROs associated with the national airlines. Examples of the latter include: Lufthansa Technik in Germany, British Airways Engineering in the UK; Air France KLM Engineering in France; Alitalia Maintenance in Italy and Iberia Maintenance in Spain. This is partly a symptom of the once mostly nationalised aerospace industry, and is unlikely to change in the short-to-medium term. In Germany, the majority of maintenance, repair and overhaul work is performed by Lufthansa Technik, Air Berlin Technik, and the OEM MTU Maintenance. The main market for European remanufacturers is in their home country, followed by other EU Member States.

[75] An industry contact in the MRO sector

[76] An independent operator in the UK

[77] USITC *Remanufactured goods: An overview of the US and Global Industries, Markets and Trade*, 2012, available from http://www.usitc.gov/publications/332/pub4356.pdf

[78] German LBA

[79] UK CAA

[80] French Civil Aviation Authority (DGAC)

[81] European Commission, *Annual Analyses of the EU Air Transport Market 2013*, Final Report 2015: http://ec.europa.eu/transport/modes/air/internal_market/observatory_market/doc/annual-2013.pdf

Maintenance, repair and overhaul in the military aviation sector is normally carried out by a division of the national air force itself. Occasionally work is contracted out to civil aviation industry players. For example, Rolls Royce partners with military and civil aircraft operators to set up and run engine overhaul centres designed to maximise time 'on wing' for their customers.

5.4 Opportunities and barriers

5.4.1 Opportunities

The growth outlook for remanufacturing in the aerospace sector over the next 5-10 years is for steady positive growth.[82] Opportunities in this sector are driven essentially by economics: the cost of remanufactured product is around half the cost of newly manufactured, making remanufacturing the most cost-effective option in an industry characterised by the long durability of aviation components and their high capital costs.[83]

Technological advances, such as that in new composites, present cost savings that are difficult to equal on older stock, but the high cost of aircraft components and strict remanufacturing regulations mean that operators will always consider remanufactured products before a new purchase.[84]

The industry's strong remanufacturing position is reinforced by the presence of large firms on the cutting edge of aircraft technology and remanufacturing. OEMs in particular are becoming increasingly active in the sector, as the larger airlines switch to service-based purchasing agreements. Service contracts with airlines or aircraft leasing companies provide some resistance to economic downturns. Furthermore, the cost of remanufactured components is less affected than newly manufactured components by fluctuations in resource prices.[82] Despite budgetary pressure on the military segment of the aerospace market, the retention of older aircraft in Europe and the support required to keep them flying provides a further opportunity for remanufacturers.

According to the recent EC *Annual Analyses of the EU Air Transport Market*, the Asia-Pacific region overtook Europe in 2013 to become the second largest maintenance, repair and overhaul market after the USA.[85] The growth of new global aerospace clusters presents both an opportunity and challenge for European MRO and remanufacturing activity. Whilst the market is likely to become more competitive in the future – for example 60 % of wide-body heavy maintenance is sent to Asia-Pacific and China from the USA due to the labour cost differential between the two regions[85] – the growth in regional airlines in the Middle East-Africa and Asia-Pacific is due to higher MRO spend.

The market for maintenance, repair and overhaul in Eastern European is significantly smaller than that in Western Europe, but is forecast to grow by average 6.2 % per year until 2024, compared to the European average of 2.9 %.[85] A key driver of this growth is the age of the fleet in the region. Regional airlines tend to use older aircraft on average that require more airframe heavy maintenance.

---

[82] ERN market survey data

[83] http://www.zerowastescotland.org.uk/sites/files/zws/Remanufacturing Study - Full Report - March 2015_0.pdf

[84] *Remanufacturing in the UK*, 2009, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

[85] European Commission, *Annual Analyses of the EU Air Transport Market 2013*, Final Report 2015: http://ec.europa.eu/transport/modes/air/internal_market/observatory_market/doc/annual-2013.pdf

Environmental responsibility, while not the main driver of remanufacturing activity in this sector, is nevertheless an important motive towards greater remanufacturing.[82] Whilst remanufacturing of aircraft components and systems saves material resources and embodied energy, it may be more efficient in terms of life cycle energy to retire older fleets and replace them with newer, more fuel-efficient aircraft.[86]

5.4.2 Barriers

Remanufacturing within the mature European maintenance, repair and overhaul market is facing increasing competition from emerging economies, particularly in Asia which is developing into a major market for aerospace.[85]

In addition, legislative and trade barriers, a lack of standards across EU Member States, and relatively high European cost levels adversely affect the growth of remanufacturing in this sector.[87] This can result in an 'uneven playing field' hindering market entry and making it difficult to promote remanufacturing in the sector. Operators interviewed as part of this research suggested that their remanufacturing activities were sometimes frustrated by a lack of product knowledge and access to data such as technical documentation. A shortage of quality spare parts was also cited as presenting a barrier to remanufacturing activities.[87]

Whilst economics favours remanufacturing and remanufactured systems reduce costs to the customer, technological developments such as large advances in fuel cell technology could also change the aerospace and associated maintenance, repair and overhaul industries drastically. Externally imposed environmental impact constraints or the price of fuel will ultimately dictate the economics of running older aircraft and affect the move to more efficient technologies.[86]

[86] *Remanufacturing in the UK*, 2009, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

[87] ERN market survey data

6 Automotive

6.1 Description of the sector

6.1.1 Definition of the automotive sector

The automotive sector encompasses motorised road vehicles, motorbikes and vans. HGVs and lorries are not considered here to avoid an overlap with the HDOR sector covered in Chapter 9. Remanufacturing in this sector is focused around automotive components but also includes tyre retreading.

6.1.2 Structure of the automotive sector

Operators in the automotive sector can be categorised as vehicle manufacturers (VMs), such as Volkswagen and the Fiat Group, or as one of three tiers of component suppliers (see Table 14 below), or as repairers.

Table 14: Description of the tiers of component supplier in the automotive industry

Tier	Description
1	Large, sometimes international, high volume operators that supply businesses requiring large quantities of usually new parts.
2	Smaller businesses that can source and provide moderate volumes of good quality parts that require significant technical skill to produce. These businesses usually specialise in a certain product or area.
3	Micro-businesses, usually employing 1-5 people and serving smaller, niche markets. They have capabilities to carry out a range of services. VMs and component OEMs utilise these companies to supply replacement parts or other services to consumers during their warranty period.

There are two distribution channels within the automotive sector, these being original equipment sales and the independent aftermarket. Each of these distribution channels has around 50 % of the market at consumer level. Three main players exist: OEMs that are usually multinationals, independent operators that are mainly SMEs, and parts manufacturers that can be both multinationals or SMEs. Vehicle manufacturers are themselves usually OEMs only in respect of their unique intellectual property, typically the engine and transmission systems.

With the introduction of the US Right to Repair Act and legislation in the EU in the form of the Motor Vehicles Block Exemption Regulation, automotive manufacturers have to provide their aftermarket with the same procedures and information which they currently pass to their dealers.[88,89] This legislation is also applicable to the HDOR sector as discussed in Chapter 9 and is in place to protect consumer rights.

[88] http://www.hdrg.org/2014_Presentation/Kripli_HDRG_2014.pdf, Accessed October 2015

[89] House of Commons, 2010. *Independent garages and the Motor Vehicle Block Exemption Regulation*

6.2 The European automotive remanufacturing landscape

The aftermarket in the automotive sector covers all repair, maintenance and servicing activities for the EU network of vehicles on the road.[90] The annual volume of the aftermarket is approximately €100 billion for automotive spare parts (consumer level without VAT).[91] The European Association of Automotive Suppliers (CLEPA) estimates remanufacturing in this sector is worth €8-10 billion of retail sales, with 27 product groups able to be remanufactured. Weiland estimates annual sales of €5.7 billion.[92] These estimates are broadly aligned with the findings in this study (see Table 15) which fall between these two estimates.

CLEPA also reports there is potential to reduce CO_2 emissions in the EU-27 by 400,000 tonnes. Remanufacturing in this sector is assessed as employing 32,000 people in the EU-27 and employment is increasing as remanufacturing expands.

6.2.1 Automotive components

Remanufacturing of automotive components is well established, having been carried out for decades. Although it is well integrated into the industry, few end-users are aware of its prevalence. It is therefore a good example of the transparent integration of remanufacturing into consumer orientated services.

The top level vehicle manufacturers (VMs) typically operate as final assemblers, relying on a network of smaller OEMs for the production of many components. Vehicle aftermarket maintenance is carried out either through approved VM garages or through the aftermarket (a network of garages and parts suppliers excluding VMs). Due to the presence of remanufacturing in both of these sectors, there is a significant supply of remanufactured parts to support both markets.

Remanufacturing processes usually supply replacement parts through two routes: VM warranty services or the third party aftermarket.[93] The US-based Automotive Parts Remanufacturers Association (APRA) identifies over 50 different components which are commonly remanufactured, in comparison to the 27 components identified by CLEPA. Components for remanufacturing need to be of high value and technical expertise is required in the manufacturing and remanufacturing of these products.

At the automotive component level 'remanufacturing' appears to be consistent with the definition of remanufacturing used elsewhere. Parts for the large automotive out-of-warranty aftermarket are mostly supplied by Tier 2 remanufacturers, which again perform true remanufacture. At the Tier 3 level the term is used more flexibly, and may refer to lower value 'reuse' activities.

There is growth potential in the automotive component market, particularly with respect to interventions from public procurers.[94] For example, the US Senate passed the Federal Vehicle Repair Cost Savings Act in October 2015 which requires all federal agencies to consider using remanufactured parts when maintaining the federal vehicle fleet. The

[90] http://www.acea.be/industry-topics/tag/category/automotive-aftermarket, Accessed 06 October 2015

[91] CLEPA 2014: *Current aftermarket activities and projects at CLEPA*

[92] Weiland, 2014. *European Automotive Remanufacturing*

[93] *Remanufacturing in the UK, 2009*, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

[94] http://www.zerowastescotland.org.uk/sites/files/zws/Remanufacturing Study - Full Report - March 2015_0.pdf

Federal Government has over 580,000 vehicles in its agency fleets, and spends US$975 million a year on vehicle maintenance.

6.2.2 *Tyre retreading*

Tyres have long been a remanufactured item and can be broadly classified into the following broad areas of application:

- cars, light commercial vehicles and motor-cycles
- commercial and off-road vehicles – see Section 9.1.2 for further information regarding HDOR tyre retreading activity as well as market data findings
- aircraft.[95]

The process of tyre retreading involves removing the worn out tread rubber, leaving the structure of the tyre intact[96]. New tread is then applied to the tyre structure, either by the pre-cured or mould-cured method, sometimes colloquially referred to as 'retreads' and 'remoulds' respectively. For automotive tyres, only the mould-cured process is used.[96] Rigorous inspections are carried out on the tyres after retreading has taken place to ensure that there are no defects and that the tyre will be safe on the road i.e. 'roadworthy'.

Low cost import of new product are in direct competition with rising domestic standards for remoulding. When taken with the alternative end-of-life options for tyres – such as energy from waste - the overall impact has been that it has become established in those parts of the market where a high degree of provenance, control of use and security of reverse logistics can be exercised over individual tyres.

Between the 2004 and 2009 there was considerable rationalisation in the tyre remould market; the number of members of the Remould Manufacturers Association fell from 30 to less than 20. There is a distinct shift of emphasis to servicing the cost-conscious fleet markets (heavy commercial vehicles, HCVs), abandoning the light commercial vehicle (LCV) market, and to aerospace sectors where activity follows aerospace growth trends. Like many commodity products, there is intense competition in the lower value passenger vehicle end of the market, especially from Far Eastern suppliers.

There has been a growing trend towards LCV use in home delivery and other small scale delivery services. These too are fleet-managed services, but are equipped with LCV-gauge tyres. Consequently, there is enthusiasm to address this segment, which is currently not being met by the established providers. An opportunity is therefore presented to increase capacity in this market.

6.3 Market size/survey data

The automotive sector, which encompasses LCV retreading, repair and maintenance activities, is worth €644 billion to the European economy.[97] This value is based on a summation of 14 group category codes as reported in the Eurostat database.

---

[95] *Remanufacturing in the UK, 2009*, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

[96] http://www.retreaders.org.uk/retreading/retread-made/, Accessed 29 October 2015

[97] Eurostat Data, 2014

The remanufacturing market for the automotive sectors is estimated to be €7.4 billion (Table 15). This includes a small amount of LCV tyre retreading, a market that has declined with the import of cheap (and effectively non-retreadable) tyres from the Far East.

Table 15: Remanufacturing landscape for the automotive sector

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	400	650	690	750	2,370	700	790	270	770	**7,390**
Employ-ment	2,000	4,200	6,900	5,300	10,400	4,900	4,600	2,000	3,100	**43,400**
# Core ('000)	1,390	2,330	2,620	2,820	8,510	2,830	2,990	1,010	2,790	**27,290**

Note: see Table 9 for definitions of regions

The major player, with a third of EU activity, is Germany with an estimated €2.4 billion turnover. The next tier is represented by France, Mediterranean member states (including Spain) and UK & Ireland have a little more than 10 % of the market each. The third tier is represented by Italy, Eastern and Central Europe regions with around 9% of the market each.

Within the EU, Weiland estimates that 22 million remanufactured units are produced annually, with an approximate split between Tier 1, Independent and OEM remanufacturers of 38 %, 48 % and 14 % respectively.[98] Our survey found 34%, 47% and 19% respectively. Growth in the EU automotive aftermarket is anticipated to come from increasing vehicle ownership in Eastern Europe and thus the need for maintenance and repair services will increase.[99] Germany, France and the UK have emerged as market leaders in European automotive remanufacturing, and the German vehicle replacement parts market makes up approximately 10 % of the market.[100]

The data collected in the survey revealed that a significant proportion of remanufacturing takes place within the non-OEM category, with 31 % of their turnover relating to remanufacturing activities. This is of little surprise since these organisations are predominantly involved with repair and maintenance activities and thus are ideal businesses to take up remanufacturing activities as they already have thorough knowledge of automotive repair work and associated components. OEMs and Tier 1 businesses were found to have a smaller proportion of turnover related to remanufacturing: 0.6 % and 1.5 % respectively. This reflects the much larger amount of manufacturing which takes place within these businesses in comparison to the quantity of remanufacturing. Large automotive OEMs are quite often involved with remanufacturing; however, it represents only a small part of their overall business, whereas small repair and maintenance organisations carry out proportionately much larger amounts of remanufacturing, although employing far fewer people per firm.

[98] Weiland, 2014. *European Automotive Remanufacturing*

[99] http://www.just-auto.com/analysis/eastern-europe-to-drive-eu-aftermarket-growth_id143978.aspx, Accessed 12 October 2015

[100] http://www.zf.com/media/media/document/corporate_2/products_3/services_2/remanufacturing_1/zf_reman_brochure_EN.pdf, Accessed 12 October 2015

6.3.1 Tyre retreading

Tyre retreading in the EU has decreased in recent years and is now worth €140 million. There are approximately 450 retread plants currently carrying out retreading activities, with 50 in Italy, 30 in the UK and fewer than 10 in France.[101, 102]

6.4 Opportunities and barriers

6.4.1 Opportunities

Vehicle longevity has gradually been increasing, and the average age of vehicles on the road is now over seven years. This should provide an opportunity for the remanufacturing sector as a whole as it is likely that more spare parts will be required.

The EU's End-of-Life Vehicle (ELV) legislation could buoy the remanufacturing industry in this sector. Historically, the automotive industry has demonstrated a high degree of reuse and recycling. New regulations are gradually increasing this level from 75 % 10 years ago up to a target of 95 % by 2015.[103] Remanufacturers may be able to take advantage of this by providing alternative and superior reuse options for the industry.

Remanufacturing growth opportunities also exist from a technical perspective particularly in the following component areas:

- **Air-conditioning compressors.** A significant opportunity with air-conditioning units due to large uptake in new cars, but little replacement upon failure due to high cost. OEM-based facilities (e.g. Valeo-Four Seasons in Europe) have come on-stream in recent years. If supply can be connected with demand, there is a significant opportunity for other compressor remanufacturers: these may not be traditional automotive operators.
- **Electronics.** Electronics is a highly under-estimated sector, but is an increasingly specialised area that demands significant information systems expertise, which is not a traditional automotive competence. Companies such as ATP Electronics have invested significantly in diagnostic and reverse engineering capability to decouple complex integrated systems. This is likely to be beyond the reach of smaller companies for the foreseeable future, but could provide significant growth potential. Indeed anecdotally we heard from engine remanufacturers that were in danger of losing business due to insufficient electronics capabilities.
- **42 volt systems.** The move to 42 volt systems for electric vehicles will move certain engine components from the pure mechanical realm into the rotating electrics realm. However, 42V also presages lower maintenance brushless motor units, hence the net effect on the sector may be neutral.
- **Retread tyres**. Concerted campaign of consumer education with firm data underpinning safety and performance has been suggested as an approach to support increased uptake. The HDOR and aerospace markets (the latter is particularly sensitive to safety issues) are resilient, which indicates that potential does exist within the B2C market.

---

[101] http://www.moderntiredealer.com/article/311568/retreading-a-european-perspective, Accessed 12 October 2015

[102] http://cordis.europa.eu/result/rcn/171197_en.html

[103] http://www.theguardian.com/sustainable-business/renault-jaguar-nissan-toyota-sustainability-circular-economy, Accessed 12 October 2015

6.4.2 Barriers

Barriers of particular relevance to the automotive sector (and some ways of circumventing them) that were identified in the market survey of remanufacturing actors are presented below:

- The **increase in complexity** of products, in some cases potentially driven by OEMs wanting to make it harder for others to copy their products offers significant problems for remanufacture[104]. Complexity *per se* is not the biggest issue, but rather access to technical information that allows diagnosis and workaround. This is subject to intense debate over intellectual property.
- The increasing **electrification of cars** on the road[105] creates pressure on the sector in relation to Waste Framework Directive[106] requirements and the required skills and technical knowledge to be able to carry out remanufacturing processes.
- **Competition** from low-cost new and used parts: imports of low-cost new products, predominantly from the Far East, are a particular challenge to manufacturers of starters and alternators. Companies offering repaired or reconditioned (i.e. not fully remanufactured) parts can offer lower price products which can compete against remanufactured products, but these used products might not perform as expected and may damage the reputation of remanufactured goods.
- The **availability of appropriate and good quality core** is seen to be a significant barrier to the growth of remanufacturing in this sector, with increasing competition for access. The vast range of automotive models and components is a key factor here.
- **Speed of technological innovation**: engine technology, for example, is changing very quickly - perhaps every 2-3 years - primarily as a response to increasingly stringent emissions regulations.[107] While engine operation has remained broadly the same, the technology has advanced significantly and engines have become increasingly complex. These advances mean that remanufacturing engines has become incrementally more difficult due to their increasing complexity and improved reliability. This has led to a steady decline in third party engine remanufacturing, and is a trend that is likely to continue for the foreseeable future. Also the increased use of electronics parts means remanufacturers need to invest in bringing in the relevant capabilities, partnering with other firms, or increasing resources into R&D to keep pace with this development. Note this is a good illustration of the 'sweet spot' for remanufacturing activities described in Figure 3. When the evolution rate of products increases, it becomes increasingly difficult to justify remanufacture due to the associated costs of keeping pace with development.
- In April 2015, the European Parliament voted in favour for **eCall regulation** meaning all new cars from April 2018 needs to be equipped with eCall telematics technology. eCall is an initiative intended to bring rapid assistance to motorists involved in a collision anywhere in the EU. According to CLEPA, this has the potential to undermine the regulation for the aftermarket for parts and services, currently regulated by MVBER (461/2010) and EURO5/6 RMI, by allowing OEMs to adapt vehicles for OEM-specific

---

[104] http://www.zerowastescotland.org.uk/sites/files/zws/Remanufacturing Study - Full Report - March 2015_0.pdf

[105] http://www.apra-europe.org/dateien/News/News2015/APRA_GreenPages_02_15.pdf, Accessed 12 October 2015

[106] Waste Framework Directive EC Directive 2008/98/EC available from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN

[107] *Remanufacturing in the UK, 2009*, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

telematics, favouring OEMS and shifting maintenance and repair away from independent aftermarkets.[108]

- **High labour costs** can create a barrier to businesses carrying out remanufacturing activities as they have relatively higher labour requirements; this combined with the price pressure of cheap new components, typically imported from outside the EU, can make margins unattractive for remanufacturing.
- A **shortage in skills** creates a significant barrier to remanufacturing within the automotive sector, as fewer people are developing the technical skills to carry out remanufacturing processes.
- Since 2009, **car scrappage schemes** have been introduced across the EU in countries such as Austria, France, Germany, Italy, Portugal and Spain.[109] This has encouraged consumers to purchase new vehicles to generate growth in the sector, to the detriment of repair.

The following list describes the barriers of particular relevance to tyre retreading:

- **Low priced imports** have been flooding into the passenger car / LCV market and are generally considered the greatest barrier to retreading.
- There is a **persistent view** that retread tyres are **sub-standard** compared to manufactured tyres; this - coupled with low price imports of new tyres as an alternative for the consumer – limits interest for retreads.
- In the delivery van tyre market (car-sized tyres), there is a demand for remould tyres; however with the collapse of the underlying passenger car capacity, there is now a **shortage of capacity** amongst credible suppliers.
- Retreading has been marketed on the basis of cost saving per tyre; however, the **lack of data** available on this and related fuel efficiency and wear-life could be hampering consumer uptake of retreads.

[108] Current Aftermarket activities and projects @ CLEPA, CLEPA, 14/02/2014

[109] http://www.qcea.org/wp-content/uploads/2011/04/fs-carscrappage-en-2010.pdf, Accessed 12 October 2015

7 Electrical and electronic equipment (EEE)

7.1 Description of sector

7.1.1 Definition of EEE sector

For the purposes of this report, the EEE sector will be defined as consisting of: information and communication technologies (ICT) and consumer electronics; ink and toner printer cartridges; and white goods. These three sub-sectors, as described in Table 16, will be addressed individually throughout this chapter.

Table 16: Description of the electronics sub-sectors on which this chapter focuses

Category	Description
ICT and consumer electronics	ICT infrastructure including server machines and network switches. Office imaging equipment. Consumer electronics (also known as 'brown goods') encompasses laptops, desktops and mobile phones.
Ink and toner cartridges	As used in inkjet and laser printers.
White goods	Washing machines, fridge/freezers and dishwashers.

7.1.2 Structure of EEE sector

The ever evolving consumer electronics market in Europe is driven by global names: Acer, Apple, Google, Lenovo, LG, Motorola, Nokia, Panasonic and Sony. Key players in the broader electronics sector (including ICT and office imaging equipment) comprise Asus, Dell, Hewlett Packard, Huawei, IBM, LG, Microsoft, Ricoh and Xerox.

The manufacture of ink and toner cartridges is dominated by internationally recognised companies. These include Brother, Canon, Dell, Epson, Hewlett Packard, Lexmark, Olivetti, Ricoh and Xerox, while Samsung and Apple tend to specialise in laser printers. Some of the aforementioned OEMs have production facilities located in the EU, though most of the production is based in Asia or the Middle East and North Africa.

The 'white goods' sector is made up of relatively few manufacturers that operate under different well-known household appliance brands. For instance, global player Whirlpool Corporation recently acquired one of Europe's leading white goods manufacturers, Italian-based Indesit Company, which itself owned brands including Indesit, Hotpoint and Scholtès.

7.2 EEE remanufacturing in Europe

7.2.1 ICT and consumer electronics

'Remanufacturing' is not a term commonly used in the electronics sector. In ICT and consumer electronics the word 'refurbished' is more usual and refers to replacing faulty components with functioning components cannibalised from other stock or bought new. Units are then tested to ensure electrical safety. Refurbished units are also tested to ensure that they work to an 'as new' standard, and are then sometimes resold in their original packaging. Electronic units returned to an 'as new' condition through 'refurbishment' can be said to have been remanufactured. However, a significant proportion of refurbished PCs and laptops are end-of-line models, repaired warranty returns and customer returns and/or cancellations which have, effectively, never been used. Dedicated OEM outlets as well as third party companies specialise in selling these units; however, it could be argued that they

would fall outside the realm of remanufactured products in the strictest interpretation of 'remanufacturing'.

Many OEMs provide a 'product afterlife' service for products that come to the end of their useful life. Consumer electronics manufacturer Apple[110] and ICT equipment manufacturer and consulting corporation IBM[111] run recovery schemes to collect end-of-life electronics with the view to remediating them through a refurbishment process for resale with a new warranty.

There is a significant market selling old (over one year old) desktops and laptops and a large number of both private and third sector organisations operating in this area. Businesses that want to dispose of unwanted computer equipment usually do so through these types of enterprises. Anecdotally through interviews, it would seem that most private consumer electronics tend to get cascaded through family, friends and private sales, with only the oldest (and therefore least suited for reuse) being sent for disposal.

ICT management companies offer complete ICT service packages including new installations, life-time upgrades and off-site backups. Reuse then forms just one part of their operation. Almost every company that operates in the ICT sector alludes to reuse as part of its green credentials. The waste generated in refurbishing ICT equipment can either be cannibalised for functioning parts or segregated and sold to authorised treatment facilities for recycling.

The contract renewals used by mobile phone networks drive the rapid replacement cycle of mobile phone handsets in Europe, together with the rapid evolution rate of handset technology. There are robust markets for high-quality smartphones both within and outside Europe. Due to their inherent value, there is some scope for refurbishing mobile phones (mainly battery replacements and screen repairs) prior to resale. However, if there is no significant damage to the mobile phone most units are sold without modification, though a data-wipe is usually performed. As with many other reuse sectors, the market is constrained by supply. Supply could be increased by convincing consumers to sell their old phones more quickly after they have upgraded their handsets, while they still retain a high market value: all too often devices are kept as backups that are never used again.

The office imaging equipment sub-sector e.g. photocopiers has been associated with remanufacturing for some time with Xerox remanufacturing parts for over twenty years. Often the business model is based on a photocopier leasing company offering an upgrade during a lease contract. This allows the leasing company to replace the photocopier with a new copier under a new contract while recovering a copier with a known history. This recovered printer can then be remanufactured and resold under another lease agreement. Due to the relatively slow evolution rate and high value of the equipment, it has historically been a market that has supported remanufacture by OEMs through to third party firms that may provide wider repair services.

Industry standards

Most organisations recognise the need to completely remove personal and confidential data from units being refurbished for resale. There are internationally recognised standards for

[110] http://www.apple.com/uk/shop/browse/home/specialdeals

[111] http://www-03.ibm.com/financing/us/asset-recovery/index.html

data security, such as ISO/IEC 27001:2005, which outline frameworks for the safe destruction of data. The *Digital Pipeline* scheme[112] offers further security options.

Some countries have specific regulations designed to ensure the safety of consumer electronics, including those that would be sold following remanufacture. In the UK, a portable appliance test is mandatory for all reused portable appliances. Further, the UK has developed the standard PAS 141 to outline processes for the reuse of used and waste electrical and electronic equipment, to support those who wish to export their products abroad. This standard was also designed to reduce the illegal disposal of WEEE in developing countries. Product specific standards for electrical equipment include a standard for the reuse of RFID[113] tags and international standards for rewinding electric motors. VDI (the Association of German Engineers) reportedly has a standard on the reuse of electrical equipment. Unfortunately, although references were found, the standard document itself could not be located, suggesting that it had either been removed or had not been published in a final form.

7.2.2 Ink and toner cartridges

Ink cartridges (as used in inkjet printers) and toner cartridges (as used in laser printers) are consumables associated with printing. Though laser printers dominate business-based and commercial printing, inkjet printing is still commonplace in homes. Depending on their manufacturer and design, inkjet cartridges either consist of a separate print-head and ink reservoir, or the ink reservoir and a high precision print-head are combined in what is known as a unified cartridge. Unified cartridges are regularly remanufactured, whereas the low value of the separate print-head and reservoir cartridges prohibits their remanufacture. Toner cartridges are more valuable than ink cartridges, containing a large aluminium print head and more than 100 moving parts. Due to their high value, toner cartridges are widely remanufactured.

The remanufacture of ink and toner cartridges is carried out mainly by independent remanufacturers. In this industry OEMs account for a minority of the remanufacturing activity. Historically there has been significant tension between those companies that manufacture cartridges (OEMs) and those that remanufacture only (non-OEMs or third party). The business model of OEMs in this sector is to use printer sales as 'loss leaders' and to make a significant margin on the sale of new cartridges. The European remanufacturing trade association, ETIRA, is of the view that OEMs see competition in the cartridge market from remanufacturers as a significant threat to margins, and therefore some OEMs have instigated various measures to restrict the activities of third party cartridge remanufacturers:[114]

- **Smart chips** – some OEMs have previously fit microchips in their cartridges to stop remanufacturing activity. Printers do not recognise the microchips in 'tampered' cartridges.
- **Cartridge design** – some OEMs manufacture cartridges in a way which makes remanufacturing either impossible or very difficult. A common method is to use glue, rather than screws to attach the cartridge components.

[112] http://www.digitalpipeline.org/

[113] RFID = radio frequency identification

[114] http://www.etira.org/wp-content/uploads/2015/06/Annual-Report-2015-2016.pdf

- **Warranty status** – some OEMs state that use of 'foreign' (including unbranded) cartridges in their printers will void the warranty. This approach is particularly prevalent in the USA.
- **Closed loop collection schemes** – these are set up by OEMs to ensure that they receive their empties, limiting non-OEM remanufacturers' access to core material. However, these represent a relatively small proportion of OEM cartridge sales, and even within these schemes the collection rate is some way below 100 %.
- **Cartridge patents** – some OEMs have filed for patents on printer cartridge remanufacturing to deter non-OEMs.

OEMs hold a different view to handling cartridges at the end of their useful life. They reserve ownership of their products which they have invested significant resources into to develop and produce, and thus encourage their customers to return their empties for recycling or refills. As mentioned above, most OEMs run collection schemes to maximise their return rates either directly or through electronics retailers. Additionally, some OEMs (e.g. Lexmark) encourage sustainable printing habits: print less and only when necessary.

The perceived threat for OEMs from non-OEM remanufacturers has recently been overtaken by rising imports of compatible but un-branded cartridges. These cartridges, often in breach of copyright, are priced to undercut both new and remanufactured cartridges, posing a threat to all players in the industry.

The remanufacturing industry relies on being able to undercut the prices asked by the OEMs for their newly manufactured cartridges. The public often do not perceive remanufactured inkjet cartridges as being 'remanufactured' because most of them are sold under a trade name, for example *Ink Again*, or as own-label products, such as PCWorld's *PCline* brand.

For inkjet cartridges, which are predominantly sold directly to consumers for use at home, gaining access to the core is difficult for remanufacturers. Cartridge remanufacturers often associate with volunteer and charitable organisations to obtain a supply of the end-of-life products they require. Some have their own collection programmes, but most European remanufacturers rely on independent brokers i.e. core suppliers.[115]

Industry standards

Two standards cater to the non-OEM / third-party remanufacturers that dominate this sector. Although only voluntary, they are endorsed by the UK (UKCRA[116]) and EU (ETIRA[117]) trade associations. The standards cover the technical quality of the product and allude to service-based issues such as customer interaction. They are briefly described here:

- DIN Standards specifically for remanufactured cartridges[118] - consists of three sub-standards that cover the requirements and tests to be conducted when (re-)processing inkjet and toner cartridges.
- 33870-1: Requirements and tests for the preparation of refilled toner modules
- 33870-2: Requirements and tests for the preparation of refilled toner modules
- 33871-1: Requirements and tests for the preparation of refilled inkjet modules

---

[115] http://www.hp.com/hpinfo/globalcitizenship/environment/productdesign/suppliesstudyNA.pdf

[116] http://www.ukcra.com/

[117] http://www.etira.org/

[118] http://www.din.de/en

- ISO Standard 8887 - MADE: Manufacture for product design, Assembly, Disassembly and End-of-life processing 119 - under development, applies more broadly to a typical remanufacturing process but with relevance to the design and processing of printer cartridges.

7.2.3 White goods

White goods are typically maintained, and faulty components repaired, during their lifetime with recycling or disposal at the end of their lives. 'Remanufacturing' in this sector is rare, and only a few small businesses offer such services. There is significant 'repair' activity in this sector carried out both by small independent non-OEMs and by the OEMs that originally manufactured the units. In cases where the OEMs do not have the capacity in-house, they subcontract out the servicing and repairs they are responsible for to repair companies, such as Repaircare, Product Care Ltd, Service Force and Knowhow.

The terms used in this sector to describe remanufacturing activities include 'reconditioning' and 'refurbishment'. The process consists of disassembly of the machine, repair and replacement of faulty parts, reassembly, and testing to ensure the machine is fit for resale.

The most valuable used white goods (and most suited to remanufacturing) are sourced from households from which old white goods are collected along with the delivery of replacement items. To source these items, remanufacturers contract with white goods retailers. The retailers themselves collect the used white goods, using the payment from the remanufacturers to reduce their delivery costs. The retailers also gain because customers' perception of their environmental credentials and customer services can be strengthened through this type of arrangement.

To verify that a reconditioned appliance is in full working order, a live test is required. For example, a washing machine has to be connected to electrical power, water supply and a drain and run through an extended cycle not only to check basic operation but also to verify the absence of defects such as weeps and drum imbalance. Although straightforward, undertaking this type of testing on large volumes of units in practice requires a large space, appliance moving machinery and the required electrical, water and waste connections. If the unit passes the live test it can be resold with a new warranty, usually for between 3 months and 1 year.[120] Reconditioned (or refurbished) appliances without a new warranty are not classified as a remanufactured product.

Predominantly Chinese white goods manufacturers have driven down the price for newly manufactured units in this sector over the last decade. This has impacted on refurbishing activities, as consumers will generally choose a new but low-quality unit to a high-quality but remanufactured unit. The public's perception of remanufactured products' cleanliness and reliability underlies this bias. Equally, affordability of manufactured domestic appliances is another reason that deters the public. Interviews during the primary information gathering phase suggested that online domestic appliances retailer, Appliances Online[121], has contributed to the falling retail prices over the last 10 years.

The resale and reuse of older (greater than five years) white goods is dominated by social enterprises where margins are relatively low and the end product is usually destined for

[119] http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=62047

[120] Discussions with white goods refurbishers, 2015

[121] http://ao.com/

secondary markets - generally low income households. These goods are usually sourced through donations or from household waste recycling centres (HWRCs). However, due to the poor condition of white goods at HWRCs, only 1-2 % of goods are suitable for reuse/ remanufacture.

Industry standards

There are currently no national or international standards associated with reuse or remanufacture of white goods other than BS 8887-220:2010, the general remanufacturing process standard in the UK. Reuse is very common in the third sector but the cost of introducing formal standards in this market would be prohibitive. However, the Furniture Reuse Network offers guidelines for refurbishing and repairing white goods. These guidelines are used to train member organisations.

7.3 Market size/survey data

Based on the analysis of Eurostat group code categories, the subsector market values are:

- ICT + consumer electronics sector is currently worth €189 billion, comprising 236 product codes.[122]
- Ink and toner cartridge sector in is currently worth €4.8 billion, comprising 4 product codes.[122]
- White goods sector is currently worth €16.6 billion, comprising 39 product codes.[122]

Table 17: Remanufacturing landscape for the EEE sector

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	110	230	580	350	650	590	310	110	190	**3,120**
Employ-ment	600	2,700	8,200	2,200	4,000	4,300	3,200	700	1,700	**27,600**
# Core ('000)	3,430	8,300	20,460	7,580	10,420	19,950	9,900	2,010	5,870	**87,920**

The EEE remanufacturing market is estimated to be €3.1 billion. This is driven by ICT + electronics at around €1.8 billion while ink and toner cartridges make up almost €1.3 billion. White goods remanufacturing is a very small segment with much of it focused on local repair activities with only one OEM identified as providing remanufacturing services.

7.4 Opportunities and barriers

Given the breadth of different products encompassed in this sector, sub-sector specific opportunities and barriers are presented below.

[122] Eurostat data 2014, 2015

7.4.1 Opportunities

ICT + consumer electronics

Requirements for the responsible disposal of consumer electronics and ICT by the public and by businesses would increase the volume, and potentially the quality, of stock for remanufacturing. Regulatory measures could be strengthened and voluntary schemes expanded to support reverse logistics for core.

Ink and toner cartridges

The majority (~70 %) of inkjet core is believed to be landfilled or incinerated still, so there is a large scope to increase the quantity of good quality core available for remanufacture. Remanufacturers claim that the failure rates of their products are usually lower than that of the corresponding new cartridges. This they attribute to the fact that, unlike new cartridges, all their remanufactured cartridges undergo print tests before they are boxed and shipped. If this can be substantiated properly, promoting this message to consumers may increase sales.

White goods

Opportunities to increase remanufacturing of white goods may lie with expanding social enterprise schemes rather than the commercial second-hand appliance sector. In the UK for example, it is estimated that social enterprise schemes process 300,000 items a year. Some of these products are refurbished to an 'as-new' condition, equivalent to remanufacture, though the vast majority are simply reused following basic maintenance and testing. Through these remanufacturing and reuse operations, these social schemes generate employment for the long-term unemployed and socially disadvantaged, and provide them with skills and training.

7.4.2 Barriers

ICT + consumer electronics

The technologies used in ICT equipment and consumer electronics are changing very fast. Two to three year old units are generally considered 'old', five year old units 'out-of-date' and even older units effectively obsolete. Although there is a very small market for 'vintage' consumer electronics - particularly games consoles, this makes up an insignificant fraction of the market. Another symptom of this fast-paced market is that the supply of certain stock and the demand for certain remanufactured products can change entirely in just a few years. A case in point is the demise of the desktop computer. Businesses that specialised in refurbishing this type of product will not necessarily be able to switch to refurbishing the lower value, more complex netbook and tablet computers.

Some consumers are put off releasing their old computers to remanufacture due to concerns about the safety of their data. This - along with economic factors - is one reason why obtaining sufficient quantities of stock and used components is a barrier to remanufacturing in this sector.

Ink and toner cartridges

OEMs can design their ink and toner cartridges to make them difficult to remanufacture. They sometimes go further and implant microchips in their products to make them inoperable if 'tampered' with. Though these actions are predominantly aimed at preventing counterfeiting, they also act to discourage remanufacturing. Collection poses another

challenge to the remanufacture of cartridges. For inkjet cartridges (largely servicing the consumer market), collection techniques include return envelopes, collection points in supermarkets and dedicated shops. Heavier toner cartridges (servicing commercial markets) can be collected directly from office premises. Sales channels for remanufactured inkjet cartridges are dominated by 'own brand' cartridges whilst toner can also be supplied as part of a print management contract.

White goods

Due to the saturation of the market in recent decades with imports of low cost white goods, the repair and return infrastructure for these products has shrunk. This in turn reduces the supply of core in this sector. Furthermore, fitted kitchens (in which the white goods are often hidden from view) are given as a reason that the quality of the core collected from community recycling centres is low and generally unsuited to remanufacture. The social enterprises that account for a large share of the collection and distribution of used white goods historically received grants and funding from charitable donations and governments. Therefore it makes little economic sense for commercial enterprises to try to compete in this sector where other players are effectively subsidised.

Legislative barriers

The changing guidelines of the Basel Convention[123] treaty may pose a risk to remanufacture, refurbishment and repair of electronics. Through the treaty a proposal was made to modify a technical guideline to address the ongoing issue regarding illegal transboundary movement of hazardous e-waste but, in doing so, potentially classify used electrical and electronic equipment as e-waste. The purpose of this specific guideline is to tighten regulations and prevent developed countries from transporting hazardous e-waste to less developed countries, specifically where informal recovery industries operate, in some parts of Asia for example.[124]

The original proposal would have impacted significantly on the amount of these shipments and impose a large barrier for remanufacturers. Core would become more difficult to obtain, prices would be estimated to increase by 50 % which in turn would discourage consumers - who are already known to be highly price sensitive regarding maintenance and repair.[125] Medical devices industry representatives were concerned that refurbishment activities would similarly be hampered. In essence all remanufacturing sectors which handle end-of-life electronics would have been impacted. For example, in the automotive sector technologies are continually upgrading and vehicles are fast becoming highly dependent on electrical and electronic components. Availability of these parts and components would become limited and supply would begin to shrink as result of both the change in legislation relating to transboundary movement of e-waste and the transition to increased use of advanced electrics/electronics in the manufacture of vehicles.

At the Basel Convention in May 2015, representatives from APRA, CLEPA, VDA and others put forward the argument for the need for transboundary shipments to enable remanufacturing. Digital Europe, a European electronics trade association, also highlighted the potential risk to remanufacturing of the e-waste transboundary guideline amendment. To quantify the value added from remanufacture, refurbishment and repair in the industry

---

[123] The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is an international treaty designed to regulate transboundary movements of hazardous waste to ensure environmentally sound management

[124] http://www.apra-europe.org/dateien/News/News2015/APRA_GreenPages_02_15.pdf

Digital Europe conducted a survey, and found that its members collectively transport 118,000 tonnes of e-waste a year worth up to €10 billion.[125]

The guideline was adopted in May 2015 and clarifies the distinction between electrical and electronic waste and used electrical and electronic equipment, and ultimately determines what is and what is not classified as e-waste. Through the efforts of the remanufacturing actors, transboundary transportation of used equipment in the future was protected for remanufacturing.[126] It is thought that compliant nations will modify their applicable legislation to align with the Basel Convention amendment.[127] Due to the somewhat blurred line differentiating refurbishment from remanufacturing in some sectors, this guideline may still pose a risk to the remanufacturing industry.

Other legislative barriers which are sector specific include:

Automotive

The increasing electrification of cars on the road creates pressure on the sector through WEEE and Waste Framework Directive[128] requirements and the required skills and technical knowledge required to be able to carry out remanufacturing processes.

With the introduction of the US Right to Repair Act and similar legislation within the EU in the form of the Motor Vehicles Block Exemption Regulation, automotive manufacturers will have to provide their aftermarket with the same procedures and information which they currently provide to their dealers.[129,130] This legislation is also applicable to the HDOR sector as discussed in Chapter 9 and is in place to protect consumer rights.

[125] http://www.digitaleurope.org/DesktopModules/Bring2mind/DMX/Download.aspx?Command=Core_Download&EntryId=679&PortalId=0&TabId=353

[126] http://www.simsrecycling.com/Newsroom/~/media/Documents/Newsletters/SRS OEM/OEM Newsletter Spring 2015.ashx

[127] http://www.cocir.org/index.php?id=109

[128] Waste Framework Directive EC Directive 2008/98/EC available from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN

[129] http://www.hdrg.org/2014_Presentation/Kripli_HDRG_2014.pdf, Accessed 12 October 2015

[130] House of Commons, 2010. *Independent garages and the Motor Vehicle Block Exemption Regulation*

8 Furniture

8.1 Description of sector

8.1.1 Definition of furniture sector

The furniture sector can be divided into furniture for personal use and furniture for business use including offices. In this study we consider the furniture sector to include companies that produce free-standing or built-in furniture units, to be used for storage, seating, sleeping, working on/at and eating on/at. Thus furniture, as defined for the purpose of this project, includes chairs, tables, wardrobes, shelves, cupboards, etc. used for business purposes, e.g. in offices and schools, as well as for domestic purposes. It excludes building products (e.g. steps, walls, mouldings and panels), sanitary equipment, carpets, fabrics, office supplies, and other products, the primary purpose of which is not to function as furniture. Office furniture generally includes seating, desks and pedestals, steel or wooden storage units, and a small percentage (2.5% of sales) of miscellaneous items such as partitions.

Furniture is a 'workhorse' item, built for durability and a long lifetime. Chairs typically have a lifespan of 5-10 years, whereas desks might be expected to last for 15 years. In addition, furniture is more of a 'functional' item, and new purchases are typically made for replacement purposes. Office furniture is somewhat different, often replaced due to aesthetic and corporate branding reasons rather than functionality. Hence items are often replaced on an entire-office basis, rather than individual pieces being replaced. These characteristics make office furniture ideal for remanufacturing activities, as the bulk nature of e.g. reverse logistics means costs are not prohibitive.

8.1.2 Structure of furniture sector

One quarter of the world's furniture is produced in the EU. In 2010, around 940,000 European workers were employed in approximately 130,000 firms.[131] In the same year, the sector's production amounted to more than €83 billion with a value added of nearly €29 billion. Germany, Italy, Poland and France ranked among the top 10 furniture manufacturers worldwide, and held a combined share of 17 % of world production and almost 60 % of EU production. Yet the EU's share of world furniture production has declined over the last decade and the value of furniture production in 2012 was back to the level of a decade ago. It is worth noting that the EU has performed better than other historically large manufacturing areas like North America and Japan.

The furniture industry is a dynamic one. Its success lies in its creative capacity to combine raw materials and technology in order to satisfy consumers' needs. The industry consists predominantly of SMEs making up a rather complex and fragmented supply chain. Players in the furniture industry can be classified as being in one of four categories: raw material suppliers, manufacturers, distributors, or companies that deal with end-of-life furniture.[132]

[131] http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=7918&lang=en&title=Study-on-the-EU-furniture-market-situation-and-a-possible-furniture-products-initiative-

[132] http://www.wrap.org.uk/sites/files/wrap/Office Furniture_final.pdf

The furniture supply chain

1. Raw Materials

The furniture industry uses a range of raw materials such as wood-based panels, metal, aluminium, plastics, fabrics, leather and glass, as well as mechanical and ICT components. Most furniture products use at least some wood or wood panels, and wood makes up a substantial proportion of the raw material used in furniture production. For example, the average item of Swedish furniture consists of 70 % wood-based material, 15 % padding materials (mainly polyurethane and polyester foam), 10 % metals and 5 % other materials (plastics, textiles, glass, etc.).[133] In general, the environmental impact of furniture stems mostly from the production and treatment of the raw materials used in their manufacture, rather than from the production of the furniture itself.

With wood making up the majority of the material inputs of the furniture industry, European furniture manufacturers have three main suppliers: the sawmills, the wood-based panel producers and the producers of components and furniture parts (e.g. cabinet doors, drawers, baseboards and caps, worktops, chair legs and curved parts). Other suppliers are the metal industry, which produces machinery and fittings, the chemical industry, which provides paint, glue, and varnishes for furniture as well as foam for upholstering furniture, and the producers of textiles and leather.

The upstream portion of the furniture sector has become increasingly fragmented in the last few decades, as suppliers to the furniture industry face challenges including raw material availability, ability to fund investment and higher production costs. Growing global competition, regulations concerning environmental and technical standards and raw material demands from industries other than the furniture industry have reduced the availability of raw materials for furniture, increasing the volatility of their prices. The production of materials for the furniture industry requires large plants and specialised machinery. This, along with high labour costs in Western Europe, has resulted in many suppliers moving their operations to areas where production costs are lower, such as in Eastern Europe and outside Europe.

2. Manufacturing

European furniture manufacturers are predominantly involved in assembling parts produced by other companies to create the final products. The sector is dominated by SMEs, with around 85 % of these classified as micro enterprises (10 employees or fewer) while 12 % have between 10 and 49 employees. The dominance of SMEs is also high in niche market segments, such as in high-end, custom made and design-led products. Large enterprises (greater than 250 employees) account for less than 1 % of the total number of furniture manufacturing companies. These larger firms often find it more convenient and profitable to outsource and fragment their activities into many functions carried out by different actors in different locations.

While nearly 85 % of furniture demand in the EU is still satisfied by EU production, declining tariffs on foreign trade, growth of emerging markets, improving logistics, and increasing demand for low-price items have lowered the barriers to entry for foreign goods. European furniture production is hence increasingly subject to competition through low cost of labour.

[133] http://ec.europa.eu/environment/gpp/pdf/toolkit/furniture_GPP_background_report.pdf, Accessed 06 October 2015

Ten years ago, furniture exports to extra-EU countries exceeded furniture imports, whereas the balance has been negative or zero in subsequent years.

In order to retain their market shares in the face of increased extra-EU competition, European firms are shifting their operations far from their headquarters. By restructuring their businesses, including downsizing, outsourcing, using branding strategies, trialling new retail formats, optimising manufacturing processes and investing in new plants in low-wage countries, these companies hope to remain profitable. Companies have also taken advantage of the benefits of being part of the EU, by using the cheap labour available in countries such as Romania and Bulgaria, sourcing raw materials from countries where it is abundant such as the Czech Republic, and exploiting the technological endowment and unique know-how of German and Italian engineers and designers.

However, competition in the furniture market is not only based on price but revolves around other attributes such as quality and aesthetics of the finished product and/or its production process. As a result, European manufacturers are turning to design as the best means of differentiating their products from mass production and of acquiring access to the high-income market segments. European manufacturers still have a competitive edge and are recognized globally for embedding innovation into furniture products, researching different styles and developing creative manufacturing methods. EU furniture manufacturers are trendsetters at a global level and hold a prestigious image among designers, media and consumers. Although companies implement outsourcing or production fragmentation strategies, Europe still retains core competences in design, research and product innovation that enables companies to retain their market share.

3. Distribution

The distribution channels of furniture have becoming increasingly concentrated, relative to the fragmented nature of the upstream sections of the furniture sector. There were about 170,000 companies engaged in furniture retailing and distribution in the European Union in 2010, down 8 % compared to 2008. Generally speaking, over the last decade the sector has undergone important structural changes. Large-scale distribution of furniture, which has increased dramatically in recent years, takes place through independent chains, franchises, and joint associations of retailers. Small-scale distribution occurs mainly through small independent sales outlets, retail outlets and department stores. Additional channels include do-it-yourself stores, mail order, and e-commerce.

For office furniture, the increasingly important contract channel for furniture distribution also exists. The term ‘contract’ is used whenever the simple provision of furnishings, under the contracting formula (responsibility for all the work involved in a specific job order), is accompanied by a series of collateral services, such as support for designing spaces, and finding and coordinating subcontractors for the completion of the furnishings. The contract segment includes furniture for hotels, hospitals, schools, businesses, governments, etc.

Contract and office furniture purchasers form a crucial link in the supply chain, as they have one of the biggest influences on sustainable procurement of furniture. These purchasers might buy furniture on the basis of its environmental credentials. They might also specify the use of alternative product/service systems as well as a requirement for a constructive end-of-life outlet for their used furniture. Remanufacturers of (office) furniture are increasingly adopting this model.

4. End-of-life

On reaching its end of life, most furniture is sent to landfill. Reuse activity in the sector is very low. According to European Federation of Furniture Manufacturers (UEA) statistics, in the EU furniture waste accounts for more than 4 % of the total municipal solid waste, of which 80-90 % is incinerated or dumped in landfills, with 10 % recycled. Where reuse does occur, it is mostly through commercial second-hand shops, social enterprise companies or charities. Some furniture items are also exchanged via free and paid exchanges, such as Ebay and Freecycle, though the number of items traded in this way is difficult to quantify.

8.2 Furniture remanufacturing in Europe

Remanufacturing activities in this sector are often referred to as 'refurbishing', which may or may not include a promise of an 'as-new' product and a warranty. In the USA, the furniture remanufacturing industry emerged from the office furniture area. In particular, it was supported by the commonplace use of partitions which are relatively easily remanufactured and thus underpinned other remanufacturing activity.

In order to stay competitive in the global market, European furniture manufacturers are starting to provide support services (both pre- and post-sales) and allow products to be returned. A model adopted by half of the OEMs in the furniture sector is a take-back scheme where third-party subcontractors remove, process and resell old (primarily office) furniture. OEMs also offer a refurbishment service to augment their sales of new furniture. In addition, some OEMs offer a scheme whereby an old item is traded either for a newly remanufactured product, or for the same product after a full service and warranty. An example would be Hermann Miller's Aeron chairs with the remanufactured product marketed as Aeron Revive[134]. The Aeron is a premium and relatively high cost product meaning that the Aeron Revive is highly sought after.

Wilkhahn, one of Europe's leading furniture manufacturers, offers a 'trade-in' service for its products. The strongest market in which it is involved is that of the custom-designed or 'personal' chairs, to which the customers may be emotionally attached. Another manufacturer, Orangebox, has a range of chairs (G64) that are designed to be easily taken apart and put back together with standard components. Orangebox will visit the customer's site, remove any worn parts and replace them with new parts. Orangebox is expanding the range of chair designs it offers, whilst ensuring that its new lines are based on the same 'pieces' as those which make up the G64. Rype Office offers *Remade* furniture with a holistic offer of design, installation and maintenance provided through buy (with warranty/buy-back guarantee) or lease options. Other notable companies remanufacturing furniture include Kinnarps, Vitra and Martela.[135]

For the small proportion of furniture that does get recovered at end of life, in addition to remanufacture and refurbishment strategies, reuse is also commonplace. Furniture for reuse can be found in auctions, second-hand and charity shops, car boot sales and markets. Due to its size and fragmented nature, it is difficult to accurately quantify the level of commercial furniture reuse. Where reuse is offered by manufacturers, it is common for them to partner with charity organisations to enable reuse and sustainable disposal of office furniture. Reusable furniture can also be collected by social enterprise partners including

[134] http://www.actionsustainability.com/documents/downloads/Reuse%20of%20office%20furniture%20report%20CRR.pdf

[135] http://www.abromhead.co.uk/userfiles/Final project report - BFM ZEEE8.pdf

charities such as Emmaus France, France and the Furniture Reuse Network, UK.[136] In these cases, member organisations recover end-of-life furniture items to be donated to domestic and international educational facilities and other enterprises benefiting disadvantaged people.

8.3 Market size/survey data

Table 18: Remanufacturing landscape for the furniture sector

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	10	20	50	20	70	70	20	20	30	310
Employ-ment	100	200	1,200	200	500	500	300	100	300	3,400
# Core ('000)	70	110	370	170	470	460	160	120	240	2,170

The remanufacturing market for furniture is estimated to be about €300 million, employing an equivalent of 3,400. The remanufacturing intensity in the furniture sector is not as high as in other sectors, partly due to the large amount of reuse in the sector. The high relative cost to remanufacture products compared to the (re-)sale price means large product batches are required; therefore remanufacturing occurs mostly in the office (business-to-business, B2B) subsector. Similarly to the rest of the furniture industry, furniture remanufacturers are predominantly SMEs.

8.4 Opportunities and barriers

8.4.1 Opportunities

Given the fragmented nature of the European furniture supply chain there is an opportunity to create new products and reach new markets with remanufactured end-of-life furniture. The biggest motives for remanufacturing in the furniture sector, based on the ERN survey, are to secure a supply of spare parts, protect the image of the brand, adhere to government legislation and, most importantly, express responsibility to the environment. Any extension to the product's life through remanufacturing activities reduces the economic and environmental costs of that product.

Anecdotally one office furniture remanufacturer is seeing increasing consumer confidence in the quality of remanufactured products as the list of (high-profile) example customers grows, meaning new customers are less worried about quality issues.

Office furniture offers a remanufacturing opportunity as it can be embedded within a number of supportive business models, such as leasing. These are more conducive to enabling recovery of quality furniture not least because the retention of ownership by the leasing company means that location is well known and the risk of investing in good product at the outset is much reduced. Such examples are, however, currently rare.

[136] http://www.frn.org.uk/frn-news/342-who-is-pioneering-furniture-re-use-recycling.html

8.4.2 Barriers

A range of barriers and challenges must be addressed for remanufacturing to be adopted in an economically viable manner. From the ERN survey, the top barriers to remanufacturing in the furniture industry are customer recognition, volume and availability of furniture for remanufacturing, and legislation restrictions.

Several OEMs highlighted that remanufactured furniture did not attract suitable value for the costs incurred. Manufacturers highlighted a 'limited market' for remanufactured furniture due to lack of consumer confidence in its quality, but as noted above, there is some evidence to suggest this is changing. Some are also concerned with remanufacturing cannibalising their primary market, possibly reducing the higher profit margin obtained from the sale of new furniture.

Obtaining suitable products at the point where they can be remanufactured is another key issue in developing a robust process. The multitude of furniture items manufactured with low-cost rather than durability in mind makes it difficult to identify furniture makes and models suitable for remanufacturing. On the other hand, lack of care and proper handling can lead to furniture being damaged or destroyed during collection. Attempting to remanufacture such unsuitable products may not only result in further damage to consumer perception, but also increase the costs involved to bring these items back up to a warrantable condition.

In addition, the materials available for remanufacturing are determined by those which have been integrated into furniture products in the preceding years. The variability of incoming raw material streams from end-of-life products in terms of quantity, size, thickness, colour, and quality leads to mismatches in material supply and demand and prevents broader scaling of furniture remanufacturing. Moreover, when recovering furniture items at the end of their service life, it is not feasible to accurately list the coatings and other chemicals used in their production. This may present legal issues for the sale of remanufactured products if new legislation has prohibited the sale of chemicals which were used in the original production process.

Finally, storage capacity at OEMs is limited, which in turn limits the capacity of the industry to take back and store furniture for remanufacturing. Greater investment in larger properties or extensions are required in order to enable greater remanufacturing practices. In addition, transportation of products back to the manufacturing site can pose a difficulty, particularly if the manufacturer is not responsible for direct supply to customers which is often the case. To address this issue, companies would have to form strategic partnerships with third parties to collect furniture.

9 Heavy-duty and off-road equipment

9.1 Description of sector

9.1.1 Definition of HDOR equipment sector

The heavy-duty and off-road (HDOR) equipment category encompasses the manufacturing, installation, maintenance and repair of a wide variety of equipment including: engines and turbines, except those used in light vehicles and aircraft; forestry and agricultural equipment, mining and quarrying equipment, lifting and handling equipment and the equipment used in the manufacture of cars and other vehicles.

This chapter focuses on lifting and handling equipment, off-road machinery, and HDOR tyre retreading as a representation of this sector, as described in more detail in Table 19.

Table 19: Description of the sub-sectors of HDOR on which this chapter focuses.

Category	Description
Lifting/handling equipment	Cranes and hoists, industrial handling equipment including forklift trucks and lifts and escalators all fall within this category.
Off-road	Mining, quarrying, forestry and agricultural vehicles and equipment, both motorised and unpowered.
Tyre retreading	Tyres used on equipment in this sector as described above.

9.1.2 Structure of HDOR equipment sector

The nature of enterprises involved in the manufacturing, distribution, installation, maintenance and repair of HDOR equipment depends on the type and purpose of the equipment. Legislation is in place surrounding equipment used in this sector - which includes Euro III and Euro V[137, 138] - relating to emissions, mandatory ABS systems and ECE Regulation 13 lane departure warning and advanced emergency braking systems[139].

As each sub-sector of HDOR is different, information regarding the wider market structure and size will be addressed separately.

Lifting/handling

Cranes and hoists: Cranes and hoists form the largest group of machinery in this sub-sector. They are most commonly used in the construction, manufacturing and transport industries. Worldwide there is a small number of well-established specialist OEMs which dominate the market. This is accentuated for larger cranes where companies such as Sarens (Belgium), ALE (UK) and Mediaco Lifting (France) are pre-eminent.

Equipment in this category is sometimes bought directly from the OEMs by end-users; this is more typical of static or small equipment, or where long term use is required. However, a large industry also exists around leasing equipment from specialist hire companies, which in

[137] http://ec.europa.eu/environment/air/transport/road.htm

[138] https://www.dieselnet.com/standards/eu/ld.php

[139] https://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/updates/R013r8e.pdf

turn are the direct customers of the OEMs. This is particularly true of the equipment used for specialist purposes, or to meet short term needs.

Forklift trucks and other industrial handling equipment: The use of forklift trucks and other industrial handling equipment is common for the movement of heavy items, usually in warehouses. A range of sizes and models exist to suit user requirements, from smaller items to move pallets through to large items which can manoeuvre items such as ship containers[140]

A sales estimate from a reputable source within the industry is that 30,000 forklift trucks are sold annually, with an average price of over €20,000; this corresponds to a total market value of almost €650 million.[140]

Lifts and escalators: Lift and escalator products include a range of items such as passenger and goods lifts, moving walks, home lifts, lifting platforms and escalators as well as component parts.[141] The Lift and Escalator Industry Association reports that UK members are involved with the maintenance of more than 250,000 products in this sub-sector.[142]

Off-road

The majority of machinery in this sector is produced by large final assemblers, for example Caterpillar, which operate globally, and typically specialise in a particular type of equipment. Once assembled, this machinery is sold to end-users or equipment leasing firms with a warranty and often a service agreement. To support these agreements final assemblers have large servicing divisions, and often integrate purchasing and servicing into a single offering.[140]

Tyre retreading

Tyre retreading has previously been discussed in Chapter 5 which covers much of the relevant background although there are significant differences between HDOR and the automotive sector. Unlike the automotive tyre industry, the HDOR tyre market is not subject to quite the same level of competition from low cost new tyres that tend to be of too low quality to retread (these typically originate from the Far East). These tyres undercut the price point of retreaded automotive tyres and therefore has drastically shrunk the automotive retread sector. HDOR tyres are necessarily more robust in construction and their level of performance, and particularly safety, is perhaps valued higher than in the general automotive consumer market that has a greater focus on lowest cost meeting minimum safety requirements. Within the EU, it is reported that up to 50 % of commercial vehicles use tyres which have been retreaded, thus avoiding waste and providing financial savings.[143] This market is reputed to employ approximately 18,000 people. Trade associations in some markets report that almost half of the truck and bus tyres on the roads have been retreaded, and that operators providing this service are located Europe-wide.[144] In the aerospace sector, it is reported that up to 95 % of tyres are retreaded and this process can take place up to five times during the life of the tyre.[145]

---

[140] *Remanufacturing in the UK*, 2009, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

[141] http://www.leia.co.uk/, Accessed 29 October 2015

[142] http://www.leia.co.uk/index.php?cid=2, Accessed 29 October 2015

[143] http://ec.europa.eu/programmes/horizon2020/en/news/labels-show-how-retreaded-tyres-stack-against-new-tyres, Accessed 12 October 2015

[144] http://www.retreaders.org.uk/retreading/questions-answered/, Accessed 09 October 2015

[145] Autonrenggaslitto, *Retreaded Tyres; Quality, Economy and eco-efficiency*

9.2 HDOR remanufacturing in Europe

Remanufacturing in the lifting and handling sub-sector is not well-established. It is not a standard service provided by the OEMs, nor does there seem to be much consumer interest in taking it up. Remanufacturing in the cranes and hoists sub-sector is uncommon - though regular maintenance and refurbishment, including component replacement and reuse, is more prevalent. A moderate amount of remanufacturing of industrial handling equipment, including forklift trucks, does take place but is concentrated in a small number of OEMs that service some of their own product lines. The refurbishment and reuse of forklift trucks and other industrial handling equipment is much more common than their remanufacture. An insignificant amount of remanufacturing occurs in the lifts and escalators sub-sector, though the refurbishment and reconditioning of elevators and their mechanisms is more widespread.

'Remanufacturing' in the off-road sector is well understood, accepted and clearly distinguishable from 'refurbishment' and other renewal type activities. There is a high level of activity, the vast majority of which occurs on engine-powered machinery such as tractors and earth-moving equipment. This machinery utilises engines, gearboxes and other drive train sections; parts which are commonly remanufactured in other industries. HDOR is somewhat distinguished from automotive sectors where remanufacturing occurs effectively at the component level. In HDOR, there is also some system level remanufacturing, where for example a whole earth mover will be remanufactured.

Refurbishment and reconditioning also occurs, but this is more prevalent for less complex equipment. Remanufacturing forms a core part of many FAs' business activities in this sector. For example, the parts used for warranty replacements and servicing are often remanufactured.

By far the largest practitioner of remanufacturing in this sector (and potentially all sectors) is Caterpillar, which operates remanufacturing schemes globally. However, other FAs and OEMs such as JCB, Cummins and Komatsu have sought to increase the level of parts remanufacturing as they recognise and promote the economic and environmental benefits. These OEMs often contract out the remanufacturing of specific parts to smaller, specialized firms.

Examples of off-road equipment companies embracing the circular economy through remanufacturing

Caterpillar Inc: Caterpillar is a US-headquartered manufacturer of construction and mining equipment, diesel and natural gas engines, industrial gas turbines and diesel-electric trains. ***Cat Reman*** is the Caterpillar remanufacturing programme that in 2012 took back over 2.2 million end-of-life units for remanufacturing. This programme aims to return end-of-life products to an 'as-new' condition, and seeks new ways to reduce, reuse, recycle, and reclaim materials which would otherwise go to landfill. Incentives such as a deposit scheme and voluntary take-back of any surplus products (for a higher price that would be achieved at scrap value) ensure that large quantities of parts are returned to Caterpillar. Caterpillar has a global network of remanufacturing hubs in which the returned products are remediated; in Europe the following sites under take remanufacturing activities:

- Chaumont, France
- Bazzano, Italy
- Castelvetro, Italy
- Frosinone, Italy
- San Eusebio, Italy
- Radom, Poland
- Shrewsbury, United Kingdom
- Skinningrove, United Kingdom

JC Bamford Excavators Ltd (JCB): Based in the UK, JCB is one of the world's top three manufacturers of construction equipment. Through the ***JCB Service Exchange***, the business aims to reduce plant-owning and operating cost. To achieve this the company offers a comprehensive range of 1,650 remanufactured parts across all its machines. These remanufactured parts meet the same standards as new parts and are protected by the same warranty conditions. If practical, remanufactured parts are also upgraded to use any relevant new technologies. Priced 40-50 % lower than new parts, they can restore machines to their optimum condition at a more affordable price.

9.3 Market size/survey data

*The HDOR sector is currently worth €122 billion[97] to the European economy, which includes new manufacturing and repair of HDOR equipment, including retreading of HDOR tyres. This value is based on a summation of 8 group codes, which include 111 product codes, reported in the Eurostat database. See Note: *product code (not allocated a group code)*

Table 41 in Annexe A for a list of the group codes considered here to represent the HDOR sector.

As highlighted in Table 20, the European remanufacturing market is estimated to be worth €4.1 billion, which includes €850 million of HDOR retreading activity. Germany is estimated to account for 27 % of the market, with France, Italy and UK & Ireland representing 15 %, 13 % and 12 % respectively. The sector is estimated to employ a little over 20,000 people across more than 500 firms. A few smaller businesses indicated that they felt they were too small to be involved in remanufacturing activities and it would not be cost-effective for them to undertake such activities. Their facilities and the skills of their workforces were cited as limiting factors to taking on remanufacturing work.

Table 20: Remanufacturing landscape for the HDOR sector

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	160	230	340	630	1,110	540	380	240	510	4,140
Employ-ment	1,500	1,700	3,400	5,800	6,400	5,100	2,300	1,800	3,000	31,000
# Core ('000)	290	430	680	1,160	1,550	930	870	430	1,050	7,390

To establish the rate and value of remanufacturing in the HDOR sector, 136 enterprises working in this sector across Europe were sampled. 23 % of the sampled businesses were involved in remanufacturing in some way. In the OEM businesses which were sampled (79), 29 % responded that they carried out remanufacturing and of the 57 non-OEM businesses, 14 % are involved with remanufacturing. The higher prevalence of remanufacturing within OEM organisations is not of great surprise due to the dominance of firms such as Caterpillar and JCB carrying out a significant amount of remanufacturing. Within the OEM businesses, 8 % of their annual turnover was found to be related to remanufacturing, compared to 14 % of the turnover for non-OEM businesses. Remanufacturing activities were commonly found in components such as engines, turbochargers, air compressors and braking systems for lorries and agricultural machinery. In some cases, it was found that equipment which has been remanufactured would be returned only to the original customer and not offered for resale.

It was also found that some companies that were once OEMs, and may still class themselves as OEMs, now predominantly carry out distribution services for others, alongside refurbishing and repair work on equipment they had previously manufactured. Some indicated that they have the capacity to refurbish newer items which may have been manufactured by others.

Of the remanufacturing-type activities carried out by the sampled companies some counted cleaning and re-painting as refurbishment. One agricultural and farm equipment manufacturer reported that it may simply clean and paint a tractor before selling it on as a second-hand item. Refurbished products in this sector are often marketed for resale as pre-owned items, as opposed to products in a 'like-new' condition.

Non-OEMs without the knowledge or facilities to be able to carry out remanufacturing sub-contract the work to specialist companies. Companies supplying parts for HDOR equipment may sell remanufactured parts but do not directly carry out the remanufacturing process themselves. Again this element is likely to be sub-contracted. Where remanufacturing was undertaken, warranties (though dependent on the product and work carried out) typically ranged from 3 to 6 months long.

9.4 Opportunities and barriers

9.4.1 Opportunities

Remanufacturing opportunities in the HDOR sector are likely to be related to high value elements of mechanically complex products. Current HDOR remanufacturing activity is focused in the off-road sub-sector. Potential opportunities for increasing the understanding and acceptance of remanufacturing across the whole sector include:

- Promote remanufacturing OEM exemplars and disseminate information on the economic and environmental benefits through manufacture.
- Legislation addressing the safety of remanufactured products would increase consumer confidence in reused and remanufactured products.
- If detailed data were collected on the type and extent of work carried out on HDOR equipment, particularly cranes, the remanufacturing potential of end-of-life units could be better assessed.
- Standardised parts in lifts and escalators would help encourage remanufacturing and encourage companies to build inventories of second-hand and remanufactured parts, for their own use or to put up for sale.

9.4.2 Barriers

Safety is of high importance to the end-users of the HDOR equipment under consideration here. The construction, industrial, agriculture and other industries' end-users face tight regulations in Europe with regard to workplace safety and the environment, with corresponding large penalties for employers for non-compliance. This safety-conscious mentality can dissuade potential purchasers from taking the perceived risk associated with remanufactured products. Detailed records and testing, as well as educating and marketing, would be required to convince and reassure these actors of the safety of remanufactured, relative to new, equipment.

The economic benefits of remanufacturing are also less pronounced in this sector, with consumers traditionally favouring a 'cheap and new' product over a similarly priced remanufactured product. Third-party remanufacturers operating in the heavy duty and off-road sub-sectors are squeezed by high labour costs and competition from cheap components, mostly imported from Asia. This has been driven by competition between companies within the sector as they seek to lower the cost of their warranty and servicing operations.

Increasing levels of electronics in HDOR equipment in recent years poses a challenge for remanufacturers. Overcoming this challenge would mean re-training or extending the skills base of the employees of remanufacturing-active companies. Given the long service lifetime of many HDOR units, this problem is likely to become more pronounced in the future.

HDOR equipment, and the components from which it is built, is very heterogeneous (non-standard) and has relatively small, specialist markets. The requirement to keep large inventories of remanufactured components to cover all the potential parts that may need replacing is a prohibitive issue for all but the largest OEMs (e.g. Caterpillar and JCB).

With regard to tyre retreading in this sector, there are almost no technical barriers within HCV and off-road vehicle segments. There can however be market barriers through the limited awareness of tyre retreading by fleet managers, predominantly those in-house. Contract fleet managers appear to be better informed than in-house fleet managers, a feature which can be exploited to increase the cross-selling of other remanufactured products.

10 Machinery

10.1 Description of sector

10.1.1 Definition of the machinery sector

The machinery sector encompasses the manufacturing, installation, maintenance and repair of a wide variety of equipment including: machinery for food and beverage processing, machine tools, pumps and compressors, engines and turbines (excluding aircraft, vehicle and cycle engines), alongside the installation and repair of machinery and equipment.

In this chapter, three categories of machinery (Table 21) and the remanufacturing opportunities they present, are considered.

Table 21: Categories of machinery considered in this chapter

Category	Description
Industrial food processing equipment	Packaging and sealing equipment, liquid and powder filling machines, slicing and mixing equipment, along with ovens, moulders, batch cooking and line processing equipment.
Pumps and compressors	Pumps are used or form the core component of a vast array of equipment. Compressors are used in applications including heating, ventilation and air conditioning (HVAC) systems, transporting natural gas and equipment which requires compressed air to function.
Industrial tools	Industrial tooling comprises machine and cutting tools, such as those used to work and shape metal or other materials into the correct form before product assembly occurs.

10.1.2 Structure of the machinery sector

The machinery sector in the EU comprises predominantly SMEs providing equipment and services to numerous manufacturing sectors. Specialities within the European machinery sector include producing the machinery for metal product fabrication, food and beverage production and chemical industries.[146] Research conducted for this study suggests that the vast majority of companies operating within the machinery sector have 100 or fewer employees.

10.2 Remanufacturing in the European machinery sector

In the machinery sector the remanufacturing process generally involves machine disassembly, replacement of any components which are damaged, machine re-assembly and testing to the same standards required of a new product. Warranties, typically 1-12 months, are offered on remanufactured machinery though this depends on the type of product and the specifics of the remanufacturing that has been carried out.

The terminology used to describe the remanufacturing process in the machinery sector varies between companies and countries, though common phrases describing remanufacturing activities include 'rebuild upgrades' and 'retrofitting'. Other generic terminology used in the sector includes 'reconditioning' and 'refurbishing'. When the latter services are undertaken the equipment tends to be returned to the same customer and will

[146] *EU Industrial Structure*, a publication prepared by The Director General for Enterprise and Industry

include either a limited warranty (generally covering only the work carried out or parts replaced) or the warranty offered with the original product (if still valid) and not a reissue of an new warranty.

In this study we have identified that many more companies identify themselves as being involved with servicing, repairing, refurbishing and machinery reconditioning activities, compared to those involved in remanufacturing. The decision by a company to carry out a specific type of repair or maintenance activity - be it remanufacture, refurbishment or other - is partly shaped by the consumer of the machinery. If a customer asks for a manufacturer to remanufacture a product, the manufacturer will carry out this service where it has the capability to do so, even if it does not necessarily make up a regular or significant part of the business.

Remanufacturing in the machinery sector is somewhat fragmented but widespread across Europe, with activities taking place in a variety of countries including the UK, Germany, Spain, Belgium and the Netherlands.

10.2.1 Industrial food processing equipment

Industrial food processing equipment is suited to remanufacturing as it generally consists of casings and moving parts which are designed to be accessed and replaced upon failure. Regular servicing and maintenance work is used frequently in this sector to prolong the lifetime of the machinery and minimise equipment downtime.

Legislation, including hygiene and safety standards, exists to ensure the equipment used in this sector is convenient and safe to use.[147] This legislation presents a potential barrier to remanufacturing in this sub-sector of machinery, in as much as it may make the entry and acceptance of remanufactured products in the sector difficult. Nevertheless, a small amount of industrial food processing equipment remanufacturing currently occurs. In the UK for example, it is reported that second-hand items account for approximately 15 % of the market for industrial food processing equipment.[147]

Companies in this sector providing remanufacturing services tend to do this alongside their new sales. There is no evidence to suggest that companies exist which specialise only in the remanufacturing of industrial food processing equipment, or that there are opportunities for such businesses in this specific sub-sector.

Compass is an example of a company providing a remanufacturing service alongside its wide-ranging portfolio of new food-processing equipment. Its products include items such as tray sealers, flow wrapping machines, cold smoking chambers and automatic packers.[148] The remanufacturing service offered by Compass is to restore older machinery, including partial or complete rebuilds, to customer specific requirements. Full safe-guarding is offered throughout this process and, to ensure that standard compliance is achieved, equipment is tested to the latest standards and awarded a ‘CE’ mark as evidence of this taking place.

10.2.2 Pumps and compressors

Their mechanical nature and the fact that their design has not changed drastically in decades, means that pumps and compressors are particularly well suited to remanufacture and other forms of reuse. They are durable, and many components such as the casing will

[147] Centre for Remanufacturing and Reuse, *Product group report: Industrial food processing equipment*, 2009

[148] http://www.compassmk.com/food-processing-machinery, Accessed 22 October, 2015

last almost indefinitely. Typically, failure is associated with moving parts such as motors, bearings and shafts. These receive harder wear than other components; therefore these are the parts which most commonly require renewal as part of a remanufacturing or other process.

Low value units are often not worth salvaging for economic reasons and reuse is concentrated in higher value items. If reuse is not viable the units are either scrapped or components retrieved to use as spares. In addition, remanufacturing provides the opportunity to upgrade components and install new functions such as monitoring and logging devices. Between these extremes a spectrum of reconditioning, refurbishment and other reuse type activities occur. As in other sectors, factors such as value and condition criticality define which level of reuse is viable.

There are, however, some differences between the pump and compressor sectors which in turn has influenced the scale and the nature of the associated remanufacturing activities. Within the pump industry remanufacturing is well established and understood. The overall scale of this reuse market provides plenty of incentive for OEM engagement and they dominate the market in product volumes and value. A recent shift towards more service-based business models was noted, which further favours remanufacturing. Third party operators are also common, but on a much smaller scale than the OEM activities.

Remanufacturing and reuse in the compressor sub-sector is less well recognised than it is in the pump sub-sector. Historically there has been little scope for these activities, which were limited to small scale third party refurbishing and remanufacturing. More recently OEMs have established services which offer various options for compressor and component reuse. Independent third parties are also improving their services to offer fully remanufactured products, and some now specialise in this equipment.

10.2.3 Industrial tools

Industrial tooling, including machine and cutting tools, is an essential component of almost all manufacturing industries.[149] The Manufacturing Technologies Association, which represents them, defines machine tools as “power drive machines” and “not portable by hand”.[150] This equipment is used to work and shape metal or other materials into the correct form before product assembly occurs. The size and operation of machines in this sub-sector varies greatly, due to the wide range of functions carried out. Due to the advances in technology in this sub-sector in recent years, more complex systems have been introduced into this equipment, notably computer numerical control (CNC) systems.

In contrast to data reported in 2009, which stated that many OEMs were ignoring the demand for second-hand or reconditioned equipment[150], our research reveals that the proportion of OEMs undertaking remanufacturing and reconditioning activities is similar to the number of non-OEMs. This is further discussed in Section 10.3.3.

10.3 Market size/survey data

The machinery sector in the EU is worth €138 billion.[151] This value is based on a summation of 15 group codes, which include 186 product codes, as reported in the Eurostat database.

---

[149] *Remanufacturing in the UK, 2009*, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

[150] CRR, 2009. *Product Group Report: Machine Tools*

[151] Eurostat data 2014, 2015

See Table 40 in Annexe A for a list of the group codes considered in this report to represent the machinery sector.

Germany's machinery and equipment sector is the largest in Europe, according to Germany's foreign trade and investment agency Germany Trade & Invest (GTAI).[152] In Germany, SMEs produce the majority of both standard and customised products and services related to machinery for domestic and international demand. The GTAI reports that there are over 6,400 companies, employing more than 1 million workers who are involved throughout the value chain in the machinery and equipment sector in Germany.

Table 22: Remanufacturing landscape for the machinery sector

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	40	50	80	110	340	200	70	50	90	1,030
Employ-ment	300	200	700	700	1,600	1,300	400	300	300	5,800
# Core ('000)	40	40	80	110	330	200	70	50	90	1,010

Remanufacturing in Europe is valued at around €1 billion with Germany making up a third and Italy, France and UK making up 20%, 11% and 9%. Employment is estimated at 5,800 across about 500 firms. We expected the remanufacturing value to be higher than this when compared to figures reported in the US[153], but during discussions found that much of the activity was focused around repair and refurbishment with limited or no warranty provided, or that the proportion of the business undertaking remanufacturing activities was small. Thus this activity does not constitute remanufacturing as defined here. If the scope was extended to refurbishment as another key strategy of the circular economy, the value reported would be considerably higher.

From the survey, the overall remanufacturing rate for the machinery sector across the 157 companies sampled was 17 %. Within the OEMs of the machinery sector, 15 % (of 112 OEMs) were involved in remanufacturing activities, compared to 20 % (of 45 companies) in the non-OEM businesses. Many of the companies involved with remanufacturing were smaller businesses, with fewer than 50 employees. Remanufacturing activities within the OEM sector accounted for ~4% of the overall business turnover, whereas a higher figure of ~16% was observed in the non-OEM businesses.

10.3.1 Industrial food processing equipment

Within this sub-sector customers are generally left to dispose of their equipment and, in most cases, the manufacturer does not want to be responsible for the disposal of used equipment. Equipment resale benefits some companies and there are businesses which specialise in selling on used equipment. 18 % of the 44 companies sampled were found to be carrying out remanufacturing activities. The sample contained 41 OEMs and 3 non-OEMs,

[152] http://www.gtai.de/GTAI/Navigation/EN/Invest/Industries/machinery-equipment.html, Accessed 22 October, 2015

[153] *Remanufactured goods: An overview of the US and Global Markets and Trade* 2012. USITC. Accessible from http://www.usitc.gov/publications/332/pub4356.pdf

highlighting the predominance of OEMs in this sector. All the remanufacturing activities were being carried out by the OEM businesses.

It was also observed that a small number of companies reported that they had previously undertaken remanufacturing activities, including carrying out significant machine rebuilds on their own equipment, though they have since stopped operating in this space. For example, one large company was involved in refurbishing equipment until 3-5 years ago, but due to changes in production units, staff capabilities and facilities available to them, the company now only carries out servicing and repair work. The closure or relocation of facilities and production units, along with financial instability, could all contribute in the decision of a company to cease remanufacturing activities.

Food processing units can be large machines requiring a vast amount of floor space and special facilities such as heat extraction or ventilation, making it necessary to fit a custom built machine in a workspace area. The prevalence of custom built equipment in this sub-sector was cited as a reason that remanufacturing to a 'like-new' condition is not a priority for some businesses. In instances where equipment is built around a specific factory floor layout or space, finding a buyer for the remanufactured equipment would be very unlikely. The important factor in these instances is to keep the equipment properly serviced and any remanufacturing activities would be carried out for the original customer, in the knowledge this equipment is unlikely to be sold on to another customer.

10.3.2 Pumps and compressors

Following discussions with manufacturers and businesses carrying out repair/maintenance services in this area, repair activities were found to occur more often than remanufacturing. 11 % of the 71 businesses sampled in this sector carry out some remanufacturing activities. Two of the 41 OEMs and six of the 30 non-OEMs surveyed were involved with remanufacturing. A higher proportion of remanufacturing activities are currently being carried out by non-OEM companies (20 % of non-OEMs vs 5 % of OEMs). In the case of pumps and compressors this could be due to non-OEM businesses specialising in wholesale distribution, servicing and aftersales services. The most common activities these companies carry out, making them central to their business models, is the regular servicing and repair of pumps and compressors. Conversely, refurbishing or rebuilding units tended to be customer driven, rather than by business, and our evidence suggests that much of the remanufacturing taking place in this sub-sector was based on customer pull.

10.3.3 Industrial tools

In the industrial tools sub-sector of machinery and equipment, 24 % of the 42 companies sampled were involved in remanufacturing activities. 30 OEMs and 12 non-OEMs were surveyed; 23 % of OEM businesses participated in remanufacturing, with a similar proportion (25 %) in the non-OEM category. Typical services provided by these companies include grinding, reworking and refurbishing. In general, warranties were not offered by these companies if the original warranty had already expired. Also, in most cases the remanufactured products were returned to the original customer, rather than selling on 'like-new' to a different customer. The companies involved in remanufacturing activities in this sub-sector taking place were generally small, with fewer than 40 employees.

10.4 Opportunities and barriers

In the three machinery sub-sectors considered in this report there are some common, but also some sub-sector-specific, opportunities and barriers to remanufacturing.

10.4.1 Opportunities

- In the pumps and compressors sub-sector there some desire to establish and develop best practice and set standards for reuse and remanufacture. A specialist interest group linked to a trade association could oversee such activity.
- The profile of remanufacturing and reuse in the compressors sub-sector could be raised, using the pumps sub-sector as an exemplar. The economic and environmental benefits seen for pump remanufacturing may spur more interest in the compressor sub-sector if communicated and marketed effectively.
- In the industrial food processing equipment sub-sector, incentives for companies to purchase high quality remanufactured or reused machinery products could help establish these products and promote awareness.
- Consistent use of terminology would help consumers choose remanufactured and reused equipment. This could be achieved by the adoption of a remanufacturing standard e.g. BS8887-220:2010, or by developing industry-specific guidelines.
- A proportion of remanufactured equipment, typically high value machine tools, is exported. Expanding this activity to wider tools may provide an opportunity for remanufacturers to strengthen their businesses.

10.4.2 Barriers

- The lack of awareness of remanufacturing and reuse options, in all sub-sectors except pumps, is a barrier to increased remanufacturing.
- The demand and size of the market for reused or remanufactured machinery is comparatively small, such that there is little incentive for businesses to offer these services beyond the mainstay repair and maintenance offer.
- The cost of remanufacturing is often prohibitive for businesses, particularly for the complex and custom-built products used for the industrial processing of food. Remanufactured products need to be competitively priced, especially against cheaply manufactured new products from Asia.
- The capacity for carrying out remanufacturing activities in Europe may be limited by the size and competencies in the surviving manufacturing base, as significant manufacturing base has moved to Asia.

11 Marine

11.1 Description of sector

11.1.1 Definition of the marine industry

The marine industries manufacture and provide support services in the leisure, naval, commercial, offshore renewable energy and other sub-sectors.[154] Almost 90 % of global trade is waterborne. Dry bulk and containerized cargoes constitute 70 % of the global seaborne trade while oil and gas tankers account for the other 30 %.

Transport by sea is characterized as low cost compared to other means of transport, due to energy efficient vessels and efficient port infrastructures and logistic chains. The dominant position of shipping is not threatened by other forms of transport; the need for waterborne trade is driven by international demand, and shipping will continue be the leading international freight modality.[155]

World trade has been recovering from the economic and financial crisis in 2009 which resulted in overcapacity of the merchant fleet, historically high oil prices and the use of 'slow steaming' (operating cargo ships at far below their maximum speed to save on fuel costs). 2013 was the first year since the financial crisis where significant growth was seen in the order books of the world's shipbuilding industry. Demand for shipbuilding capacity generally follows ship owners' profit margins which are not necessarily tied to the volume of freight. Thus the current low cost of oil has increase profitability, and hence the outlook for shipbuilding volumes is positive. Given the expectations that the global economy will almost double by 2030, it is clear that additional waterborne transport capacity will be required. However, low oil prices are likely to result in lower investment in offshore extraction and wind energy sub-sectors.

11.1.2 Structure of the European shipbuilding industry

The European shipbuilding industry is the global leader in the construction of complex vessels such as cruise ships, ferries, mega-yachts and dredgers. It also has a strong position in building submarines and other naval vessels. The top four countries in ship construction are Germany, Italy, Netherlands and Romania[156].

The European marine equipment industry is a world leader for a wide range of equipment needed on-board ships and in harbours, ranging from propulsion systems, through large diesel engines and environmental and safety systems, to cargo handling and electronic systems.

Ship repair does not necessarily require dry docking, as work can be undertaken alongside the vessels at berths or at sea (Table 23). Normally ships are dry docked for maintenance and overhaul at regular time intervals e.g. every 2-3 years. Larger ship conversion services alter the structure and/or configuration of vessels to enable them to carry out a different purpose than was originally intended when the vessel was built. Some special characteristics of the ship repair business include:

---

[154] http://www.zerowastescotland.org.uk/sites/files/zws/Remanufacturing Study - Full Report - March 2015_0.pdf

[155] ECSA, The European Community Shipowners' Associations. http://www.ecsa.eu/

[156] Study on the Competitiveness of the European Shipbuilding Industry, 2009, ECORYS SCS Group

- Significant planning and scheduling activity well in advance rather than *ad hoc* or unplanned activities.
- Short delivery times - an intensive short period to mitigate the opportunity cost while the ship is unable to generate sales.
- Labour intensive i.e. low level of automation.
- Use of a variety of skilled labour and partners.
- Use of a wide variety of products.
- One-off large ships, but many small components and work objects.

Because of these special characteristics each dry docking has its own unique circumstances; this, coupled with the generally low operating margins, means shipbuilding is a conservative business.

Table 23: Different types of ship repair activities, their frequency and typical location[157]

Milestones in a ship's lifecycle	Frequency	Location
Maintenance	Continuous	Any
Small scale voyage repairs	Occasionally	At sea
On-board repair	Occasionally	Harbour
Planed dry-docking, ship overhauls	2 times per 5 years	Repair yard
Large scale retrofit & refurbishment	After 10 – 15 years of operation	Repair yard
Modernising and extending the commercial life by another 20 years	First lifetime usually 20 – 30 years	Repair yard
Conversion, lengthening, transformation to other usage	Ad-hoc	Repair yard
Emergency repair & damage repair	Unscheduled	All

European enterprises dominate the passenger ships and cruise liner shipbuilding industry, while the repair activities take place globally, mostly close to where the ships normally operate. Europe is the home to some major companies involved in remanufacturing as part of their ship building and repair operations including BAE Systems Maritime, Faslane, Babcock Marine and Rolls-Royce.

11.2 Remanufacturing in the European marine industry

The terms 'remanufacture' or 'refurbishment' are not usually associated with ships. The most common and closest terminology is 'refitting'. Refitting includes a variety of operations from basic maintenance and refresh to repurposing and fully upgrading a ship for a different use. Though complete ships are not remanufactured in the sense that they are not restored to a 'like new' condition, the principles of remanufacturing can be applied to small sections, components and other ship's equipment.

As remanufacturing typically occurs at the component level there is potential for 'leakage' to HDOR; for example we spoke with remanufacturers who identified as HDOR remanufacturers that remanufactured engines for submarines.

The first three types of ship repair activities, listed in Table 23, are typically small and do not require dry docking. The components replaced as part of these repairs can be collected from the ship and sent to a remanufacturing company for remediation. The remanufactured product can then be used in other ships or, depending on the product, in another business

[157] Remanufacturing & Ship Repair Possibilities, networking and outlook, World Remanufacturing Summit 2013, Kim Jansson http://www.vtt.fi/files/sites/demanet/jansson_reman_summit_2013.pdf

sector entirely. Examples of these types of repair activities are corrective maintenance (e.g. breakdown maintenance), spare parts and component replacement, and HVAC system maintenance[158], but also planned, predictive and preventive maintenance.

Extensive ship repair or refurbishment work requires the involvement of a repair yard and typically also dry docking of the ship. The frequency of planned dry docking is approximately twice in a five year period. In dry docking operations components and parts being replaced or removed as part of the overhaul can be collected at the repair yard and sent to a remanufacturing company with the remanufactured product entering the aftermarket as above. There are similar opportunities for remanufacturing associated with the modernisation and conversion of ships, though these activities occur much less frequently.

Specialist OEMs carrying out remanufacturing may associate with the shipbuilding industry in a region. For example a diesel engine manufacturer may provide the ship-builders with remanufactured components such as cylinder covers, pistons, piston crowns, piston rods, exhaust valves and connecting rods. The greatest opportunity for remanufacturing in shipbuilding lies with small, regular maintenance scale activities, because such repairs are relatively frequent in the shipping industry and because they are more likely to require standard parts and components in multiple quantities. Therefore the number of core suppliers and customers is greater than for the one-off products typical of larger scale ship repair activities.

11.3 Market size/survey data

There are about 85,000 ships in the world, with 82% being at least 5 years old, and over half being at least 15 years old[159]. All these ships require, or will require, regular repair and maintenance. Ship repair yards provide ship-owners with maintenance services to ensure that the ships are kept in a seaworthy condition in line with the standards set by the:

- Requirements made by their flag states (the state under whose laws the vessel is registered)
- International Maritime Organization
- Classification societies - non-governmental organisations that establish and maintain technical standards for the design, construction and operation of ships. There are twelve member societies within the International Association of Classification Societies (IACS)

The overall size, value of and employment associated with three sectors of the marine industry are shown in Table 24.

Table 24: Structure of the European marine industry[160]

	Marine equipment	Shipbuilding	Maintenance, repair and conversion
Production value	€47 bn	€30 bn	€3 bn
Direct employment	241,000	150,000	20,000
No. of enterprises	22,400	300	88

[158] HVAC = heating, ventilation, and air conditioning

[159] The world merchant fleet in 2014, Statistics from Equasis. European Maritime Safety Agency

[160] *Supplying, Building & Maintaining the Future*, 2014. Sea Europe

The remanufacturing market for marine is relatively small compared to aerospace, automotive and HDOR, estimated at €76 million. As previously highlighted, this is likely due to much of the maintenance, repair and conversion activity being more in the repair and refit domain i.e. not to the level of rigour of remanufacturing with a warranty. There is potentially a secondary effect due to allocation, with HDOR receiving credit for marine component remanufacture; this effect is difficult to disaggregate as remanufacturers self-identify with HDOR and therefore it is hard to ascertain what proportion of HDOR activity may be more marine oriented.

Table 25: Remanufacturing landscape for the marine sector

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	11	2	15	3	11	8	13	5	6	76
Employ-ment	120	20	250	40	70	90	110	40	40	780
# Core ('000)	11.9	2.7	16.8	3.7	12.4	9.1	14.0	5.1	7.0	82.6

11.4 Opportunities and barriers

Remanufacturing will only be established at scale in the conservative marine industry if the economic drivers make sense. Maximising the time a ship is in active operation means reducing dry dock time as much as possible through using reliable materials and time-saving processes wherever possible. Remanufactured products need to meet these requirements if they are to be widely accepted in the marine industry.

11.4.1 Opportunities

Remanufacturing opportunities are more evident in ship repair activities focused on the equipment- and component-level and smaller operations. This is because of the difficulties of servicing the variety of non-standard products with very limited markets for larger ship-overhauls in the marine sector. However, the cost-savings available from standardisation and scale are increasingly being realised in the industry with very large ships and batches of 'sister' ships becoming more commonplace. Technology upgrades are also leading to better standardisation of on-board equipment. All this standardisation improves the prospects for profitable remanufacturing going forward.

Ship-yards might consider partnering with components, equipment and systems OEMs to increase the reliability of supply, considering the tight timeframes associated with dry dock time. These OEMs may find that, given these time scales, non-standard parts might be better remanufactured rather than sourced new from elsewhere.[161]

[161] Competitive Position and Future Opportunities of The European Marine Supplies Industry, Final Report. BALance Technology Consulting GmbH, 2014

11.4.2 Barriers

The complexity of shipbuilding, and the fact that every dry docking of a ship is effectively unique, poses many challenges to remanufacturing. As mentioned above, non-standardised marine equipment and components hinder efficient remanufacturing. A further challenge to remanufacturing in the marine sector lies with the uncertain timing and quantity of returned parts. This in turn makes finding customers for the remanufactured products difficult as well as meaning that the reverse logistics necessary for a closed remanufacturing loop are almost impossible to plan in advance.

There is another specific challenge that faces marine industry remanufacturing in some parts of Europe, namely a lack of capacity. Where the shipbuilding industry has been in decline for decades there are knowledge, skills and yard-capacity shortages which would be a considerable barrier to any growth in ship-refitting activities.

12 Medical devices

12.1 Description of sector

12.1.1 Definition of the medical devices sector

Medical devices and equipment are items used on patients to carry out medical care, including testing, diagnosis, surgery and after-care. Thousands of products fall into this category, from simple disposable supplies to highly capital-intensive devices (Table 26).[162] The products manufactured by the medical technology industry range from spectacle lenses to cardiac implants, from blood-glucose monitors to hospital beds and MRI scanners.[163] In Europe, what is considered to be a medical device or a piece of medical equipment is clearly outlined in the European Union Medical Devices Directive (93/42/ECC).[164]

A common thread of intrinsic safety and regulatory measures runs through the business and technology aspects of this sector. Whilst this is a high priority in a health-led industry, compliance with the relevant safety and regulatory benchmarks presents a business risk to the companies involved. Since June 1998 all medical devices sold in Europe must bear the CE Mark. Currently, this regulatory framework is being revised with the roll-out of the new regulation planned for 2016.

Table 26: Examples of the medical devices and equipment

Medical division	Type of equipment
Anaesthesia	Face masks, patient monitoring equipment
Endoscopy/laparoscopy	Range of implements and equipment
Hearing aids & audiometry	Instruments to aid hearing and diagnose hearing loss
Hospital capital fixed plant	Body scanners, linear accelerators to x-ray apparatus
Hospital supplies & disposables	Sterilisers, gloves, needles, syringes to sample holders
Implantable devices	Miniaturised instruments such as pacemakers
In-vitro diagnostics & kits	'Lab-in-a-box' kits
Infusion & inhalation therapies	Instruments to dispense drugs or nutrients
Invasive surgery	Surgical tools and disposables
Prosthetics and artificial joints	Implants or limb replacements
Ultrasound	Imaging, diagnostic and treatment devices

'Remanufacturing' or 'refurbishing' in the medical device sector favours medical equipment that are designed to have a long lifespan, are non-invasive, require significant R&D investment and are capital intensive to build and buy. Devices that fall into this category include magnetic resonance imaging (MRI), ultrasound and computed tomography (CT) scanners, X-ray and cardiology equipment as well as precision and optical devices. In general this equipment is well made resulting in a long useable life. Remanufacture and servicing plays an important role in keeping a piece of equipment functioning for as long as it is

[162] PRIME Faraday Partnership: *Medical Devices: The UK Industry and its Technology Development*, 2003

[163] http://www.eucomed.com/uploads/Modules/Publications/medtech-medicaltechnology_broch_v05_pbp.pdf

[164] UK: Department for Business, Innovation and Skills (DBIS), UK Trade and Investment (UKTI), Department of Health (DH): *The landscape of the medical technology, medical biotechnology and industrial biotechnology sectors in the UK*, Annual update 2010 available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31810/10-p90-strength-and-opportunity-bioscience-and-health-technology-sectors.pdf

needed or until it becomes obsolete because of technological advancements or due to functional redundancy.

12.1.2 Structure of the medical sector

A small number of device manufacturers dominate the capital-intensive imaging equipment segment of this sector. Depending on how much the hospital or health authority want to invest, these companies can supply different levels of equipment quality. They will also design equipment to the needs of specific divisions of medicine. For example, a company might market an x-ray imaging device for use in orthodontics which, though based on the same underlying technology, varies significantly from a similar device marketed to paediatric and orthopaedic departments. As described in more detail in the following section, these instruments are predominantly serviced and repaired by the OEMs that originally produced them.

Lower cost electrical and mechanical equipment used in the medical sector - including hoists, pumps, monitoring devices and laboratory equipment - are produced by a wide range of OEMs that, if applicable, will also offer after-sales care contracts. However, because of the significantly lower cost of this type of equipment, maintenance is more likely to be carried out in-house or by independent third-party (non-OEM) companies.

12.2 Medical device remanufacturing in Europe

According to the US Federal Food and Drug Administration and EU regulations, 'refurbished' medical devices are those that are restored to their original performance specification, i.e. retain the CE Mark. 'Remanufactured' devices, on the other hand, are those whose performance is significantly changed from their original performance specification. Thus, remanufactured products would need to be re-certificated for them to be legally used again in a European medical facility.[165]

COCIR, a body representing the European radiological, electromedical and healthcare IT industry, has developed a *Good Refurbishment Process* (GRP) that is regularly revised. Since 2009, Version 2 has been the industry standard used to establish good refurbishment practice for medical equipment. Another term used in the medical equipment sector is 'reprocessing'. This is usually carried out on surgical instruments; high-value electrical instruments such as X-ray machines or MRI scanners are refurbished or remanufactured. The EC is currently considering what should be accepted as best practice for 'reprocessing' which will undoubtedly have consequences for OEMs and reprocessors.[166]

There are two distinct categories of enterprise that remanufacture medical devices: OEMs and third-party / independent operators. Most of the higher-end remanufacturing and refurbishment is done by OEMs such as GE Healthcare (UK), Philips Healthcare (Netherlands), Siemens Healthcare (Germany), and Toshiba Medical Systems Europe (Netherlands) - see

Table 27. The after-sales service provided by the OEMs - including warranties, leases and service contracts - is an integral part of their strategies for capturing as high a market share of the market as possible.

---

[165] FDA

[166] COCIR: http://www.cocir.org/index.php?id=136

Table 27: Examples of OEMs carrying out remanufacturing work

Company	Description of remanufacturing services offered
GE Goldseal Refurbished Systems[167]	General Electric's *GoldSeal* process starts with systems which are well-known and have service histories that show that they can meet GE's stringent standards for refurbishment. *Goldseal* refurbished systems include computed tomography, X-ray, MRI, nuclear medicine, PET/CT, mammography, surgical imaging and ultra sound equipment. • Once de-installed and delivered to a GE global facility, each system is restored, possibly alongside the manufacture of a new GE Healthcare system. • Using only OEM parts, every system goes through an exacting, proprietary process to meet original system specifications and performance. • GE owns the entire process end-to-end and provides a same-as-new warranty. • GE claims that "once a product has been through its refurbishment process, you'd be hard pressed to tell the difference between a GoldSeal system and a new system." GE highlights that GoldSeal products promote the reuse and recycling of imaging systems and therefore incorporate GE's "ecomagination commitment".
Philips Diamond Select system[168]	Every *Diamond Select* system undergoes a five-step refurbishment process: • Identification and selection of prime performers with a reliable track record; • De-installation and specialized transport; • Refurbishing process that involves testing of all components, replacement of obsolete or defective parts, installation of the latest software and field updates, configuration of the system, cleaning and painting, and a full performance and image quality check performed according to OEM specifications; • Re-installation of the system; • Provision of a full warranty and customer service.
Siemens Quality Refurbishment Process[169]	Siemens Ecoline system is an example of a remanufacturing process which increases the useful life of used medical equipment and incorporates Siemens' up-to-date technologies. Siemens highlights that the process ensures compliance with Siemens' *Proven Excellence* quality seal which represents compliance with strict international standards, security regulations and environmental responsibility goals. The '5 steps' are: • Selection of suitable devices that are 'upgradable' with new hard/software; • De-installation, transport and inspection;

[167] GE Healthcare: www3.gehealthcare.com/en/products/categories/goldseal – refurbished systems

[168] Philips Healthcare: www.healthcare.philips.com/main/products/refurbished_systems/

[169] Siemens Healthcare: www.healthcare.siemens.com/refurbished-systems-medical-imaging-and-therapy/refurbishing-process

	• Cleaning, disinfection, painting, replacement of worn parts, checking of components and systems, software updates, application of *Proven Excellence* quality certificate and seal; • Installation and performance check; Warranty equivalent to a new system, spare parts availability for a minimum of 5 years and worldwide service contracts.
Toshiba Secondlife Refurbishing Program[170]	The Toshiba *Secondlife* refurbishing program mostly remanufactures imaging equipment traded in with the purchase of a new Toshiba instrument. Toshiba deals with the remanufacture of brands of instrument other than its own. After the careful selection of suitable units, they are collected, refurbished and provided with a one year warranty. • Refurbishment involves disinfection of the system, testing and clean of all parts and components, replacement of worn or damaged parts with OEM spares and repainting of covers. • As a standard procedure, each system is upgraded to the latest applicable software. • The process is rounded off by an electrical safety test and an extensive quality control procedure to ensure all Toshiba OEM specifications are met. A *Secondlife* sticker is placed on the product as a seal of quality and a full one year OEM warranty is provided.

The independent third-party SMEs that account for the remaining remanufacturing activity within this sector in Europe service a wide range of less complex equipment. Best practice among third-party refurbishers, which is voluntary, involves replacing broken and worn parts with OEM parts, using OEM-trained engineers to perform repairs, and providing a warranty (ranging from 30 days to one year) with the finished product.[171] However, standards of refurbishing tend to vary among third-party refurbishers, and may not comply with the GRP standards to which the OEMs adhere. Refurbishing activity in the sector is highly regulated, and may therefore involve greater business risk to a smaller third-party operator. Whilst some of these third-party enterprises may offer services that include complete electromechanical refurbishing to an 'as-new' standard, most offer reconditioning or instead act as medical instrument and spare-part brokers.[172] This segment of the industry is characterised by smaller operators, typically with fewer than 10 employees, working within a relatively specialised product area.

Due to the high-capital nature of the devices remanufactured in the medical device sector, these smaller third-party enterprises often operate within a niche market or provide parts or services to larger businesses. Furthermore, a segment of these non-OEM refurbishers focus on marketing their products at the veterinary sector and developing countries, where the standards required of medical equipment are not as rigorous. In some instances OEMs authorise third-party operators to refurbish their devices and provide OEM technological

[170] Toshiba Medical Systems Europe: www.toshiba-medical.eu/eu/service-and-support/secondlife/refurbishment/

[171] WRAP, CRR: *Remanufacturing of medical imaging devices*; www2.wrap.org.uk/downloads/ProdRepMedDev1.698d252d.9001.pdf

[172] USITC: *Remanufactured goods: An overview of the US and global industries, markets and trade*, 2011.

knowledge, training and parts. Such a collaborative arrangement with an OEM can also lend credibility to the third-party provider.

The principal sources of medical device core are leading healthcare providers and OEMs, which may re-acquire the core upon completion of the device's first life cycle. This puts OEMs at an advantage over independent third-party operators. Trade-ins by customers upgrading to a more up-to-date system are estimated to account for almost three-quarters of imaging device core in the USA.[173]

12.3 Market size/survey data

According to Eurostat data for 2014, the total market value of the medical device sector within the EU was €35billion. This includes new manufacturing and repair activity. The value is based on a summation of 6 group codes, which includes 35 product codes, reported in the Eurostat database - see Table 39, Annexe A for a list and description of the Group codes considered in this report to represent the European medical device sector.

Table 28: Remanufacturing landscape for the medical devices and equipment sector

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	40	70	100	110	320	60	70	80	120	970
Employ-ment	200	800	1,600	700	2,000	400	500	400	500	7,100
# Core ('000)	40	70	110	120	330	60	70	90	120	1,010

Remanufacturing of medical devices is estimated to be worth around €1 billion to the European economy employing over 7,000. These vary in size from small third-party operators employing fewer than 10 people to the large OEMs employing over 5,000 with embedded remanufacturing divisions. Most of the higher-end medical device remanufacturing in Europe is undertaken by the big four OEMs mentioned previously – GE Healthcare (UK), Philips Healthcare (Netherlands), Siemens Healthcare (Germany) and Toshiba Medical Systems Europe (Netherlands).

OEMs reportedly resell approximately 80 % of the medical devices that they receive back from customers as trade-ins; the remaining 20 % are sold for spare parts. [174] The so-called 'grey market' represents the remaining medical devices that are not returned to the OEMs. Some of these devices will be refurbished by third-party operators and the remainder sold for spare parts by brokers.

The amount of remanufacturing of medical devices that takes place in Europe varies greatly from country to country. German remanufacturing production is estimated to be approximately three times greater than that of the next largest European market. The UK, France and Italy have relatively well-established remanufacturing sectors.

[173] USITC: *Remanufactured goods: An overview of the US and global industries, markets and trade*, 2002

[174] A contact with an OEM

It is understood that these markets have significant export markets. In the UK for example, the NHS is the major buyer of medical devices and does not currently purchase refurbished medical equipment. The market within the UK for refurbished medical equipment is therefore relatively small, reflected in the relatively few dealers of second-hand medical devices.

From a sample of 74 repair and distribution type organisations, 70 % reported being involved in remanufacturing-type repair and overhaul activities. Among these firms, the proportion of business turnover that was related to remanufacturing was lower for OEMs than for non-OEMs.

From a sample of 29 medical equipment manufacturer companies in the UK, around 38 % of these companies undertakes some form of remanufacturing – refurbishing, repurposing, reconditioning, overhaul, repair or maintenance work. Of these companies, the proportion of business turnover that related to remanufacturing specifically was 12 %.

While remanufacturing, as defined by the Medical Device Directive is still relatively uncommon in Europe compared to the USA (the largest medical device remanufacturing market in the world), organisations in the medical device sector surveyed for this study expected steady growth over the next five to 10 years.[175] It is likely that demand for medical equipment will be driven by its lower cost relative to new manufactured products and by the growth in private healthcare institutions.[176]

12.4 Opportunities and barriers

12.4.1 Opportunities

For the major OEMs surveyed as part of this research, the most important motives for remanufacturing were: a secure supply of spare parts; product warranties; to increase their market shares; customer pressure; government legislation; company profitability and strategic advantage. Fluctuations in raw material prices and environmental sustainability had a smaller impact on their decision to be involved in remanufacturing. For third-party operators, the availability of spare parts from outdated equipment and used systems was of more importance as a driver for (or barrier to) remanufacturing.

Medical equipment procurement generally depends on the purchasing strategies of public health authorities and private healthcare providers. Though safety regulations must be strictly adhered to, there is still an opportunity to influence the decision making processes at this level in favour of remanufacturing. Reassuring purchasers that remanufactured and reused products are not of an inferior quality to new products would be the most direct way to increase remanufacturing activity in this sector. Currently purchasers predominantly associate remanufacturing with the low-standard refurbishment activities used to repurpose medical equipment for the veterinary market or export to emerging markets.

There is enormous pressure on all medical institutions to provide the best patient care at the lowest possible cost and this is an issue which can only increase in importance in the future.[177] Given the high price of these devices, hospitals and healthcare providers across

---

[175] ERN market survey

[176] Frost & Sullivan, 2010: www.slideshare.net/FrostandSullivan/refurbished-medical-imaging-equipment-growing-business-during-lean-economy

[177] WRAP:CRR: *Remanufacture of medical imaging devices*; www2.wrap.org.uk/downloads/ProdRepMedDev1.698d252d.9001.pdf

Europe are becoming less averse to acquiring remanufactured medical devices, which can cost end users up to 50 % less than a respective new device.

12.4.2 Barriers

According to the OEMs surveyed as part of this research the main barriers hindering their remanufacturing activity was the quality of the feedstock available, lack of sales channels and legislative restrictions. They perceived these barriers to remanufacturing as being more significant than labour costs and the availability of technology and product knowledge.[178]

Independent third-party operators reported their remanufacturing activities were constrained by the quality of the feedstock, lack of technology and product knowledge and high labour costs. One small third-party operator said that it used to refurbish its own bladder scanners, but that this was no longer cost effective.[179]

The differences in legislation between EU Member States and the lack of awareness of refurbished systems are further challenges to the growth of remanufacturing in this sector. Improvements in after-sales servicing are required to allow for quality to be maintained which, in some cases, may be better provided by OEMs. Difficulties in finding suitable dealers and distribution networks is also a barrier that face third-party refurbishers operating in this market.[179]

A large number of regulations must be met before a remanufactured product can be sold. While these rules are clearly necessary for the safe operation of this equipment, they place an additional cost burden on potential and existing remanufacturers. One third-party operator told us that it did not refurbish devices but repaired and reconditioned only, as it "did not want to get into CE-Mark territory".[180]

A belief that remanufactured and reused products are of inferior quality may be reinforced by lower quality refurbished equipment being acquired by less restrictive markets in developing countries or by the veterinary industry. In particular, customer perceptions strongly influence the precision and optical device sector. Purchasing attitudes that favour new over pre-owned medical devices push down the price of reused equipment, thereby reducing the viability of remanufacturing.[181] In some cases insurance firms will pay a reduced amount or refuse to pay out for medical claims using equipment over a certain age (typically 5 years) and/or remanufactured equipment - presumably based on the premise that the equipment is not as efficacious as new equipment. This practice clearly has knock-on effects of decreasing the demand from healthcare providers for remanufactured products.

---

[178] ERN Market Survey

[179] ERN Market Survey/Interview with industry

[180] Interview with industry

[181] *Remanufacturing in the UK, 2009*, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

13 Rail

13.1 Description of sector

13.1.1 Definition of the rolling stock sector

For the purpose of this report, only rolling stock remanufacturing will be considered in the rail sector. Rolling stock are the vehicles used in the rail industry and include: traction units (providing motive power to pull passenger and freight trains), passenger carriages, self-propelled passenger vehicles, freight wagons and infrastructure maintenance vehicles. Their manufacture is lengthy and capital-intensive, thus rail systems need huge investments.

The rail sector encompasses inter-city passenger and freight rail services as well as urban rail services, including light rail systems, trams and street cars, automatic people movers (APMs) e.g. driverless trains often used in large airports, metro train systems monorail and personal rapid transit (PRT) systems, also called podcars.

13.1.2 Structure of the rolling stock sector

The rail supply industry is broadly structured around operators, infrastructure managers and manufacturers; in some countries these roles can be combined within one organisation. The rolling stock industry is thus a part of the rail supply industry. The rail supply industry supplies and equips all kinds of rail travel: high speed, regional, urban/suburban or freight.

Europe is the home to major rolling stock operating companies (ROSCOs) such as Alstom SA (France), Standler Rail AG (Switzerland), and Siemens AG (Germany). Table 29 lists the leading rolling stock manufacturers worldwide in 2012, ranked by revenue.

Table 29: Largest ROSCOs by revenue[182]

Company	HQ Country	Revenue in 2012 (€ bn)
CSR Corporation	China	5.2
China CNR Corporation	China	4.8
Bombardier	Canada / Germany	4.8
Alstom	France	3.0
Siemens	Germany	2.3
Transmashholding	Russia	1.5
CAF	Spain	1.3
Hyundai Rotem	Korea	1.2
Kawasaki	Japan	1.1
GE Transportation	US	1.0

While these very large enterprises exist, small and medium enterprises make up the majority of the approximately 800 businesses involved in the manufacture of railway locomotives and rolling stock.[183] [184]

[182] Rail Outlook Study 2013-2022, Frost & Sullivan, 2013

[183] UNIFE, European rail manufacturing industry. http://www.unife.org/

[184] Frost & Sullivan, Strategic Analysis of Growth Opportunities in the Western European Urban Rail Market for Rolling Stock Systems, 2013

13.2 Remanufacturing in the European rail sector

Financial motivations rather than environmental reasons tend to drive remanufacture in the rail supply industry. 'Refurbishment' and 'remanufacture' are well established practices: industry contacts indicated that rolling stock is refurbished approximately every four years. After 5-8 years in operation most units will receive a major overhaul involving the servicing and possible replacement of systems such as doors and electronics. The body of the vehicle and interior fittings usually require refurbishment at the half-life refit (typically after 15 years of operation).

Most remanufacturing-orientated activity is associated with rolling stock as it undergoes heavy use and requires regular work to keep it running efficiently and safely. The running gear will require more frequent remanufacture, and is normally serviced at a fixed mileage interval. This involves the removal of the bogies (the structure with axles and wheels under a railway carriage or locomotive) for complete strip-down and remanufacture of all sub-systems. The engine or motor and transformer will also need to be removed and remanufactured at similar intervals. Industry contacts indicate that rolling stock is completely remanufactured at least once in its 30 year lifetime.

Extensive and regular maintenance is central to this part of the industry. Routine low-level maintenance is the responsibility of the train operating companies (TOCs). The periodic complete overhaul and large-scale remanufacturing of rolling stock, however, is typically the responsibility of the ROSCOs. The ROSCO owns and maintains railway engines and carriages which are leased to TOCs who actually operate the trains. Along with the lease of the vehicle there is normally a service agreement between the TOC and the ROSCO, worth around half the original equipment value, whereby the ROSCO agrees to be responsible for the periodic refurbishment of the rolling stock. As part of these servicing activities, components of tractor units and carriages will be repaired, replaced and modernised. The ROSCOs are responsible for this periodic heavy-level maintenance work, up to and including the complete refurbishment or remanufacturing of whole trains, but it is OEMs that actually carry out most of this work.

Key players in the remanufacturing of rolling stocks in the rail sector

Rolling stock operating companies (ROSCOs) – Companies that own and maintain the rolling stock leased to the TOCs (see below). ROSCOs are responsible for the periodic heavy maintenance, refurbishing and remanufacturing of rolling stock.

Original equipment manufacturers (OEMs) – Companies that carry out the heavy maintenance, refurbishing and remanufacturing of rolling stock on behalf of the ROSCOs.

Train operating companies (TOCs) – Companies that lease the rolling stock from the ROSCOs. TOCs are responsible for the low level regular maintenance of the rolling stock.

There is a healthy industry associated with the remanufacture of components for the routine maintenance carried out by TOCs and the periodic thorough maintenance carried out by ROSCOs. This is particularly true for components with moving parts which undergo heavy use. Some of these parts are commonly seen in other remanufacturing sectors, such as diesel engines and pumps. The diesel engines which drive locomotives are the most commonly remanufactured components. Other parts are more specific to the rail industry; for example, bogies. Typically remanufacturing is subcontracted out to specialist third parties, which have the knowledge, skills and reputation to carry out this work. These

organisations also need to be large enough to provide the volumes of parts required by the ROSCOs, and are often not linked to the final assemblers. The operation of remanufacturing within this industry limits the scope for small, independent remanufacturers - these only operate in highly niche sectors, such as steam trains.

Railway systems require heavy investment and the life-cycles of rolling stock are typically long, stretching over several decades. Rapid development in communications and diagnostic technologies is moving across into the rail operating environment, providing near-continuous condition monitoring of assets. This therefore provides a sound platform for remanufacturing as a technique for keeping these capital-intensive assets in full use and up to date with the latest technology.

13.3 Market size/survey data

The EU is the largest market for rail products and services (Table 30), including rolling stock. Here, the rolling stock sector is experiencing a stable period of modest growth (CAGR of 2 %), driven by the European Commission's encouragement of cleaner energy use through new fuel and propulsion systems. The demand for rolling stock is in line with general industrial growth and manufacturing volumes, such as seen in Germany, the UK, and France in particular. Consumer pressure, with travellers expecting comfortable and safe train travel, is also expected to positively impact the demand for better quality rolling stock.

As Table 30 indicates, between 2008 and 2010 the European rolling stock market had an annual value of €11.7 billion and is forecast to grow to €13.5 billion by 2014-16, while the wider rail industry employs approximately 400,000 people.

Table 30: Value of rolling-stock market by region, and change since 2008-2010

Region	Annual value between 2008 and 2010 (US$ bn)	Forecast annual value 2014 to 2016 (US$ bn)	CAGR (%)
Europe	**11.7**	**13.5**	**2 %**
China	10.5	8.4	-4 %
North America	3.4	4.2	4 %
CIS, including Russia	2.3	4.3	11 %
Latin America	1.6	1.3	-4 %
India	1.3	2.1	9 %
Asia-Pacific	1.6	2.3	6 %

Source: Statista at http://www.statista.com/ & Eurostat

The remanufacturing market for the rail sector is valued at close to €350 million employing approximately 2,700 people (Table 31).

Table 31: Remanufacturing landscape for rail sector

Region / Member State	Benelux	Central	Eastern	France	Germany	Italy	Medi-terranean	Nordic	UK & Ireland	Total
Turnover (€m)	10	50	40	20	60	40	50	30	50	350
Employ-ment	100	300	500	200	400	400	300	200	300	2,700
# Core ('000)	10	50	40	20	70	40	50	30	50	360

13.4 Opportunities and barriers

13.4.1 Opportunities

The growth in urbanisation worldwide will further promote the integration of the traditional city centre with its expanding suburbs creating demand for local trains, while high speed rail-links will be needed to connect cities with each other. This infrastructure will impact the mobility, working life and many other aspects of society. In the future, mega-cities and regions connected with efficient rail and metro systems will be more prevalent.

A 'smart city' is the future concept that uses digital technologies or ICT to enhance the quality and performance of urban services, and to reduce costs and resource consumption. More than 50 % of the smart cities of 2025 are projected to be in Europe and North America, increasing the demand for quality transport infrastructure, including rail network development, in these regions.

The rail market has significant potential for growth; however, economic uncertainties and lack of unified quality standards restrain growth. The main drivers for growth are:

- urbanisation
- government stimulus
- requirements to reduce resource consumption and greenhouse gases
- replacement of ageing rolling stock.

The rolling stock sector benefits from the fact that remanufacturing and similar activities are already well established. There is enough experience in the industry to determine which process – remanufacturing, replacement or otherwise - is most appropriate for a given part in given operating conditions, based on economic factors.[185] Harmonised standards and policies, which could increase confidence in remanufactured products, may help the industry make informed decisions regarding the safety, operational lifetime and relative costs of remanufactured and other components.

An opportunity also exists to expand the infrastructure related to remanufacturing activities: it is reported that there are insufficient overhaul sites and other facilities required to carry out the refurbishing and remanufacturing activities to keep up with the rising volumes of rolling stock requiring maintenance. Indirect influences may also provide opportunities, such as the targeted growth in rail use for both passenger and freight transport, meaning a commensurate increase in rolling stock quantities.

Finally, changes in technology - particularly integrated electronics - may present a significant opportunity as it will provide remanufacturers with a new market (i.e. new types of component to work on). This could be a significant growth area if the appropriate electronics expertise is available – a common theme found in other sectors such as automotive and HDOR.

13.4.2 Barriers

Though the rail industry is looking relatively robust in Europe, it is also susceptible to downturns. Further or deepening economic crises, such as experienced in the EU since

[185] *Remanufacturing in the UK, 2009*, CRR: available at http://www.remanufacturing.org.uk/pdf/story/1p342.pdf

2009, would negatively impact growth in the rail sector. Other specific barriers to remanufacturing in the rail sector include:

- The initial capital costs of new rail projects, large scale modernisation and remanufacturing activities.[186]
- The extensive testing requirements for new, refurbished and used equipment (for example, specified in the UK by the Railway Industry Supplier approval scheme), are a costly burden for remanufacturers.
- The complexity of remanufacturing operations may increase in line with the trend for the increased integration of electrical systems into parts and systems in modern rolling stock. A lack of specialists with the necessary electronics skills may hamper growth of remanufacturing.
- The size of the rail sector is defined by only a handful of contracts annually, and thus its value will fluctuate dramatically from year to year. This uncertainty in the size of the market is unhelpful for planning and may restrict potential expansions in associated remanufacturing activities.
- Fixed route operating costs may negatively impact growth in the remanufacturing sector, because fixing the cost at which the TOC must operate a train route indirectly restricts the amount that a TOC can spend on rolling stock.
- Competition from alternative transport including Bus Rapid Transport or, eventually, self-driving vehicles could decrease interest and investment in the rail sector

[186] http://www.zerowastescotland.org.uk/sites/files/zws/Remanufacturing Study - Full Report - March 2015_0.pdf

14 Advanced materials

14.1 Introduction – critical and advanced materials

Materials are key in every technological activity that humans have ever undertaken; we even name our historical phases after the materials that dominated that phase of history, for example, the 'bronze age' or 'the iron age'.

Over time, there has been a shift from renewable materials to non-renewable materials. This transition happened about the time of the industrial revolution, as the steel age began. Non-renewables form the majority of materials in remanufacturing activities today. Ashby highlights this, stating metals are the dominant materials in engineering[187].

Presently, the world is undergoing another far-reaching materials transition towards a closed loop or circular economy, triggered by increasing pressures on the supply of energy and minerals resources in a world of 7-10 billion people. Work by the EU in defining the most at-risk and economically important materials was published in 2010[188] and updated in 2014[189]. The materials in question are termed critical materials and are components of advanced materials essential in a wide range of high-tech products and equipment, not least products that are vital in Europe's transition to a low carbon economy.

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 European Innovation Partnership (EIP) on Raw Materials, Strategic Implementation Plan, 2013[190] highlights the following objective:

> *The overall objective of the EIP on Raw Materials is to contribute to the 2020 objectives of the EU's Industrial Policy – increasing the share of industry to 20% of GDP – and the objectives of the flagship initiatives 'Innovation Union'[191] and 'Resource Efficient Europe'[192], by ensuring the sustainable supply of raw materials to the European economy whilst increasing benefits for society as a whole.*

Within these objectives, it can be seen that there are a number of touchpoints with the ERN project. In particular, the themes of resource efficiency, critical and scarce raw materials, framework conditions for reuse (remanufacturing) and raw materials-efficient product design are key. Furthermore, the proposal to establish sustainable raw materials management organised as a Knowledge and Innovation Community (KIC) has been realised as the KIC European Institute of Innovation and Technology[193] - Raw Materials (EIT RM)[194].

---

[187] Ashby M. Materials and the environment – eco-informed materials choice. 2nd ed. Butterworth-Heinemann; 2012.

[188] Catinat M et al, (2010) *Critical Raw Materials for the EU – Report of the ad-hoc working group on defining critical raw materials*, Brussels, Belgium, EU,

[189] Pellegrini, M (W.G. chair), (2014) *Report on Critical Raw Materials for the EU, Report of the Ad hoc Working Group on defining critical raw materials*, European Commission, DG Enterprise and Industry, May 2014.

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

[191] http://ec.europa.eu/research/innovation-union/index_en.cfm

[192] http://ec.europa.eu/resource-efficient-europe/

[193] http://eit.europa.eu/

[194] http://eitrawmaterials.eu/

Several of the ERN partners are members of the EIT RM in which critical materials (being advanced materials) are a focus with remanufacturing, as part of a circular economy, playing an important role.

It is the purpose of this section of the report to shed light on the contribution remanufacturing can play in ensuring the availability of advanced, critical materials in products and technologies in three target products from the energy, transport and electronics sectors. It demonstrates significant market size and/or growth potential; and show that they possess characteristics of products/technologies suitable for remanufacturing. For these target products, further data from a previous EU project[195] has been collected to gauge whether any remanufacturing activities currently occur for these products. This data and discussions have been used to create an estimate of the size of total European remanufacturing activities for these products.

14.2 The scope of advanced materials

This report does not purport to provide a comprehensive definition of critical materials in relation to advanced materials. However, a literature review of 30 existing published definitions and descriptors of critical materials has been conducted to explore the relationship between the two, and to manufacturing processes. This has established with some certainty that most were not written with remanufacturing in mind, or in particular regarding the practical issue of material choices for parts and sub-assemblies at the design stage.

The obvious starting point for a consideration of the relationship is the list of critical raw materials (CRMs) as published by the EU and reported in Table 32.

Table 32: Critical materials for the EU, 2014[196]

Elements	Non elements
Lithium, Beryllium, Magnesium, Scandium, Chromium, Cobalt, Gallium, Germanium, Niobium, Platinum Group Metals, Indium, Antimony, Tungsten, Light Rare Earth elements (not Polonium), Heavy Rare Earth elements including Yttrium.	Borates, Magnesite, Silicon metal, Coking coal, Fluorspar, Natural graphite & Phosphate rock.

This list evolves over time due to the shifting balance of factors which contribute to the assessment of criticality. However, there are some elements that do appear frequently on the EU List and other national assessments globally. Of note are those elements that form the so-called rare earth elements[197] and the platinum group metals[198]. As a basis, this report will use the 2014 EU list of CRMs, excluding the non-elements shown in Table 32.

A further consideration of the topic draws on the approach of Peck et al. (2015).[199] In general the CRMs of interest are elements, whereas advanced materials are typically alloys, ceramics, polymers or other composite, multi-element substances. In simple terms,

---

[195] See project reports at http://www.criticalrawmaterials.eu/

[196] Pellegrini M (WG chair). Report on critical raw materials for the EU, report of the ad hoc working group on defining critical raw materials, European Commission, DG Enterprise and Industry; May 2014.

[197] Cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, promethium, samarium, scandium, terbium, thulium, ytterbium, yttrium

[198] Iridium, osmium, palladium, platinum, rhodium, ruthenium

[199] Peck D, Kandachar P and Tempelman E, *Critical materials from a product design perspective,* Journal of Materials and Design 65, (Jan 2015) Pages 147-159.

elements have properties, but materials have functions. Typically, it is the nature of the elemental contribution to these functions which defines their uniqueness and – potentially - their criticality. In support of this, a recently concluded EU FP7 project entitled CRM_Innonet[200] made the following observations: the term 'critical' should not only be used to describe a resource that is scarce, but also a resource that provides unique properties and functions and therefore has few substitutes.

14.3 Remanufacturing as a 'substitution' strategy

In the context of remanufacturing, it is therefore highly relevant to consider which functional properties are beneficial and which materials contribute to these benefits. In turn, this directs the search for products that embody those functions, and the strategies that might be employed to recover and preserve these materials. The results of work by CRM_Innonet are highly relevant in this activity. In a series of expert interviews, important functions of CRMs were named by respondents, as shown in the left hand column in Table 33. These functions confer mechanical properties which mean that products are mechanically suitable for processing and life extension. They are also properties that might be enhanced or upgraded during remanufacture to offer performance which is better than 'like new'.

The right hand column in Table 33 shows the direct benefit of the CRM advanced material to remanufacturing. Note that whilst some of the benefits will apply to non-remanufacturing product providers as well, many do not.

Table 33: Desirable functional properties enhanced by CRMs in advanced materials

CRM-derived mechanical attributes relevant to remanufacturing	Benefits to remanufacturing
Weight savings leading` to high efficiency	Weight savings = lower costs & impacts
High degree of hardness	Hardness = less wear = lower costs
Good corrosion sensitivity	Lower corrosion = lower costs
High temperature resistance	Temp resistance = less damage = lower costs
Low maintenance requirements	Low maintenance = lower costs
Long lifetime of products	Long life = improved revenues

The important point is the essential role that remanufacturing itself delivers by providing a longer life of CRM-containing advanced materials. Longer life is achieved by the cycles of use-remanufacturing-use-remanufacturing etc. This reduces the rate of material consumption and loss of the advanced materials. Remanufacturing offers further advantages: the organised and controlled removal of components also enables higher value recycling of components beyond repair.

The functions in the right hand column in Table 33 are relevant because remanufacturing provides a mechanism for preserving those components which embody those attributes and benefits. It is these functional aspects that form the basis for choosing the products to examine in this section of the report.

The results of CRM_Innonet also suggest that remanufacturing forms a valid substitution strategy. It proposed that the concept of substitution is broadened to include changes to processes, new technology (engineering) approaches and the introduction of a service to

[200] Critical Raw Materials Innovation Network – *Towards an integrated community driving innovation in the field of critical raw material substitution for the benefit of EU industry*

take up products at the end of a first life, are all 'substitution' approaches. Service can include reuse, remanufacturing and recycling activities.

In summary, the current practice for product designers is that they select materials - not elements - when designing products. The elements are therefore selected implicitly not explicitly. However, there is a range of substitution strategies that, were the product designer aware of them, could be used to address advanced material challenges. This approach includes remanufacturing activities, as be shown below.

14.4 Advance materials in three remanufacturing markets / products

This section focuses on three markets / products: automotive (alternators / motors / exhausts), renewable energy (wind-turbines) and electronics / ICT (including medical imaging equipment). An assessment is made of the opportunities that remanufacturing can provide which in turn supports Europe's critical material security of supply.

14.4.1 Automotive

Identification of CRM dependencies and current status

The automobile manufacturing sector employed around 2.3 million people in Europe in 2012. Three European car companies are in the top ten producers and several Japanese companies, such as Toyota, have manufacturing plants in Europe. The market segment in Europe is highly competitive and is driven by high pricing pressure, hence the success of low cost sub-brands such as Skoda or Dacia. Based on data from Eurostat, production in Europe is distributed over the whole supply chain but clearly concentrated to the later steps of the chain.

Table 34 lists which sub-sectors of the transport sector are dependent on the use of CRMs. It also reports their economic impact and status.

Table 34: Economic screening for CRM supply chain analysis

Sector and its production value (2011)	Application	CRM-Use	EU economic importance			Progress to full Supply chain analysis
			Value (2012)	Share of prod. >25%	Share of products in sector >0.2%	
Manufacture of motor vehicles, trailers and semi-trailers €678906 M	Automobiles	Pt, Pd, Rh, Ta, Nb, Mg, Sb, Nd, Gd, Be, In, Ce, Dy, La, Tb, Tm, Y, Er, Eu, Ga, Ho, Graphite	223808 M€	95%	39.97%	Yes
	Heavy vehicles	Pt, Pd, Rh, Ta, Nb, Mg, Sb, Nd, Gd, Be, In, Ce, Dy, La, Tb, Tm, Y, Li, Zn, Co, Ag	33369 M€	91%	4.9%	Yes
	Buses	Assumed similar as auto/heavy vehicles	3855 M€	86%	0.57%	(Yes)
	Goods vehicles	Assumed similar as auto/heavy vehicles	23878 M€	85%	3.52%	(Yes)
Manufacture of other transport equipment €198311 M	Helicopter	Assumed similar as aeroplane	3709 M€	83%	1.9%	(Yes)
	Commercial aeroplanes	Sb, Ge, Mg, Gd, Rh, Pd, Be, Pr, Sm, W, Ta, Ru, Nb, Y	7850 M€	27%	2.5%	Yes
	Motorcycle	Assumed similar as automobile	3463 M€	68%	1.6%	(Yes)
	Bicycle	Mg, Sc, Be	2165 M€	66%	1.1%	No

Data from 2011, except sector values from 2012

One of the main CRM dependencies is the use of platinum and palladium in catalytic converters. Leading European auto producers do not have catalytic converter production of their own. Availability of raw materials could be a potential CRM-related bottleneck and, since catalytic converters are mainly produced outside the EU and not by the European automotive companies themselves, chances to influence availability of catalytic converters in case of shortage of raw materials might be limited. Both platinum and palladium production are concentrated in South Africa and Russia. In terms of the substitution of platinum in vehicle applications, the current shift is toward palladium which is less expensive and with more diverse production areas. However, substituting one CRM with another does not reduce CRM dependency. There are currently no other substitutes for the CRMs used as catalysts in catalytic converters. The same is true for exhaust after-treatment applications that replace catalytic converters.

Platinum and other platinum group metals are recycled to some extent, but represent an exception when it comes to recycling CRMs from cars. No dedicated procedures or processes for recovering and recycling the content of gold, neodymium, tantalum and niobium of components or material fractions from end of life vehicles (ELVs) have been found in the current Swedish ELV system. Directives on recycling from ELVs in the EU are not focused on critical raw materials but more on e.g. plastic parts. However, issues related to short term supply risks and the long term increasing global demand of scarce metals can potentially be addressed through the recycling of rare materials.[201]

Different types of high strength steels are of great importance for automobiles due to safety requirements. Niobium alloyed steel is mainly used and, in some parts of the car, tantalum alloyed steel. Any material used to replace those in safety functions must meet the same requirements as the steel currently used. Composites may replace some of those steel parts in the future, as long as that does not impair the performance of the material.

The chassis contains some parts that are made of high strength or ultra-high strength steel. These parts usually have a key role in safety; for example, in the pillars that support the windscreen and in car seats. The alloys contain small amounts of niobium (Nb) or tantalum (Ta). The steering, the brake system, the security system and the heat exchanger all contain CRMs.

Table 35 gives more detail of the uses of CRMs in automotive applications in particular. They are, for example, found in exhaust treatment systems. In the catalytic converter, harmful substances in exhaust gases (such as carbon monoxide, nitrogen oxides and unburnt hydrocarbons) are converted to less harmful substances. Platinum (Pt) is the most widely used catalyst but palladium (Pd) and rhodium (Rh) are also used. While platinum is used both as a reduction and oxidation catalyst, rhodium is a reduction catalyst only and palladium an oxidation catalyst only. Cerium oxide (CeO_2) is also used in catalytic converters; cerium (IV) oxide can give up oxygen without decomposing and is therefore used to 'store' the oxygen for the oxidation reactions.

[201] Andersson, M., Ljunggren Söderman, M. and Sandén A. (2014). *Scarce metals in Swedish end of life vehicle recycling*. SUM 2014, Second Symposium on Urban Mining

Table 35: Uses of critical raw materials in the automotive sector

Sector and its production value (2011)	Sub-level Application	CRM-Use	EU economic importance		
			Value (2012)	Share of prod. >25%	Share of products in sector >0.2%
Manufacture of motor vehicles, trailers and semi-trailers €678906 M	Auto catalyst	Pt, Pd, Rh, Ce	31 M€	21%	0.01%
	Chassis	Ta, Nb, Mg, Sb	1587 M€	97%	0.23%
	Seating	Nb	12010 M€	99%	1.77%
	Steering	Nd	7452 M€	88%	1.10%
	Brake system	Gd, Rh, Pd, Be	7000 M€	84%	1.03%
	Security airbag	In, Er, Be	3118 M€	90%	0.46%

Electronics play an increasingly central role in cars. Basic cars have at least 30 electronic control units (ECUs) while luxury cars may have up to 100.[202] Some systems, such as fuel injection control, anti-lock braking systems, air bags, cooling systems and adaptive cruise control systems, depend on ECUs in a vehicle. As significant amounts of CRMs are used in electronics within those products[203], the car's ability to function is more and more dependent on CRMs.

Many of the electronic motors used in modern cars (e.g. for adjusting the seats, in the steering system and in the climate control system) use permanent magnets containing rare earths. In the future, with an increased number of electric or hybrid vehicles, permanent magnets will be of even greater importance. An electric motor of 50 kW used in a hybrid vehicle uses around 1.3 kg of permanent magnets. The supply chain for permanent magnets is examined in more detail in the CRM_InnoNet report on energy applications using CRMs.[204]

14.4.2 Wind turbines

This section identifies specific advanced materials dependencies of the energy sector through analysis of the value chain specifically of wind-power technologies (Table 36). These are dependent on permanent magnets, typically using rare-earth elements: neodymium, and dysprosium.[205] There are further CRM-containing technologies in the wind turbines such as control electronics and batteries which are excluded from this analysis.

[202] New York Times (2010). *The dozens of computers that make modern cars go (and stop)*, available at http://www.nytimes.com/2010/02/05/technology/05electronics.html?_r=0

[203] Bachér, John et al., (2013). *CRM_InnoNet - Internal report summarising the results of ICT and electronics sector analysis*. http://cdn.awsripple.com/www.criticalrawmaterials.eu/uploads/D4-1-ICTsector-reportfinal.pdf

[204] Brunot A, Charreyron V, (2013) Rapport technique DTBH/DR/2013/133 *CRM-Innonet Project - Internal report summarising the results of energy sector analysis*

[205] Institute for Energy Research, 2013. *Big wind's dirty little secret: Toxic lakes and radioactive waste*, available at http://instituteforenergyresearch.org/analysis/big-winds-dirty-little-secret-rare-earth-minerals/

Table 36: Uses of critical raw materials in the wind power sector

Application	CRM-Use (EU-14 CRM)	EU economic importance		
		Value[2] (yearly)	Share of prod. >25 % (Eurostat)	Share of products in sector >0.2 % (Eurostat)
Wind Power	Nd, Dy	12.6 GW 12.8-17.2 b€ market 6.5 b€ EU production 9.9 b€ prod. Eurostat	98%	1.8%

Wind power technologies and CRM dependence

A key contributor to renewable energy is observed to be wind energy and it is estimated that approximately 15% of the 2030 average EU electricity mix will potentially come from wind for short, medium and long term energy provision. [206]

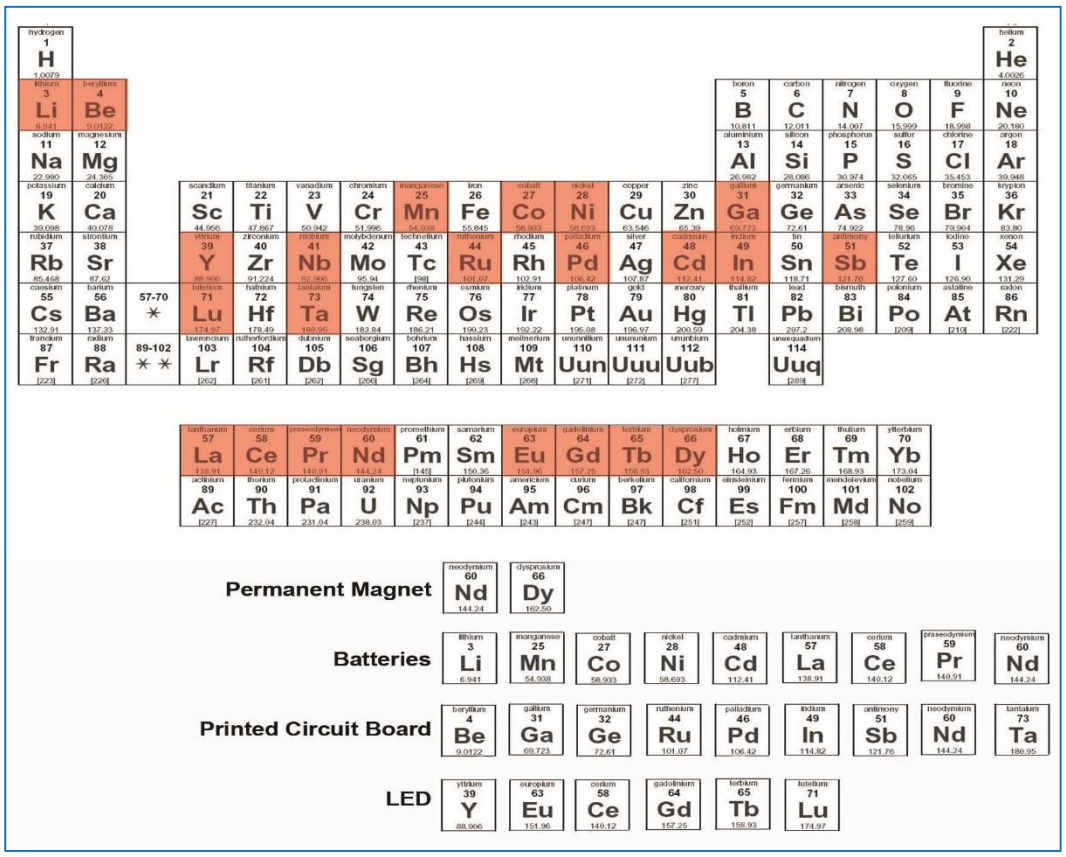
Wind turbines convert wind energy captured by blades into the rotation of a shaft. This rotation is then transformed into electricity through a generator. Two main markets exist, with different requirements on equipment: on-shore and off-shore wind turbines. The latter obviously operates in a more demanding environment (weather conditions, saline and corrosive environments) and is potentially more difficult to access. A general trend towards larger and more powerful wind turbines is observed, particularly for the off-shore market.

Wind turbines are typically made of a tower supporting a nacelle and a rotor, connected through a rotating shaft. Typical components of the nacelle are the gearbox (when necessary) to which the shaft is connected, the electric generator, and other systems components - shaft brake, controller, weather sensors, yaw control system, cooling system - all containing CRMs as shown in Figure 25. The tower also contains some electrical components, in particular related to yaw control, and the connection to the electrical cable.[207]

[206] European Commission, 2010b. *EU energy trends to 2030*, update 2009, EC – Directorate-General for Energy, 2010

[207] Wilburn, D.R., (2011) *Wind energy in the United States and materials required for the land-based wind turbine industry from 2010 through 2030*: U.S. Geological Survey Scientific Investigations Report 2011–5036, 22 p. Available online at http://pubs.usgs.gov/sir/2011/5036

Figure 25: Critical raw materials used in wind turbines



Source: Fromberg E, Peck D, Kandachar P, Critical materials, circular economy and wind turbines, 4th International Symposium "Circular Economy inspiring Sustainable Innovation", Mexico City, 2015

Future supply chain issues

Wind turbine manufacturers expect future challenges with CRMs to be 'not unmanageable' within the next three to five years and they expect to find the key solution in addressing this problem in product innovation management.[208] They assert that, currently, the main goal of wind turbine designers is to reduce the cost of energy. Expecting that wind turbine designers will develop solutions for the challenges with respect to CRMs is problematic, not least because they are usually 'invisible' to product designers.[209] This position is more complex as there has been a significant design focus on CRMs in the generator magnet.

Refurbishment / remanufacturing of wind turbines

Wind turbines that were manufactured and installed decades ago are currently being retired as they reach the end their first design life. There is a third-party market developing to refurbish / remanufacture these wind turbines, which are then sold on at approximately half of the original equipment price. The warranty of new wind turbines is on average 2-5 years despite their 20 year designed life span; even though the average lifespan of a reconditioned

[208] Vroom, M., (2012) *Critical materials from a wind turbine industry perspective*, Sustainable Energy Technology, Faculty of Applied Sciences, Delft University of Technology, Delft, p. 11, 2012.

[209] Peck D, Kandachar P and Tempelman E, *Critical materials from a product design perspective*, Journal of Materials and Design 65, (Jan 2015) Pages 147-159.

unit is typically lower at 10-15 years, it is still given the same 2-5 year warranty.[210] The third-party remanufacturer therefore has some legitimacy in claiming that these remanufactured units are 'like new'.

14.4.3 Electronics / ICT (medical / healthcare)

The ICT and electronics sector provides products and services both for consumers, industries and professional users (**Error! Not a valid bookmark self-reference.**). The products may be used in various sectors as end applications or as components; for clarification, the product applications can be roughly categorised as:

- products which capture, transmit and display data and information electronically e.g. computers, phones, displays, consumer electronics
- lighting
- domestic appliances
- professional applications e.g. medical applications, control equipment, sensors and tools
- electronic sub-components used in various applications e.g. printed circuit boards.

Table 37: CRMs in the supply chain of the ICT + electronics sector

Sector and its production value (2011)	Application	CRM-Use (EU-14 CRM)	EU economic importance			Progress to full supply chain analysis
			Value (2012) in € million	Share of prod. >25%	Share of products in sector >0.2%	
Manufacture of electrical equipment €270,000 M	Washing machines	Nd, Dy	4,600	82%	1.7%	Yes
	Dishwasher	Nd, Dy	2,200	85%	0.8%	No*
	Cooling appliances	Nd, Dy	2,400	59%	0.9%	No*
	Air conditioners	Nd, Dy	2,800	63%	0.5%	No*
	Optical fibres	Ge	1,400	69%	0.5%	Yes
	Displays and screens	Ce, Er, Eu, Ga, Ge, Gd, In, La, Nd, Pd, Pr, Ru, Ta, Tb, Tm, Sb, Y	15,200	63%	5.6%	Yes
	LED lighting	Ce, Eu, Ga, Gd, Ho, In, La, Ta, Tb, Tm, Sb, Y	7,300	79 %	2.7%	Yes
Manufacture of computer, electronic and optical products €260,000 M	Laptops	Br, Dy, Eu, Ga, Ge, Gd, In, La, Nd, Pd, Pt, Pr, Rh, Ru, Ta, Sb, Y	2,300	8%		No
	Mobile (Smart) phones	Br, Dy, Eu, Ga, Ge, Gd, In, La, Nd, Pd, Pt, Pr, Rh, Ru, Ta, Sb, Y	3,000	10%		No
	Video cameras	Ce, Er, Eu, Ga, Ge, Gd, In, La, Nd, Pd, Pr, Ru, Ta, Tb, Tm, Sb, Y	320	17%		No
	Cameras	Ce, Er, Eu, Ga, Ge, Gd, In, La, Nd, Pd, Pr, Ru, Ta, Tb, Tm, Sb, Y	320	8%		No
	Radio sets	Ga, Ge, Nd, Pd, Pr, Ru, Ta, Sb	170	14%		No
	Loudspeakers	Nd, Dy	450	59%	0.18%	No
	MRIs	Dy, Gd, Nb, Nd, Pr, Tb	3,300	81%	1.3%	Yes

Note: Data from 2011, except sector values from 2012

[210] Ortegon, K., Nies, L.F. and Sutherland, J.W. (2013) *The Impact of Maintenance and Technology Change on Remanufacturing as a Recovery Alternative for Used Wind Turbines*, 21st CIRP Conference on Life Cycle Engineering, v15, 2014 pp182-188

The ICT and electronics sector is typified by rapid product development leading to short lifetimes. Because of small size and low transport costs, the production and assembly of components and most ICT consumer products can be quite easily relocated to countries with lower production costs - not the case for larger medical applications.

CRMs are widely used and vital to the function of many different applications in the ICT and electronics sector. Therefore, reducing the number of applications and highlighting the most important applications for the European economy is required. This section focuses on magnetic resonance imaging (MRI) equipment.

MRI technologies and CRM dependence

MRI is a medical imaging technique used for visualising the internal morphology of the body. It enables imaging of soft tissues and organs in such great contrast that the technique is especially suitable for neurological, cardiovascular, musculoskeletal, as well as oncological imaging. MRI is based on nuclear magnetic resonance (NMR), measuring a radio frequency signal emitted by the nucleus of hydrogen atoms in a magnetic field. An MRI system includes magnets, a pulsed field gradient system, radio-frequency transmit coils, transmitters, a radio-frequency receiver and a computer system.[211]

CRMs in an MRI system are found in the magnet unit, spring contacts, cold heat, pole-piece computer display and printed circuit boards. There are three alternative MRI technologies based on three different types of magnets used: permanent, resistive and superconducting. The CRMs in the permanent and superconductive magnets are discussed here.[212] A superconducting electromagnet is the most frequently used magnet, accounting for over 75 % of MRI equipment installed. Almost all MRI systems use superconducting coils where a central field strength of more than 0.35 tesla is present.[213]

The manufacture of superconducting magnet based MRI systems uses niobium (Nb) alloys and chemicals, for example niobium-titanium, niobium-tin and niobium nitrite.[214] Niobium-titanium and niobium-tin are used for making coil windings for superconducting magnets, and can be fabricated into superconducting wires. Most superconductive materials produced in the world are destined for use in MRI systems. MRI magnet manufacturing consumes approximately 60% of all superconducting wire and 40% of niobium-tin alloy.[215] However, of the total amount of niobium produced annually, the MRI industry uses only few percent.[216]

Around 21% of the total rare earth consumption, corresponding to 24 thousand tonnes of rare earth metals, was used for producing permanent magnets in 2010, consisting of neodymium (Nd); prometheum (Pr); dysprosium (Dy); gadolinium (Gd); and terbium (Tb).

---

[211] Fishbein *et al*. (2005). *Hardware for Magnetic Resonance Imaging*, available at https://www.irp.nia.nih.gov/branches/lci/nmr/mri-hardware-2005.pdf

[212] MRI systems that contain resistive magnets have a minor role in the magnetic resonance imaging market due to their limited field strength, high energy consumption and cooling system dependence, and are excluded from the analysis.

[213] Cosmus & Parizh 2011. *Advances in whole-body MRI magnets*. IEEE Transactions on Applied Superconductivity, 21, Issue 3, 2104-2109, available at http://ieeecsc.org/sites/ieeecsc.org/files/ST196.pdf

[214] Moreno, L. (2011). *Tantalum and Niobium Primer, Two Critical Metals*. Jacob Securities Inc. Equity Research, July 19th, 2011.

[215] Marken, K (2004). John Hulm Memorial Session. Applied Superconductivity Conference, Jacksonville, FL, October 2004, unpublished.

[216] NioCorp Developments Ltd. (2013). *About Niobium*. http://www.quantumrareearth.com/about-niobium.html

Around 98 % of these CRMs were used for NdFeB[217] magnet production.[218] In 2012, the rare earth demand for permanent magnets was estimated to be around 25,500 tonnes,[219] with some 860 kg of NdFeB magnets of rare earths on average per MRI unit.[218]

In addition, various electric motors are needed to move units or parts in the MRI systems, and these motors may also use NdFeB magnets because of their small size. However, they are not the most essential components in terms of substitution. Various components of the computer unit controlling the MRI system, such as printed circuit boards and the display, also contain CRMs.

14.5 CRM considerations by remanufacturers

It is noted that that the involvement and views of remanufacturing companies are not widely considered in work covering materials. Some of the publications reviewed outline the role of 'recycling' (which includes 'remanufacturing' in its scope) in mitigating critical material risks. The literature suggests that the demand for critical materials is experiencing volatility and there is currently no response based on remanufacturing. The question of how companies are actually responding to critical material risks remained largely unanswered. To understand whether companies are responding to critical materials risks via remanufacturing, the research from 2012-13 on CRM considerations was revisited and reassessed for remanufacturing aspects.[220]

14.5.1 Method

Each of the five categories tackles a subject tightly connected to critical materials:

- **Familiarity with the term 'critical materials' in the company**
  This section in the questionnaire helps to introduce the participant to the subject and more importantly provides data on awareness of the participant concerning the subject.
- **Role of critical materials in the company**
  This section concerns consumption of critical materials and provides an overview of the most consumed materials; insight into whether defined materials are indeed critical for the companies; and whether the term 'critical' is interpreted by the companies in the same way as by the researchers.
- **Risk-management and critical materials**
  Whether critical materials are a part of risk management policy of the company can be a strong indicator of the awareness and understanding of the subject by the participating company concerning the subject. This section explores that connection.
- **Business and critical materials**
  Readiness of the company to react to the risks posed by the materials criticality can be seen in the way the company tailors its business. This section explores related business opportunities and threats posed by CRMs.
- **Support concerning critical materials**
  It is highly unlikely that any company is capable of dealing with the materials criticality

[217] Neodymium-Iron-Boron, 'neodymium' magnets

[218] Peiró, L.T., Méndez, G.V & Ayres, R.U. 2013a. Supporting information: Material flow analysis of scarce byproduct metals: sources, end-uses and aspects for future supply

[219] Shaw, S. & Constantinides, S. 2012. Permanent Magnets: the Demand for Rare Earths. 8th International Rare Earths Conference, November 2012

[220] Moerland-Masic, I, (2012) *Critical materials in the Netherlands – response from the technological industry*, TU Delft Library

on its own. The issues are too complex. This section explores the kind of support that companies say is needed.

Each of the categories contains one or more questions that cover that aspect of the materials' criticality as required for the research. Questions in the questionnaire are categorised into three different types:

1. Multiple choice questions, with one or more than one answer possible
2. Ranking questions (Likert scales)
3. Open-ended questions

Although the first two types have great utility for large volumes of data and for conducting analysis, this study concentrated on using open-ended questions. This is because it was expected that, for many participants, the topic would be unfamiliar; this research has sought to uncover participants' views on the matter, an outcome best served by open questioning.

Table 38 outlines the exemplar types of companies, their description and typical product classes addressed during interviews. Due to confidentiality agreements specific products cannot be named.

Table 38: Company types and product classes considered during interviews

Company type	Description	Product examples
Material producers	Processed raw materials	Copper (bar, wire)
Component producers	Producing components (mostly B2B market), using metals, basic metals and intermediate goods	Electronics, LEDs
Sub-assemblers	Producing sub-assemblies: more complex assemblies	Computing, lighting
Producers	Producing relatively simple products with relatively simple supply chain	Domestic appliances, electric tools
Integrators	Producing complex products and equipment (OEM) with a complex supply chain	Medical equipment, production systems

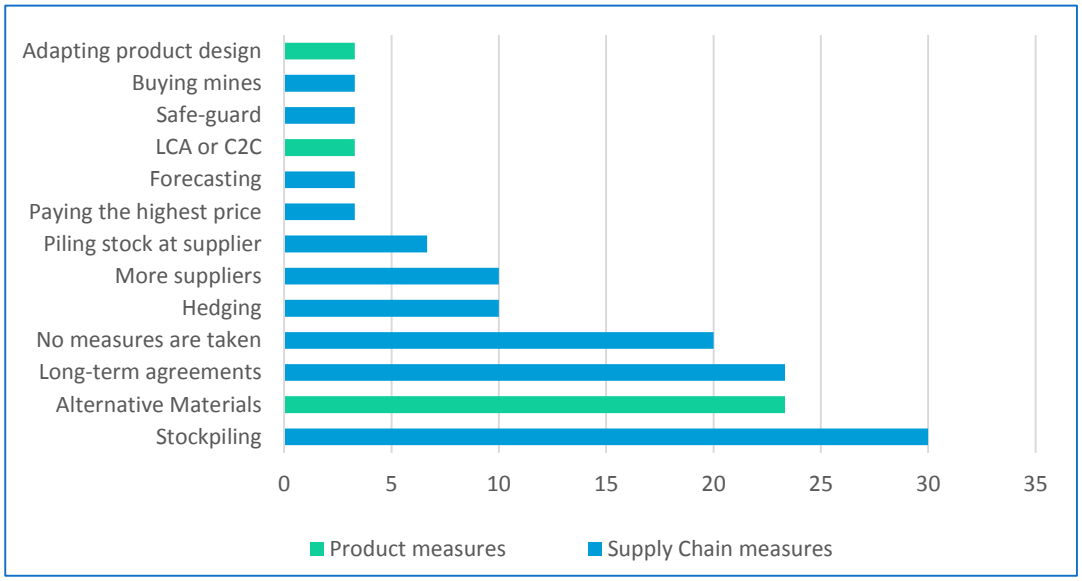
Due to the complexity of the research subject and expected lack of prior knowledge of the participants, a questionnaire was administered via a face-to-face interview. This allowed the interviewer to clarify possible misunderstandings in the questionnaire. One important advantage of a structured interview is that it ensures comparability of the data. As the questions are predetermined by the questionnaire and all questions are asked in the same order, data is more easily compared. Another advantage is the personal contact the interviewer has with the participant.

14.5.2 Responses

This report has a focus on Question 1.6: 'Can you name the measurements your company has taken as a reaction to issues caused by critical materials?'

Figure 26 illustrates the results obtained from the participants. It is apparent that few participants have provided answers which indicate product-oriented (and therefore remanufacturing) reactions to the issues caused by the critical materials.

Figure 26: Actions taken by respondents' companies over 'critical materials' issues



14.6 Conclusions

This section has framed advanced materials prevalent in modern manufacturing in terms of their component critical materials and the unique functions they confer. It describes how remanufacturing, in particular the redesign for remanufacturing activity, can create closed loop systems which preserve the material and functional content of critical materials. This is highly aligned to the EU's drive to address the availability of a wide range of critical (raw) materials.

This work has drawn upon the CRM_Innonet (FP7) research, with focus on three markets (automotive, renewable energy and electronics / ICT). It reveals that the opportunities that remanufacturing can bring to facilitate in supporting the security of Europe's critical materials appears to be limited at this time. Recycling was deemed to be poor and if remanufacturing is a subset of recycling then it was not addressed.

A set of selected manufacturers are assessed to ascertain if considerations of critical material aspects are considered via the remanufacturing of a product / equipment. Again it was clear that the companies did not propose remanufacturing as a strategy to address CRMs, despite some of the companies being remanufacturing companies.

These results show a gap: policy makers see a significant opportunity in remanufacturing in securing raw materials supply and this is seen in the EU Circular Economy Package expected in December 2015. The academia (CRM publishers), companies and other RTOs do not see the role for remanufacturing.

All CRMs are 'accessible' via remanufacturing as long as the component or sub-assembly is not scrapped. Critical to this is knowledge of embedded CRMs is if the company carrying out the remanufacturing does not know where the CRMs are they cannot make an informed decision on treating the product or component. The EU Horizon2020 project ProSUM is looking into developing such information for remanufacturers (amongst others).

14.7 Further work

It is proposed that the European Remanufacturing Network should look to promote materials agenda items into the remanufacturing sector.

The Circular Economy Package from the European Commission should be consulted to look for synergies.

The ERN project to use the KIC EIT Raw Materials to promote remanufacturing and CRM awareness / opportunities.

Annexe A Eurostat Data

Eurostat data was used in the calculation of sector values as described in the methodology in Section 4.

The tables below outline the group codes and descriptions per sector. Note in some cases the group codes descriptions do not look well aligned to typical sector activities however this is generally an artefact of group code versus product code nomenclature. For example, in EEE sector, under group code 3240 – 'manufacture of games and toys', data used relates to product code 3240250 – electric car racing sets, which should be considered as the wider EEE sector.

Table 39: List of the groups used in the calculation of the value of the aerospace sector

Group Code	Description
3030	Manufacture of air and spacecraft and related machinery
3316	Repair and maintenance of aircraft and spacecraft

Table 40: List of the groups used in the calculation of the value of the automotive sector

Group Code	Description
1392	Manufacture of made-up textile articles, except apparel
2183	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2184	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2185	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2186	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2187	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2188	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2189	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2190	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2191	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2192	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2193	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2194	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2195	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2196	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2197	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2198	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2199	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2200	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2201	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2202	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2203	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2204	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2205	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2206	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2207	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2208	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2209	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2210	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2211	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2212	Manufacture of other rubber products
2213	Manufacture of other rubber products

2214	Manufacture of other rubber products
2215	Manufacture of other rubber products
2216	Manufacture of other rubber products
2217	Manufacture of other rubber products
2218	Manufacture of other rubber products
2219	Manufacture of other rubber products
2399	Manufacture of other non-metallic mineral products n.e.c.
2550	Forging, pressing, stamping and roll-forming of metal; powder metallurgy
2740	Manufacture of electric lighting equipment
2813	Manufacture of other pumps & compressors
2825	Manufacture of non-domestic cooling and ventilation equipment
2829	Manufacture of other general-purpose machinery n.e.c.
2910	Manufacture of motor vehicles
2920	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
2931	Manufacture of electrical and electronic equipment for motor vehicles
2932	Manufacture of other parts & accessories for motor vehicles
299900Z1*	Flashlights; Image projectors; Cinematographic projectors; photographic enlargers & reducers; apparatus for photographic laboratories; negatoscopes, projection screens
3091	Manufacture of motorcycles
5020	Maintenance & repair of motor vehicles
Section G : Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	
5040	Sale, maintenance & repair of motorcycles & related parts & accessories

*Note: *product code (not allocated a group code)*

Table 41: List of the groups used in the calculation of the value of the electronics sector

	Group Code	Description
Ink + ICT + consumer electronics toner	2611	Manufacture of electronic components
	2612	Manufacture of loaded electronic boards
	2620	Manufacture of computers and peripheral equipment
	2630	Manufacture of communication equipment
	2640	Manufacture of consumer electronics
	2651	Manufacture of instruments and appliances for measuring, testing and navigation
	2660	Manufacture of irradiation, electro-medical and electrotherapeutic equipment
	2670	Manufacture of optical instruments and photographic equipment
	2711	Manufacture of electric motors, generators and transformers
	2712	Manufacture of electricity distribution and control apparatus
	2732	Manufacture of other electronic and electric wires and cables
	2790	Manufacture of other electrical equipment
	2821	Manufacture of ovens, furnaces and furnace burners
	2822	Manufacture of lifting and handling equipment
	2823	Manufacture of office machinery and equipment (except computers and peripheral equipment)
	2824	Manufacture of power-driven hand tools
	3240	Manufacture of games and toys
	3314	Repair & maintenance of electrical equipment (excluding electricity distribution & control apparatus, motors, generators & transformers, television & radio transmitters)
	2030	Manufacture of paints, varnishes and similar coatings, printing ink and mastics

	2670	Manufacture of optical instruments and photographic equipment
	2823	Manufacture of office machinery and equipment (except computers and peripheral equipment).
White goods	2751	Manufacture of electric domestic appliances

Table 42: List of the groups used in the calculation of the value of the furniture sector

Group Code	Description
1629	Manufacture of other products of wood; manufacture of articles of cork, straw & plaiting materials
2229	Manufacture of other plastic products
2572	Manufacture of locks & hinges
2599	Manufacture of other fabricated metal products n.e.c.
2620	Manufacture of computers & peripheral equipment
2825	Manufacture of non-domestic cooling & ventilation equipment
31001150*	Swivel seats with variable height adjustments (excl. medical, surgical, dental or veterinary, & barbers' chairs)
31001170*	Upholstered seats with metal frames (excl. swivel seats, medical, surgical, dental or veterinary seats, barbers' or similar chairs, for motor vehicles, for aircraft)
31001190*	Non-upholstered seats with metal frames (excl. medical, surgical, dental or veterinary seats, barbers' or similar chairs, swivel seats)
31001210*	Seats convertible into beds (excl. garden seats or camping equipment)
31001230*	Seats of cane, osier, bamboo or similar materials
31001250*	Upholstered seats with wooden frames (including three piece suites) (excl. swivel seats)
31001290*	Non-upholstered seats with wooden frames (excl. swivel seats)
31001300*	Other seats, of HS 9401, n.e.c.
31001400*	Parts of seats
31002030*	Parts of furniture, of metal, n.e.s. (excl. of seats & medical, surgical, dental or veterinary furniture)
31002050*	Parts of furniture, of wood, n.e.s. (excl. seats)
31002090*	Parts of furniture, n.e.s. (excl. metal or wood, & of seats & medical, surgical, dental or veterinary furniture)
3101	Manufacture of office & shop furniture
3102	Manufacture of kitchen furniture
3103	Manufacture of mattresses
3109	Manufacture of other furniture
3250	Manufacture of medical & dental instruments & supplies

*Note: *product code (not allocated a group code)*

Table 43: List of the groups used in the calculation of the value of the HDOR sector

Group Code	Description
2211	Manufacture of rubber tyres & tubes; retreading & rebuilding of rubber tyres
2811	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
2822	Manufacture of lifting and handling equipment
2830	Manufacture of agricultural and forestry machinery

2892	Manufacture of machinery for mining, quarrying and construction
2910	Manufacture of motor vehicles
2920	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
3312	Repair of machinery
3320	Installation of industrial machinery and equipment

Table 44: List of the groups used in the calculation of the value of the machine sector

Group Code	Description
2562	Machining
2573	Manufacture of tools
2594	Manufacture of fasteners and screw machine products
2640	Manufacture of consumer electronics
2811	Manufacture of engines and turbine, except aircraft, vehicle and cycle engines
2812	Manufacture of fluid power equipment
2825	Manufacture of non-domestic cooling and ventilation equipment
2841	Manufacture of metal forming machinery
2849	Manufacture of other machine tools
2893	Manufacture of machinery for food, beverage and tobacco processing
2895	Manufacture of machinery for paper and paperboard production
2899	Manufacture of other special-purpose machinery n.e.c.
3312	Repair of machinery
3320	Installation of industrial machinery and equipment
399900Z2*	Spark-ignition reciprocating internal combustion piston engine, for the vehicles of HS 87, of a cylinder capacity > 1,000 cm^3

*Note: *product code (not allocated a group code)*

Table 45: List of the groups used in the calculation of the value of the marine sector

Group Code	Description
2599	Manufacture of other fabricated metal products n.e.c.
2811	Manufacture of engines & turbines, except aircraft, vehicle & cycle engines
3011	Building of ships & floating structures
3012	Building of pleasure & sporting boats
3315	Repair & maintenance of ships & boats

Table 46: List of the groups used in the calculation of the value of the medical device sector

Group Code	Description
2120	Manufacture of pharmaceutical preparations
2660	Manufacture of irradiation, electromedical and electrotherapeutic equipment
2670	Manufacture of optical instruments and photographic equipment
3250	Manufacture of medical and dental instruments and supplies
3320	Installation of industrial machinery and equipment
3313	Repair of electronic and optical equipment

Table 47: List of the groups used in the calculation of the value of the rail sector

Group Code	Description
1610	Sawmilling & planing of wood
2599	Manufacture of other fabricated metal products n.e.c.

2811	Manufacture of engines & turbines, except aircraft, vehicle & cycle engines
3020	Manufacture of railway locomotives & rolling stock
399900Z5*	Railway or tramway track fixtures & fittings (excluding sleepers of wood, concrete or steel, sections of track & other track fixtures not yet assembled & railway or tramway track construction material); mechanical, including electromechanical, signalling, safety or traffic control equipment for railways, tramways, roads, inland waterways, parking facilities, port installations or airfields; parts of the foregoing
3317	Repair & maintenance of other transport equipment

*Note: *product code (not allocated a group code)*

Annexe B Survey

Included below is the copy of the short version of the survey used to collect market data on remanufacturing in the EU.

European Commission

ERN European Remanufacturing Network

European Remanufacturing Network – Market Survey

Background

Remanufacturing is an important component of a resource efficient manufacturing industry. Remanufacture involves dismantling a product, restoration and replacement of components and testing of the individual parts and whole product to ensure that it is within its original design specifications. The performance after remanufacture is expected to be the same as the original performance specification and the remanufactured product generally offers a warranty.

By keeping components and their embodied material in use for longer, significant environmental benefits can be realised. Remanufacturing also provides opportunities for the creation of highly skilled jobs and economic growth. Despite these accolades, remanufacturing is an undervalued part of the industrial landscape and an under-recognised industry.

Project overview

In order to encourage greater remanufacturing activities, the European Commission has funded a project to form, coordinate and support a European Remanufacturing Network (ERN). This Horizon2020 project will take place over a period of two years, with the ambition to:

- encourage new businesses to take up remanufacturing
- help existing remanufacturers improve their operations
- improve competitiveness of remanufacturers domestically and internationally
- create greater awareness of remanufacturing to increase demand and address barriers

The project involves eight partners from across Europe:

Circle Economy · CRR Centre for Remanufacturing & Reuse · Fraunhofer · Grenoble INP · Linköping University · University of Strathclyde Glasgow · TU Delft · VTT

Market survey

The purpose of this survey is to map the current remanufacturing landscape across Europe for the first time. This will quantify the current size and structure of the European remanufacturing industry, in key market sectors, including the turnover, number of jobs and the key drivers and barriers affecting the industry.

This evidence base will be used to inform industry and policymakers on the size and scale of remanufacturing in different EU Member States. Further project activities include mapping best practices, developing case studies, toolkits and learning materials, holding workshops and establishing a European Remanufacturing Council.

This survey consists of around 20 questions and should take less than 15 minutes to complete. The deadline for completing this survey is **Tuesday 30th June 2015**. All information provided in the survey will be kept securely and will be aggregated and anonymised in the final analysis.

If you have any questions regarding this survey please contact Olivia Bertham directly on:
Telephone: +44 (0) 1296 423915
Email: olivia.bertham@oakdenehollins.co.uk

For further information on the project: www.remanufacturing.eu

This project has received funding from the *European Union's Horizon 2020 research and innovation programme,* grant agreement No 645984

1. Business contact information

Business name:	Name/position:
Contact details:	

2. General business information (size bands only)

Home country/headquarters:				Number of staff in EU:
Turnover in EU (approx.):				EU as % of global turnover:
Business sectors: (select all that apply)				
☐ Aerospace	☐ Electronics: ICT+mobile	☐ Furniture	☐ Machinery: pumps +fans +compressors	☐ Medical equipment
☐ Automotive: engines	☐ Electronics: white goods	☐ Heavy duty/ off-road equipment	☐ Machinery: other	☐ Rail industry
☐ Automotive: parts+ components	☐ Electronics: other	☐ Ink+ toner cartridges	☐ Marine Industry	☐ Tyre retreading
Main activities/products:				

3. Remanufacturing business activities

Does the business undertake remanufacturing activities?	Yes / No	*(if no skip to section 4)*
What type of remanufacturer is the business?	☐ Original Equipment Manufacturer / Remanufacturer (OEM/OER) ☐ Third-party / Independent Remanufacturer (IR) ☐ Contract Remanufacturer ☐ Don't know/other	
Which of the following activities are undertaken by the business? ☐ Remanufacturing ☐ Reconditioning ☐ Refurbishment ☐ Repair ☐ Maintenance ☐ Preparation for reuse ☐ Repurposing ☐ Overhaul ☐ None ☐ Don't know		
Which products are remanufactured by the business?		
In which countries does the business conduct these remanufacturing activities? ☐ Austria ☐ Denmark ☐ Hungary ☐ Malta ☐ Slovenia ☐ Belgium ☐ Estonia ☐ Ireland ☐ Netherlands ☐ Spain ☐ Bulgaria ☐ Finland ☐ Italy ☐ Poland ☐ Sweden ☐ Croatia ☐ France ☐ Latvia ☐ Portugal ☐ United Kingdom ☐ Cyprus ☐ Germany ☐ Lithuania ☐ Romania ☐ Norway ☐ Czech Republic ☐ Greece ☐ Luxembourg ☐ Slovakia ☐ Switzerland ☐ Other Europe ☐ North America ☐ Asia-Pacific ☐ Africa + Middle East ☐ South America		
Please indicate the approximate percentage split of remanufacturing activities between these countries		
What % of the business relates to remanufacturing?		
Can you provide approximate figures on the scale of the remanufacturing activities in the business?	Yes / No	*(if no skip to section 4)*
Sales (units)	Approx. Turnover	Employment
What are the major (geographical) markets for the remanufactured products from the business?		

4. Knowledge of remanufacturing sector in home country

Do you know/estimate how big the remanufacturing industry is in your sector and home country?	Yes / No *(if no skip to section 6)*
Which other organisations should we talk to?	
Please provide further details e.g. number of companies, approximate turnover, employment etc.	
Who are your competitors, how do you compare?	
What are the major trends affecting the market?	
How do you expect about the market of your remanufactured products in the future 5-10 years? ☐ Strong growth ☐ Steady growth ☐ Keep the same ☐ Decrease ☐ Don't know	
What is the potential market size for remanufacturing?	

5. Business models, design and processes

Which of the following best describes the business model for remanufacturing? ☐ Direct order ☐ Service contract ☐ Deposit/credit ☐ Leasing ☐ Other (please specify)
Who are your major customers for the remanufactured products?
How much is the price of your remanufactured products compared with new products? ☐ Much lower (<40%) ☐ Half the price (40-60%) ☐ A little lower (60-80%) ☐ About the same ☐ Don't know
What warranties do you offer on remanufactured products? ☐ Same as new products ☐ Shorter than new products ☐ No warranty ☐ Other (specify) ☐ Don't know
What quality standards do you offer on remanufactured products? (ISO, EN, BS etc.)
Can you further describe the products that you remanufacture, including commenting on their suitability?
Can you describe the remanufacturing/refurbishment processes that you go through?
Regarding business models, design and processes – would it be possible to ask some further questions? To whom should these question be sent or be contacted by telephone?

6. Motives and barriers

How important are following motives for remanufacturing to your company? (1=Not important, 4=Very important)								
Secure spare parts supply	□1	□ 2	□ 3	□ 4	Product warranties	□1	□ 2	□ 3	□ 4
To increase market share	□1	□ 2	□ 3	□ 4	Asset and brand protection	□1	□ 2	□ 3	□ 4
Customer pressure	□1	□ 2	□ 3	□ 4	Government Legislation	□1	□ 2	□ 3	□ 4
Company profitability	□1	□ 2	□ 3	□ 4	Strategic advantage	□1	□ 2	□ 3	□ 4
Secure government subsidies	□1	□ 2	□ 3	□ 4	Environmental responsibility	□1	□ 2	□ 3	□ 4

Have recent fluctuations in resource prices acted as a driver for greater remanufacturing?

☐ Yes, definitely ☐ Yes, maybe ☐ Possibly ☐ No ☐ Don't know

How important are following barriers for remanufacturing to your company? (1=Not important, 4=Very important)								
Volume/availability	□1	□ 2	□ 3	□ 4	Quality of feedstock	□1	□ 2	□ 3	□ 4
Customer recognition	□1	□ 2	□ 3	□ 4	Lack of sales channels	□1	□ 2	□ 3	□ 4
Legislation restrictions	□1	□ 2	□ 3	□ 4	Lack of technology	□1	□ 2	□ 3	□ 4
Lack of product knowledge	□1	□ 2	□ 3	□ 4	High labour costs	□1	□ 2	□ 3	□ 4

Please provide any further comments on motives and barriers for remanufacturing?

7. General questions

What policy measures might be useful in supporting the remanufacturing industries?

Would you be interested in participating in a European Remanufacturing Council for industry?

(This Council will help European remanufacturers maintain global competitiveness by representing the industry's interests to EU policy makers and carrying out common work that benefits all EU remanufacturers, i.e. creating an EU remanufacturing industry association).

☐ Yes, definitely ☐ Yes, maybe ☐ Possibly ☐ No ☐ Don't know

What issues/services should a European Remanufacturing Council cover?

☐ Procurement ☐ Standards ☐ Legislative barriers ☐ Trade barriers

☐ EU Engagement ☐ Worldwide engagement ☐ Market analysis ☐ Other information

Please provide any further comments on the possibility of a European Remanufacturing Council?

8. Additional questions

Are you happy for us to follow-up your responses?	Yes / No
Are you willing to be part of a case study?	Yes / No
Would you prefer your responses to be anonymous?	Yes / No
Would you like to be acknowledged in the report?	Yes / No

Thank-you for your participation in the European Remanufacturing Network market survey.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645984