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Contribution of remanufacturing to Circular Economy

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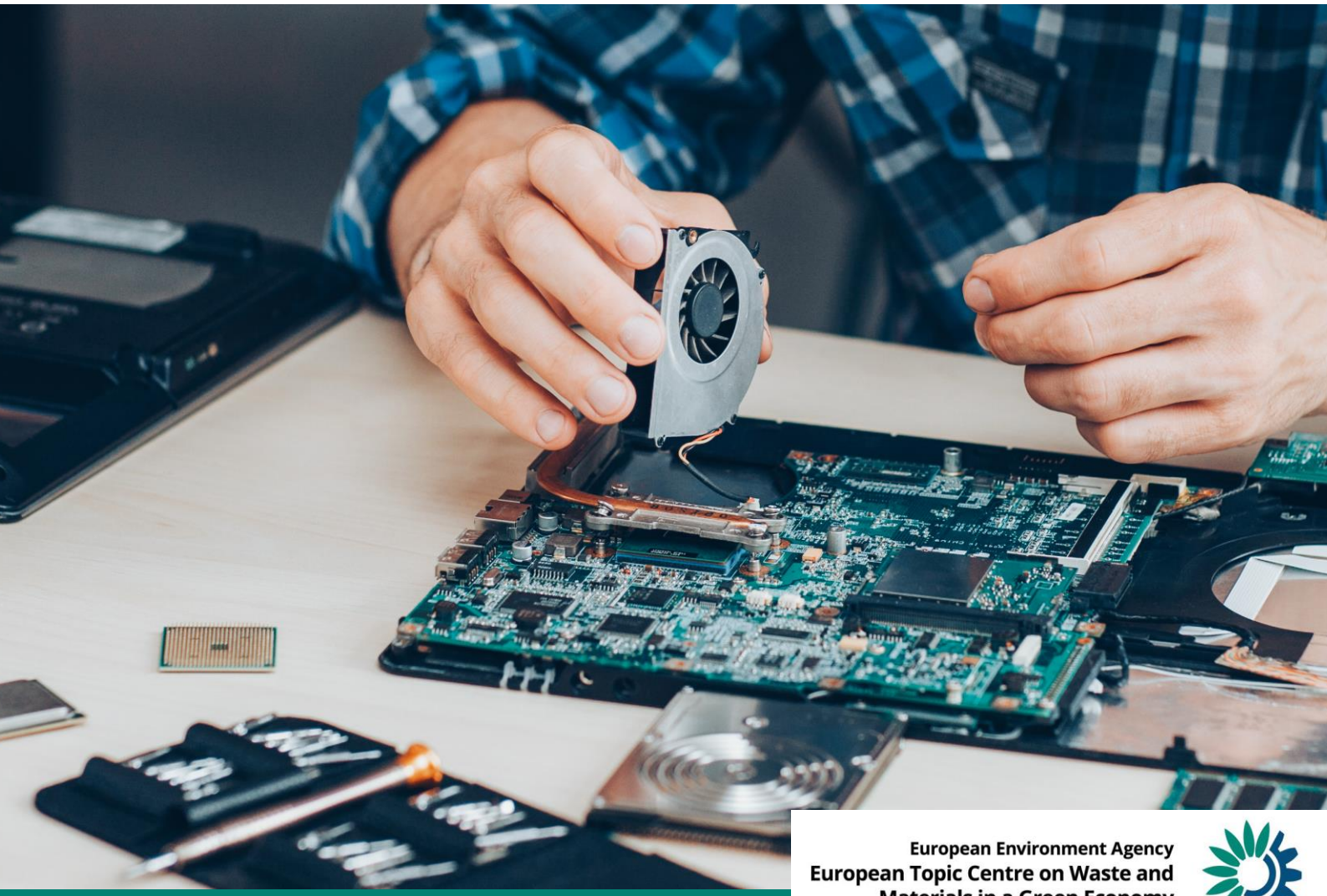

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NOTE: Throughout this report billion denotes a thousand million (10^9)

1 Introduction

1.1. Background

One element of Europe's Circular Economy Action Plan (CEAP) is to improve the monitoring of the transition to a more circular economy. While its framework (Eurostat, 2018) covers various dimensions of the circular economy at all stages of the lifecycle of resources, products and services, its set of 10 indicators (Appendix 1) is not totally suitable for quantifying the impact of different circular economy strategies, such as remanufacturing, which involves both internal material cycles and functions embedded in traditional manufacturing industry as well as in new services.

More research is needed to be able to quantify the effects etc. as these are not currently well covered by data that can be used to monitor the exploitation of the potential of individual R-strategies (Recycle, Reuse, Refurbish, Repair and Remanufacture). As a result, the actual performance of such activities needs to be mapped and its potential contribution to a circular society assessed.

1.2. Definition of remanufacturing

Remanufacturing means returning a used product to at least its original state with a warranty that is equivalent to or better than that of a newly manufactured product. Performance after remanufacturing is expected to be *at least* to the original performance specifications ([1]). Thus, from a customer viewpoint, the remanufactured product should be considered the same as a new product.

Remanufacturing does not, however, have a globally accepted or recognised definition. This is partly due to its use across a wide number of sectors, using diverse terms that could be interpreted as remanufacturing. Other less commonly used terms which are often used interchangeably although though they are not always synonyms include repurposing, reprocessing, restoration, renovation, remaking, upgrading, rebuilding, and reconditioning.

Remanufacturing is a term for which several definitions are applicable, and many companies may not be aware that they are, in fact, remanufacturing. Moreover, remanufacturing often occurs as a business-to-business (B2B) activity and is not visible to the general public (Gustavsson et al., 2021). The most industrially recognised definition of remanufacturing is the British Standard BSI BS 8887-2:2009, which defines remanufacturing, amongst a range of end-of-life options for products, as "*return[ing] a used product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product*".

BS EN45559 "Methods for providing information relating to material efficiency aspects of energy-related products" has recently defined remanufacturing as an "*industrial process which produces a product from used products or used parts where at least one change is made which influences the safety, original performance, purpose or type of the product*". The definition is based on the that provided by ISO/DIS 14009(en) (ISO, 2020).

The process involves the dismantling of a product, restoring and replacing components and testing the individual parts and whole product to ensure that it meets its origin design specifications (Figure 1.1).

[1]Definition in accordance with European Remanufacturing Network.

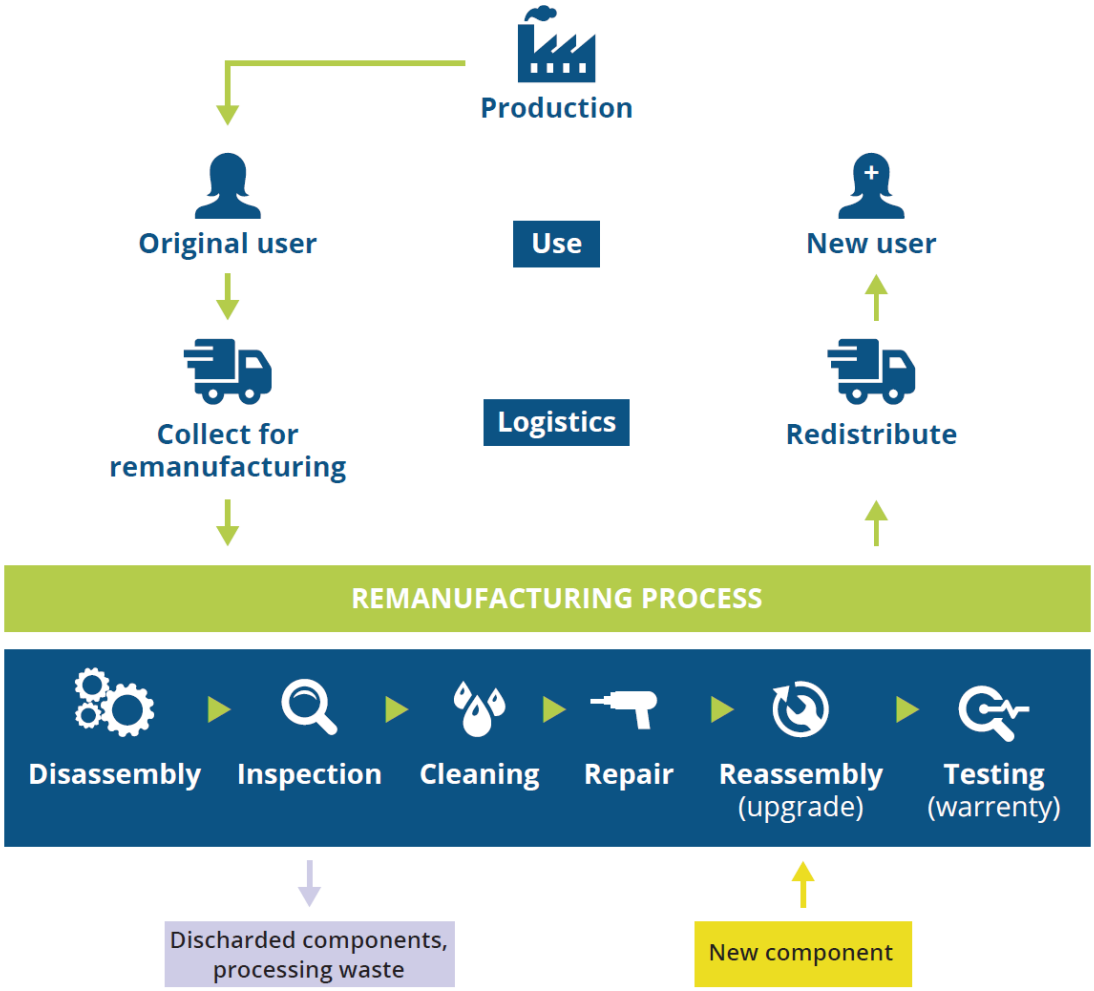

Figure 1.1 The remanufacturing process

Source: ETC/WMGE

Remanufacturing differs from refurbishing, which means collecting discarded products or materials that can be refinished and sanitised to serve their original functions. Technically, refurbishment includes the same process steps as remanufacturing, that is repairing, restoring, rebuilding and/or replacing. A refurbished product is not comparable to a new one but has been updated to a specific quality level and should be fully functional. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal definition states that a refurbished product should "*increase or restore its performance and/or functionality*" or should "*meet applicable technical standards or regulatory requirements*". The purpose of a refurbished product should be "*at least the one that was originally intended*" (IRP, 2018).

Reuse also refers to using a discarded product for its original purpose as it is or with minor modifications.

Table 1.1 provides an overview on main value-retention processes with a focus on practical implementation.

Table 1.1 Comparison between different value retention processes

		Reuse	Repair	Refurbish-ment	Remanu-facturing
Waste/non Waste	Can the used device be waste?		✓	✓	✓
	Can the used device be non-waste?	✓	✓	✓	✓
Input	Can used products get a life extension?	✓	✓	✓	✓
	Can old parts be sources of life extension?		✓?	✓?	✓
	Can parts/components partly be bought new?		✓?	✓?	✓
Purpose	Does a new device have same purpose?	✓	✓	✓	✓?
	Is the purpose of the new device at least the one that was originally intended?			✓	✓
Actors	Who mostly carries out the product's life extension?	user, OEM*, third party	user, OEM*, third party	OEM*, third party	OEM*, third party
Process steps	Is repair and refurbishment necessary?	✓			
	Is fixing faults included?		✓	✓	✓
	Is replacing defective components included?		✓?	✓?	✓
	Is disassembly and reassembly Included?		✓?	✓?	✓
	Is it a standardised industrial process?				✓
Warranty and performance	Is it brought up to date to a specific quality level to a satisfactory level?		✓	✓	to at least original quality
	Is its performance and/or functionality increased or restored?			✓?	✓
	Is it placed on the market as an 'as-new' product?			more aesthetic than functional	✓
	Is a warranty given or are applicable standards or regulatory requirements met?			✓? less valuable than for reman products	✓

✓? *= not clearly defined or definitions contradictory*

* OEM: original equipment manufacturer

Source: Gustavsson et al. (2021)

Figure 1.2 shows the position of remanufacturing in a circular economy

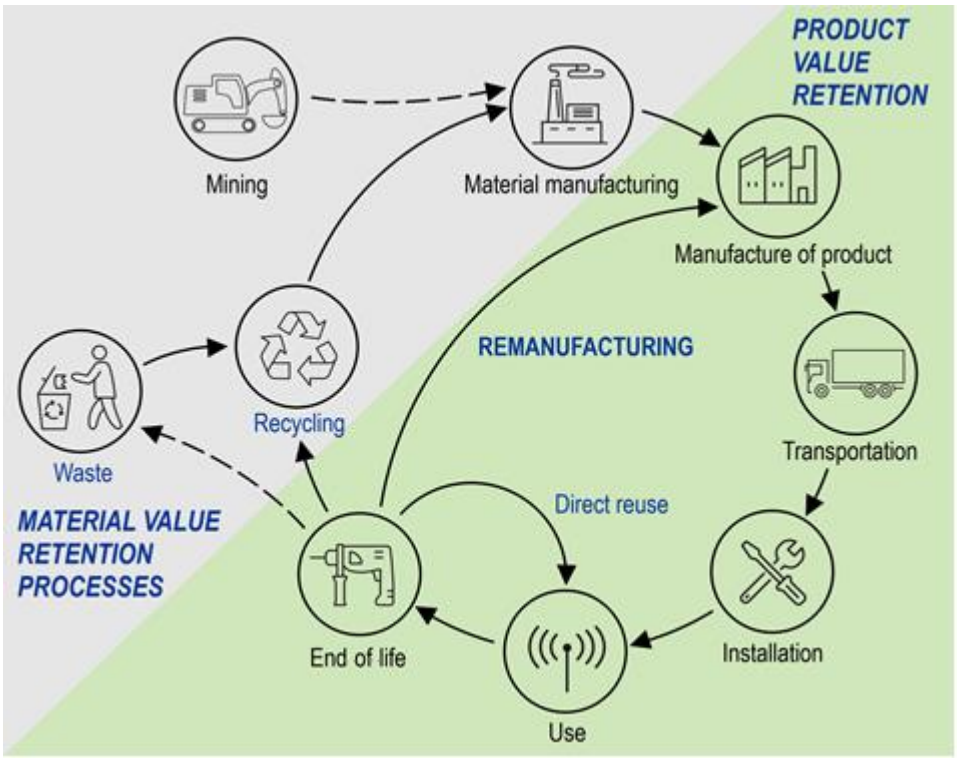

Figure 1.2. R-processes in a circular economy

Source: Bauer et al., (2016)

Common to the processes shown in Figure 1.2 is that they seek to retain value within the economic system and are therefore described as *value-retention processes* (VRPs). This epithet puts the emphasis on the impact, combining both economic and environmental goals. The impact is assessed by savings in materials, energy savings and emissions; cost advantages and employment (IRP, 2018).

Significant environmental benefits can be achieved by keeping components and their embedded material and energy in use for longer. Less energy and fewer material resources are used, and less waste is generated when the functions of products and components are retained rather than just the materials when a product is recycled. Remanufacturing also provides opportunities for the creation of highly skilled jobs and new service businesses, potentially stimulating economic growth. From the manufacturers' point of view, remanufacturing gives better control over the supply of raw materials and components, and enables a closer relationship with customers take-back systems.

The sustainability of value-retention processes can be established by comparing the reduction in economic, social and environmental impacts they bring with the additional impacts of collection systems, reverse logistics, processing, etc. As these impacts touch upon a large number of framing conditions, including labour taxation, the working environment for collection and processing staff, and energy for logistics, the establishment of potential sustainable volumes of value-retention processes is far from straightforward.

The most comprehensive and most frequently cited study of the remanufacturing sector in Europe was made in 2015 by the European Remanufacturing Network (ERN). One outcome was that its potential was not fully realised; the proportion of remanufacturing to new manufacturing being only 1.9 per cent. In Europe and both its intensity and overall value lag in comparison, for example, with the United States (US).. As early as 2012, the US was reportedly the largest remanufacturer in the world, with the sector valued at about US$ 43 billion and growing (Treat et al., 2012).

1.3. Monitoring remanufacturing

Europe's Monitoring Framework for the Circular Economy (European Commission, 2020) broadly covers the relevant thematic areas of the circular economy. It does not, however, currently cover such aspects as the contribution of circularity strategies, including remanufacturing, to the transition to a circular economy. This limitation is addressed, for example, by the Bellagio Declaration, a set of principles on how to ensure that monitoring the transition to a circular economy captures all relevant aspects and involves all relevant parties. It serves as a guide to national and European authorities in the development of monitoring frameworks and indicators (EEA et al., 2020). Moreover Vercalsteren et al. (2021) concluded in their gap analysis that value-retention strategies are the least covered by indicators in existing monitoring frameworks (Vercalsteren et al., 2021).

The following chapters look into the remanufacturing process, delineate it from other strategies for the purpose of this study, and assess the current situation of remanufacturing businesses through estimating the penetration, assessing the possible gap between the potential and penetration, analysing the possible reasons for this gap, and reporting on monitoring opportunities. More specifically, the report aims to:

- give an overview of the remanufacturing potential for different product categories (Chapter 2);
- provide an insight into the actual penetration of remanufacturing in different product categories/manufacturing and service sectors (Chapter 3);
- provide information on monitoring opportunities for remanufacturing (Chapter 4);
- explore the potential of remanufacturing for increased circularity in Europe and examine how progress can be monitored (Chapter 5).

Ultimately, the work serves as an input to help national and regional policy makers prioritise action within the framework of the European circular economy.

2 Overview of potential in different product categories

Chapter 2 provides an overview of the development of the European remanufacturing market. Comparing the assessments of two studies Parker et al. (2015) and Rematec (2020) with expert interviews carried out for this study, it is striking that all generally assume a high growth potential for the entire remanufacturing market. In addition, steady growth in the aerospace sector and high potential in the electrical and electronic equipment, and medical equipment sectors was confirmed. Some assessments, however, diverge, for example, for the automotive and marine sectors.

2.1. Size and sectors

In the ERN market study (Parker, Riley, Robinson, Symington, Jansson, et al., 2015), nine target sectors for remanufacturing were identified. These sectors are those in which significant remanufacturing activities might be expected to have a significant impact (Parker et al., 2015).

- aerospace;
- automotive;
- electrical and electronic equipment (EEE);
- heavy duty and off-road equipment (HDOR);
- machinery;
- marine;
- medical equipment;
- rail;
- furniture.

Remanufacturing is especially established in the automotive sector; various parts including engines, transmissions, gear boxes, starter motors and alternators are remanufactured. The EEE sector is particularly diverse and therefore some studies distinguish between information technology (IT) equipment and electrical parts. Detailed explanations of the remanufacturing sectors can be found in the ERN Remanufacturing Market Study (Parker et al., 2015) and in a US International Trade Commission study (United States International Trade Commission, 2012). A list of products that could be remanufactured in each sector can be found in Section 2.5. Chapter 3 gives more information on the different market shares of these sectors.

2.2. Trends and potential

The ERN market study (Parker et al., 2015) concluded that the future for remanufacturing could be quite positive. This outlook was encouraged by existing incentives for companies to incorporate remanufacturing in their operations, such as access to used products, reduced lead times and the environmental legislation. The survey conducted by Rematec in 2020 showed that remanufacturers expect a significant growth in sales worldwide in the future. More than a third of remanufacturers expected worldwide sales to increase by more than 10 per cent a year while a half expected annual growth of 5–10 per cent (Rematec, 2020c).

The future potential of the remanufacturing sector was examined using three approaches (Table 2.1):

- the future trend scenarios of the ERN study (Parker et al., 2015);
- expert interviews;
- The Global Remanufacturing Benchmark (Rematec, 2020c).

In the ERN study, the size of the European remanufacturing industry in 2030 was estimated using three scenarios: a base case, a stretch case and a transformation case. This report focusses on the base case scenario, which also has been the most widely quoted. Under this scenario, by 2030 the production value

of the remanufacturing sector will increase by 50 per cent over current levels, it will employ 300 000 people and it will save 16 million tonnes of carbon dioxide equivalent emissions compared to 2015. The underlying assumptions are low annual increases of 0.5 per cent per year in the heavy duty and off-road equipment, machinery, and marine sectors; steady annual growth of 3 per cent per year in the aerospace, automotive and rail sectors; and a high growth, 5 per cent per year, for electrical and electronic equipment, furniture and medical equipment industries. It should be noted that even though the forecast annual increase for the heavy duty and off-road equipment sector is low, remanufacturing is already quite established in the sector, producing a significant volume (Parker et al., 2015).

Table 2.1 The potential for remanufacturing: estimated annual growth, per cent

Sector	**Potential**		
	Base case scenario, Europe (Parker, et al., 2015)	**Expert interviews**	**Worldwide** (Rematec, 2020b)
Aerospace	3 %	Steady growth	Up to 4 %
Automotive	3 %	- High increases - Steady growth - Stay the same, but the products will change due to the electric mobility	Predominant focus of the remanufacturing industry on passenger cars is going to decrease in the future
Electrical and electronic equipment (EEE)	5 %	High increases	Up to 5 %
Heavy duty and off-road equipment (HDOR)	0.5 %	Steady growth	
Machinery	0.5 %	Not mentioned	Up to 5 %
Marine	0.5 %	Undervalued in the ERN study	Up to 11 %
Medical equipment	5 %	High increases	Up to 4 %
Rail	3 %	Not mentioned	Up to 7 %
Furniture	5 %	Steady growth	
Construction industry	Not mentioned	Steady growth	
White goods/ domestic appliances	Not mentioned	Growing market	
Energy			Up to 9 %

Source: Parker et al. (2015); Rematec (2020); and Expert interviews

Additionally, the interviewees reported that many developments support the future growth of the remanufacturing sector. New company targets to limit emissions as well as new sustainability reporting obligations, such as the Non-Financial Reporting Initiative and the Corporate Sustainability Reporting Directive, will put pressure on companies to find ways of minimising the negative impact their businesses have on society and the environment, and encourage them to develop their processes to retain value, which will grow the remanufacturing market.

Many companies aim for carbon-neutrality to fit within the EU's aim to be climate-neutral by 2050, an objective in line with the Paris Agreement. Companies have concluded that the carbon neutral goal cannot be achieved if they do not increasingly enter the remanufacturing and second-hand markets. Moreover, technological innovation, which enhances the performance of remanufacturing, has evolved. Especially the increase in the remanufacturing market due to emissions reduction targets, which require public companies to report emissions, and the 2015 Circular Economy Action Plan, which opened a new pathway encouraging remanufacturing, and a growing acceptance by companies and consumers will push remanufacturing forward.

As far as the future of individual remanufacturing sectors is concerned, two interviewees mentioned that the electrical equipment, medical equipment and automotive sectors have a big potential, especially when trends such as servitisation, electrification and digitalisation grow stronger (Subramoniam et al., 2021). As

these products become more expensive, the attractiveness of leasing and sharing business models will grow, which again paves the way for remanufacturing because products will be returned to the supplier, facilitating reverse logistics (Sundin and Bras, 2005).

The interviews conducted for the Market feasibility study (2018) in the European Institute of Innovation and Technology's (EIT) Raw Materials project Reman Path mentioned different sectors in which they thought remanufacturing would grow or have significant potential for the future. Four interviewees assumed a steady growth in the automotive and aerospace industry, two interviewees mentioned heavy duty and off-road equipment and one each highlighted the construction industry, office furniture, EEE and white goods (Koop et al., 2018).

The Rematec global remanufacturing benchmark survey included an assessment of the top remanufacturing industries. The results showed that the top industries continue to be passenger cars and trucks, although the predominant focus of the remanufacturing industry on passenger cars is expected to decrease whereas other focus industries are likely to remain stable or expand.

Remanufacturing is also becoming increasingly important in some niche sectors. It is expected to increase, for example, by 11 per cent annually in the marine sector, 9 per cent in the energy sector, up to 7 per cent for trains and 5 per cent for industrial machines/electronics, and 4 per cent in both the aerospace and health care sectors (Rematec, 2020c). When comparing ERN and Rematec's estimates with the statements of the experts interviewed, it is striking that in general all assume a high potential for growth in remanufacturing. In addition, the statements of the interviewees confirm the steady growth of remanufacturing in the aerospace sector and its significant potential in the EEE and medical equipment sectors. Some assessments, however, differ. Some experts and the ERN study, for example, assume steady or high growth of remanufacturing in the automotive sector, whereas one expert and the Rematec study assume that while it will stay on a high level, remanufacturing is no longer increasing. The discrepancy is also noteworthy for the marine sector; whereas ERN assumes only low increases, the Rematec study forecasts the highest annual increase, 11 per cent, and one expert mentioned that this sector is undervalued in the ERN study.

Besides the target sectors, new remanufacturing ones are evolving. Second-hand markets in, for example, the construction and building sectors are growing strongly, and in the future remanufacturing and other value retention activities the sector could develop rapidly. White goods/ domestic appliances and energy were also mentioned in the expert interviews.

2.3. Future trends

The following trends for remanufacturing appear in the literature and were also mentioned in the interviews.

- **Digital enablers:** digital technologies and elements of connectivity could play an important role in connecting value-cycle partners and related stakeholders through data sharing and increased transparency. In this, digital service elements could become the basis for smart remanufacturing. As an example, component monitoring (the internet of things) enables predictive remanufacturing, i.e., a manufacturer can collect a (leased) product at the exact moment it wears out, but is not yet broken, so that remanufacturing is technically and economically feasible. In this way, digitalisation addresses the information gap that currently often prevents circular strategies from being effective. Such monitoring online is mostly used at present for high value products and limited for lower value ones. Over-engineered products often reused rather than remanufactured (acatech/Circular Economy Initiative Deutschland and SYSTEMIQ, 2021); Subramoniam et al., 2021; Expert Interviews).
- **Additive manufacturing**: equipment durability depends on the availability of spare parts. The most sustainable solution is a combination of remanufactured parts with others produced using 3D-printing-

technology based on digital libraries, provided that it is a more environmentally and economically advantageous alternative (Ihobe, 2019; Nasr, 2020)Expert interviews.

- **New business models and reverse logistics**: these connect remanufacturing to new business models, such as product service system (PSS). In a PSS model, manufacturers retain ownership and regular service/maintenance become part of the use agreement. Therefore, product return or reverse logistics, which is necessary for remanufacturing, becomes far less complex (Nasr, 2020; Sundin and Bras, 2005; Expert Interviews.
- **Technical innovation**: automation is a key elements, especially for assembly due to the fact that the remanufacturing process is generally labour intensive. Automating assembly is, however, complicated as the products to be remanufactured enter the process in different conditions. Automated assembly can make remanufacturing more economically attractive (expert Interviews).
- **Electromobility**: remanufacturing in the automotive sector is facing some changes. As electric cars become more popular, remanufactured components will also change (Casper and Sundin, 2021). Remanufacturing is to be expected to take an increasingly important role for certain products, such as: electric and hybrid drive units, electronic components, electronic control units and batteries. But with increasing electromobility, combustion-related parts will become less important to the remanufacturing industry. A decrease is expected in combustion engines and parts, starters and alternators as well as transmissions and transmission parts(Rematec, 2020c).

2.4. Bottlenecks

According to the *Report on 10 knowledge gaps*, the successful implementation of remanufacturing faces a myriad of barriers - a construct, within which barriers are not only numerous and various but especially multidimensional and connected (Fischer et al., 2017). Table 2.3 summarising the most common barriers to remanufacturing.

Table 2.2 Barriers to remanufacturing

Barrier	Explanation	Source
Design for remanufacturing	– Products are often not designed for remanufacturing. – High diversity of products makes it difficult to standardise remanufacturing processes. – Utilisation of a high variety of materials.	(Golinska-Dawson and Kübler, 2018) (Sundin et al., 2016) (Parker et al., 2015) Expert interviews
Regulatory and access barriers	– Restrictions on cross-border flows of used, remanufactured and second-hand products. – Definition of waste: ambiguity on whether remanufacturing is considered waste processing and associated legal uncertainties.	(OECD, 2019) (IRP, 2018) (Parker et al., 2015) Expert interviews
Fear of product cannibalisation	– It may be that sales of remanufactured products replace sales specifically of traditionally manufactured premium products, thereby reducing overall profits.	(OECD, 2019) Expert interviews
Consumer attitudes to price	– Consumers are unwilling to pay the same price for remanufactured products as for new, or even nearly-new ones. This may be a partial explanation for why remanufacturing appears to be less common in consumer goods sectors (personal electronics, for example) than in B2B applications. – People are willing to spend up to 40 per cent of the price of a new product on a repaired one. In contrast, respondents were willing to spend up to 60 per cent of the price of a new product on a used/remanufactured appliance.	(Nasr, 2020) (Rematec, 2020) (OECD, 2019) (IRP, 2018) Expert interviews
Lack of certification for remanufactured	– Lack of sufficient differentiation between recycling, remanufacturing and reuse at an institutional level.	(Nasr, 2020)

	– There is a strong European focus on recycling and not so much on policies that stimulate remanufacturing, repair and reuse.	
Access to products and product returns	– Uncertainties about the quality of used products. – Uncertainties about the availability of used products. – Uncertainty about when a product should be returned for remanufacture. – High cost for the return of individual used products. – A customer has few incentives to return a product for remanufacture (core return is especially challenging for the business-to-consumer market) – "Sellers of professionally remanufactured equipment could double their turnover if they received more products to remanufactur" (Expert interview). – "Some sectors have sensitive time frames for collecting products from the customers. Often, they are not collected back quickly enough," (Expert interview).	(Rematec, 2020) (Golinska-Dawson and Kübler, 2018) (Östlin, 2008) (Rizos et al., 2016) (Sundin et al., 2016) Expert interviews
Lack of customer acceptance	– Though acceptance of remanufactured products has increased in the last five years, problems still exist.	(Ijomah et al., 2007) (Karvonen et al., 2017) (Sundin et al., 2016) Expert interviews
Knowledge and abilities of employees	– Awareness of remanufacturing opportunities and practice is low in industry. – Insufficient knowledge and capacity on remanufacturing in the industry. – Difficulty in standardising the processes of remanufacturing due to the variability of components and processes need employees with multiple skills. – Shortage of skilled employees. – Getting access to information to build the knowledge. – The lack of apprenticeships, study programmes, training and courses on remanufacturing.	(IRP, 2018) (Fischer et al., 2017) (Jansson et al., 2017) (Parker et al., 2015) (CarbonTrust, 2014) (Ijomah, 2008) Expert interviews
Access to information and tools	– Lack of access to information and tools on remanufacturing due to the unwillingness of original equipment manufacturers to share knowledge with potential competitors. – New technologies are required, particularly as a result of rapidly increasing electromobility.	(Nasr, 2020) (Rematec, 2020) (Parker et al., 2015) (Ijomah, 2008)
Production and supply chain complexity	– Requirement for reverse logistics – the cost of additional transportation or communication to recover products and return them to the appropriate facility for processing. – Cost for additional labour: remanufacturing cannot be automated to the same extent as traditional manufacturing.	Nasr, 2020) (Sundin et al., 2020) (OECD, 2019) (IRP, 2018)
Product characteristics	– Diversity of products: various types, series and versions makes disassembly more complex and different for every product. – Difference in quality levels: quality of each product may be different and unknown before acquiring it. – Cost and availability of storage space.	(Golinska-Dawson and Kübler, 2018) (Parker et al., 2015)
Market Issues	– Competing with manufacturers of new parts.	(Golinska-Dawson and Kübler, 2018) Expert interviews
Financing the establishment of a remanufacturing department	– Costs for companies to implement a remanufacturing process. – Financing remanufacturing is often seen as high(er) risk and it is therefore harder for firms to get finance for their remanufacturing project from a bank.	Expert interviews

2.5. Limitations of the remanufacturing sector

The remanufacturing market has natural limits to expansion as the industry needs to manufacture virgin products as inputs to remanufacturing. Additionally, only some of the returned parts or products will be a condition that can be used for remanufacturing. The average good product quota of remanufacturing businesses is 51 per cent, with a range of 0–90 per cent (Rematec, 2020). This wide range in the good product quota varied according to participants in the study. Participants included remanufacturing professionals from original equipment manufacturers/suppliers, 44 per cent; through independent aftermarket manufacturers who, as independent players, provide mostly lower-priced alternative parts, , 26 per cent; and component suppliers, 9 per cent; to 21 per cent of participants from diverse sectors such as product brokers and information technology (IT) service providers (Rematec, 2020).

Differences can also be seen in the revenue generated by remanufacturing. Of the industry players surveyed by Rematec, 47 per cent generate less than 25 per cent of their revenue from remanufacturing. Yet, 30 per cent of the respondents stated that remanufacturing accounts for the largest part of their revenue (see Figure 2.1) (Rematec, 2020c).

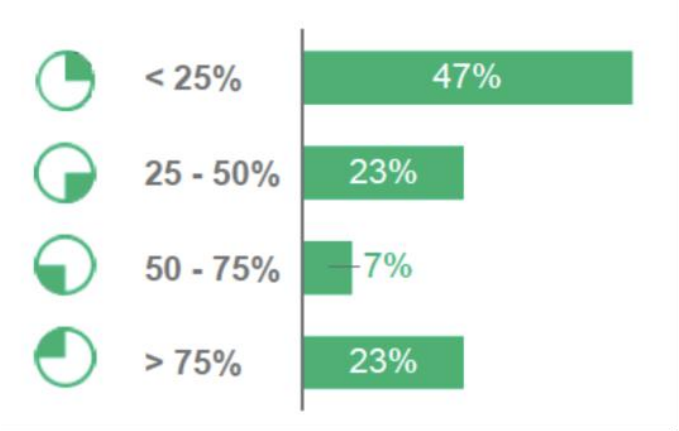

Figure 2.1 Revenue generated by remanufacturing, per cent. Left column: Revenue from remanufacturing (%), right column: companies surveyed (%)

Source: Rematec (2020c)

2.6. General drivers and enabling factors

Remanufacturing is particularly successful in industries whose products are of high value and quality, in which technologies do not change rapidly and innovation rare, and the products are durable and easy to dismantle. In the ERN Market Study, nine target sectors were identified as ones in which remanufacturing activities might be expected to have a significant impact (Parker et al., 2015). Table 2.4 provides an overview of products that could be remanufactured in the target industries.

Table 2.3. Overview of products that could be remanufactured in the target industries
Source: Vlaanderen (2018)

Sectors	Examples products
Aerospace	Helicopters, fixed-wing aircraft and parts such as turbine engines, landing gear, actuators, airframes, engines and fuel systems.
Automotive	Starters, alternators, gearboxes, engines, differentials, brakes and on-board computers.
Electrical and electronic equipment (EEE)	IT equipment: computers, laptops, servers, network switches, routers, modems, receiver stations, and imaging equipment. Electrical parts: power distribution conductors, transformers, switch gear, boards and streetlights.
Furniture	Office chairs, desks, tables, shelves and partition walls.
Heavy duty and off road equipment (HDOR)	Equipment for the construction, mining, agriculture and transport.
Machinery	Wind, gas and steam turbines, valves, compressors, pumps, heat exchangers, food processing equipment, industrial tools and industrial robots.
Medical equipment	Diagnostic, surgical and patient care apparatus.
Marine	Components of large diesel engines, such as cylinder covers, pistons, piston crowns, piston rods, exhaust valves, cylinder covers and connecting rods. Cabin components: for example, re-upholstery, headboards, and new wall, floor and ceiling coverings.
Rail	Locomotive engines, drive motors, axles and traction converters.

The most common drivers for remanufacturing relate to cost benefits and job creation. Generally, the production cost of a remanufactured product is 40-65 % less than the production cost of a new product (Nasr, 2020). As remanufacturing is more labour intensive than the manufacturing of virgin products, it can have a positive impact on the job market and create new work opportunities (Ihobe, 2019). Furthermore, remanufacturing companies can get a better knowledge of product imperfections and inverse engineering can thus contribute to better product design (Ihobe, 2019). An increase of remanufacturing activities also supports national economic security and resilience through reducing dependence on material and product imports (CarbonTrust, 2014).

In the Rematec study (2020) customers' motivation for buying remanufactured parts was predominantly cost saving, 49 %; 37 % chose remanufactured parts due to spare part availability and 14 % chose a them for environmental reasons.

Table 2.5 provides a summary of the enabling factors for remanufacturing.

Table 2.4. Enabling factors for remanufacturing

Enabling factor	Description	Source
Increased energy and material consumption	Increased energy and material consumption make the issue of resource constraint increasingly urgent and has led to the need for more remanufacturing and resource-efficient production processes to close the loop of manufacturing processes.	(Parker et al., 2015)
Increasing raw material prices and supplier resilience	Reduced dependency on raw materials and price fluctuations when a firm implements remanufacturing.	Expert interviews
New business models	Remanufacturing helps ensure the profitability of new pay-per-use business models on equipment.	(Ihobe 2019) (Sundin and Bras, 2005) Expert interviews
New directives and regulations	For example, ecodesign promotes more durable products and thus acts as a driver for remanufacturing.	Expert interviews

Enabling factor	Description	Source
Growing consumer awareness	- Better understanding and acceptance of value-retention strategies by companies and consumers. - Transition away from the idea that new products are best. - People are more familiar with the economic and environmental benefits, as well as value-retention options. Various online applications such as Depop, for fashion, and eBay exist. General fashion for being 'eco'/'green'.	Expert interviews

2.7. Environmental sustainability

Apart from the enabling factors, remanufacturing also offers environmental benefits. Particularly noteworthy are the reduction in resource use, energy, carbon emissions, general waste and pollution. Table 2.6 compares selected literature assessing the environmental impacts of remanufacturing. The key conclusion is that remanufacturing can reduce resource extraction and waste disposal by up to 80 per cent compared to the manufacture of a new product.

These benefits, in turn, translate into a variety of environmental impacts. The one that is most frequently cited in the literature is the avoidance of greenhouse gas emissions associated with extraction and processing of virgin resources into new products. The savings in carbon dioxide (CO_2) emissions, described in lifecycle analyses (LCAs), range from 23 to 87 per cent depending on the products studied. There are also, however, second order effects that may partially offset the upstream environmental benefits associated with longer-lived products. Furthermore, the environmental impacts of transporting used products, and the potential for rebound effects resulting from consumer savings are largely ignored many remanufacturing lifecycle analyses. Additionally, most of the analyses featured in Table 2.5 appear to assume zero recycling in their disposal and purchase new product scenarios when, in reality, significant proportions of some end-of-life products are recycled (OECD, 2019).

Table 2.5 Selected literature assessing the environmental impacts of remanufacturing Source: OECD, 2019; Sundin and Lee, 2011

Product focus	Change in resource extraction	Change in energy consumption	Change in greenhouse gas emissions	Waste disposal	Author	Study type
Electrical and electronic equipment (EEE)						
Photocopiers	-19 % to -25 %	-27 %	-23 %	-35 %	Kerr and Ryan (2001)	LCA
Photocopiers (modular)	-39 % to –48 %	-68 %	-65 %	-47 %	Kerr and Ryan (2001)	LCA
Printer cartridges	-	-	-33 %	-	Kara (2010)	LCA
Toner cartridges	-	-6 %	-	-	Gutowski et al. (2011)	Meta-review
Toner cartridges (different types)	-	-	-25 % to -60 %	-	Gell (2008)	-
Inkjet cartridges	-	-	-33 %	-	Kara (2010)	-
Personal computers	-	-80 %	-	-	Neto and Bloemhof (2009)	LCA
Computers	-	-57 %	-	-	Gutowski et al. (2011)	Meta-review
Electric motors	-	3 %	-	-	Gutowski et al. (2011)	Meta-review

Dishwashers	-	-44 %	-	-	Baustani et al. (2010)	-
Washing machines	-	-32 %	-	-	Baustani et al. (2010)	-
Refrigerators	-	-14 %	-	-	Baustani et al. (2010)	-
Automotive						
Engines	26 % to -90 %	-68 % to -83 %	-73 % to -87 %	-65 % to -88 %	Smith and Keoleian (2004)	LCA
Engines	-95 %	-66 %	-67 %	-	Liu et al. (2014)	LCA
Engines	-	-4 %	-	-	Gutowski et al. (2011)	Meta-review
Diesel engines	-	-10 %	-	-	Sutherland et al. (2008)	-
Turbochargers	-	-82.5 %	-73 %	-	Gao et al. (2017)	LCA
Gearboxes	>50 %	-33 %	-	-	Warsen et al. (2011)	LCA
Gearboxes	-	-	-34 %	-	Kara (2009)	-
Compressors	-	-	-90 %	-	Biswas and Rosano (2011)	LCA
Turbine blades	-	-36 %	-45 %	-	Wilson et al. (2014)	LCA
Tires	-	-9 %	-	-	Gutowski et al. (2011)	Meta-review
Other sectors						
Furniture	-	-100 %	-	-	(Gutowski et al., 2011)	Meta-review
Clothing	-	-64 %	-	-	(Gutowski et al., 2011)	Meta-review
Appliances	-	-75 %	-	-	Gutowski et al. (2011)	Meta-review

In addition to the comparative study by Organisation for Economic Co-operation and Development (OECD, 2019) reported above, the International Resource Panel (IRP, 2018) compared the environmental benefits of different products and different value-retention processes. It compared the required material and energy, and the CO_2 emissions from the new production, remanufacturing, refurbishing, repair and reuse of an industrial digital printer. It shows that there are significant savings in remanufacturing, but even more for the other processes. Table 2.7 shows the range of relative potential product-level material value retention across four different value-retention processes.

Table 2.6. Summary of ranges of potential product-level material value retention through value retention processes

	Industrial digital printers		**Vehicle parts**		**HDOR equipment parts**	
	Material value-retention range (kg/unit versus. OEM* new)		**Material value-retention range (kg/unit versus. OEM* new)**		**Material value-retention range (kg/unit versus. OEM* new)**	
	Low	**High**	**Low**	**High**	**Low**	**High**
Remanufacturing	91 %	98 %	80 %	95 %	81 %	91 %
Comprehensive refurbishment	95 %	99 %	-	-	82 %	82 %
Repair	99 %	99 %	96 %	99 %	94 %	99 %
Arranging direct reuse	100 %	100 %	100 %	100 %	-	-

* OEM: original equipment manufacturer

Source: IRP, 2018

3 Actual penetration based on available cases

3.1. Development of remanufacturing markets in Europe

In 2015 the ERN Remanufacturing Market Study (Parker et al., 2015) summarised that in the EU, remanufacturing generated around EUR 30 billion in turnover and employed around 190 000 people. The ratio of remanufacturing to new manufacturing was then assessed to 1.9 per cent, but ERN also estimated that the market tends were undervalued. At the time of the ERN study, a study by Zero Waste Scotland valued the turnover of remanufactured products in Europe at EUR 36 billion (Walsh et al., 2015). The ERN study – the most recent exhaustive study on European remanufacturing markets – estimated that there are great opportunities for growth of remanufacturing in Europe, and estimated that by 2030, the market could generate up to EUR 98.9 billion and employ 587 000 people. Indeed, in 2020 remanufacturers themselves expected significant growth in future sales: half of the remanufactures expected a growth rate of 5–10 per cent, and more than a third expected sales to increase over 10 per cent (Rematec, 2020a).

Overall, the interviewed experts, listed in the acknowledgements, estimated that there had not been major growth in the remanufacturing markets in 2015–2021, which could be due to the slowness of change in capital-intensive industries in which remanufacturing is practiced, and to the somewhat slow evolution of regulations and standards. Many of the sectors studied for this report have developed positively, however, and an increasing number of companies are introducing remanufacturing and carrying out pilot projects. A similar positive development has taken place in other value-retention activities as well, such as in reconditioning. The positive change is clearer for consumer goods than industrial products, even though it can be argued that the overall potential for remanufacturing consumer goods is lower, as in many cases, repair may be enough. There also seem to be more opportunities for third party companies, whereas original equipment manufacturers have lately been more severely affected by the COVID19 crisis.

Moreover, recent disruptive incidents and crises, including the COVID19 and the blocking of the Suez Canal incident, have highlighted issues of resilience in global value chains and resource sufficiency, thus creating incentives for remanufacturing and other more local value-retention strategies. The increasing understanding and acceptance of value-retention strategies also support this evolution. New business models, such as offering products as services, such as vehicle sharing in cities, allow service providers to better manage the whole lifecycle of their products, which also creates possibilities for remanufacturing. as companies can monitor the products' condition and collect them more easily when they reach their end-of-life. Digital platforms and applications support the development of sharing economy, in which the possibility of using products and services becomes more important than owning them. It is a promising way for example, to grow the utilisation rate of products and reduce the need to producing new ones, thereby reducing the use of raw materials.

Box 3.1 Remanufacturing in some European countries

In 2015, the ERN Remanufacturing Market Study outlined that in Europe, four key regions – Germany, the United Kingdom (UK) and Ireland, France, and Italy – accounted for some 70 per cent of Europe's remanufacturing revenue: Germany 29 per cent, UK and Ireland 15 per cent, France 14.5 per cent, and Italy 11 per cent. Germany has had a strong position in the aerospace, automotive and heavy duty and off-road sectors, while Germany, France and the UK are major global aerospace maintenance, repair and overhaul hubs. (Parker et al., 2015) The Society of Motor Manufacturers and Traders' Remanufacturing Committee has estimated that the current UK remanufacturing industry is worth EUR 2.8 billion (GBP 2.4 billion). Automotive is one the most established sectors. (SMMT, 2021)

In France, the current situation in remanufacturing markets is very similar to the European-level situation. France is leading the way with the Circular Economy Law and the Repairability Index regulation, respectively enacted in late 2020 and the beginning of 2021, which will support the development of circular technical loop activities, and also push remanufacturing forward. In Sweden, it is estimated that in general the remanufacturing market has not grown in the last 5 years, except for the EEE sector. In Poland, many value-retention activities performed in companies happen on the interface between reconditioning, repair and remanufacturing, thus there is little information available on remanufacturing *per se*. Most Polish remanufacturing companies are small, and few of them carry out large-scale remanufacturing. In Serbia, where circularity is becoming increasingly important and some companies have started to introduce activities that promote it, remanufacturing is currently on a beginner's level.

Some regional differences can be recognised. According to one expert interview, it seems that remanufacturing has not been widely introduced in Southern and Eastern Europe. In Southern and Eastern Europe, repairing is more common than remanufacturing, and this is typically carried out by third party actors or, in the case of consumer products, by consumers themselves. In Central Europe remanufactured equipment is mainly bought as a replacement for an old product.

3.2. Aerospace

In 2015 the ERN Remanufacturing Market Study estimated that the total value of remanufacturing in the aerospace sector was EUR 12.4 billion, 42 per cent of the total European remanufacturing turnover across the studied sectors, making it the strongest in terms of remanufacturing in Europe. The intensity ratio – the ratio of remanufacturing to new manufacturing – of the sector was 11.5 per cent. The major aerospace remanufacturing regions in the EU were Germany, 31 per cent; the UK and Ireland, 22 per cent; France, 19 per cent; Italy, 9 per cent; and the rest of the Mediterranean area, 7 per cent (Parker et al., 2015). In the aerospace sector, typical remanufactured products include helicopters, fixed-wind aircrafts and parts such as turbine engines, landing gear, actuators, airframes, engines and fuel systems (Vlaanderen, 2018).

The majority of recent studies on the aerospace sector cover maintenance, repair and overhaul activities (MRO) and less was found on remanufacturing *per se*. Maintenance, repair and overhaul activities include product-health monitoring and prognostics, traditional repair, overhaul and upgrading activities, as well as modifications, for airframes, components and engines (Pulidindi and Prakash, 2021). In the aerospace sector, the term overhaul is used to describe the remanufacturing of aircraft engines and airframes (Parker et al., 2015). The MRO and remanufacturing markets are not one-to-one, but have some similarities, and thus the development in MRO services also serves as an indicator for the potential for remanufacturing.

In 2019, the forecast annual growth rates of the European aircraft MRO market to 2028 for were estimated at 1.7 per cent in Western Europe and 0.9 per cent in Eastern Europe; for comparison, the highest growth rate was for India, at 9.5 per cent (Statista, 2020). Additionally, according to an expert estimate, the existing high intensity of remanufacturing in the sector is likely to remain on the same level. The Rematec

study estimated that the aerospace sector would grow 4 per cent per year (Rematec, 2020b). The size of the Western European MRO market is forecast to reach around EUR 11.8 billion (approximately US$ 13.8 billion) in 2021 (Statista, 2021). Studied on the global level, within the MRO market, the engine segment is seen as the most promising with a growth of 91 per cent (Statista, 2021).

The aviation industry was hit very hard by the COVID-19 pandemic, and the crisis also strongly affected the aircraft MRO market. Thus, in the near future, the remanufacturing market in the aerospace sector is expected to slow and even decline. The aviation industry, however, is likely to recover soon (Statista, 2021), and one expert even expects its remanufacturing activities to increase rapidly. Taking a 10-year perspective for the commercial airline fleet and its associated MRO market, the original equipment manufacturers are expected to increase their share of the MRO market (OliverWyman, 2017).

3.3. Automotive

The automotive parts industry is one of the world's largest markets for value-retention processes. This sector includes companies that process components for the production of light-duty cars and trucks, and for medium and heavy commercial vehicles; products such as starters, alternators, gearboxes, engines, differentials, brakes and on-board computers. The sector encompasses independent, contract, and original equipment manufacturers organisations, as well as a supply chain that provides reverse-logistics for products from end-of-life vehicles (IRP, 2018; Vlaanderen, 2018. The automotive parts remanufacturing market is fairly fragmented; large multi-national corporations have a significant presence as also do a fairly high number of domestic players spread across various regions (Persistence Market Research, 2019a; 2019b).

In 2015, the European remanufacturing market for the automotive sector was estimated at EUR 7.4 billion, which accounted for 25 per cent of the total value of European remanufacturing across the studied sectors, and the intensity ratio was estimated at 1.1 per cent. Germany was the major player with about a third of EU activity, EUR 2.4 billion, followed by France, Mediterranean Member States including Spain, and UK and Ireland (Parker et al., 2015). In recent years, the European market for remanufactured automotive parts is said to have grown by 7 per cent a year, with, according to Rematec, passenger cars and trucks being the top industry for remanufacturing, although that is expected to decrease in the future (Rematec, 2020b). Even though, in general, development has been promising, in some countries, such as Sweden, it has been estimated that the market penetration has not increased since 2016.

In the global remanufacturing markets of automotive parts, Europe follows the lead of North America. It is estimated that the global market will grow at a compound annual growth rate of 7.1 per cent in 2018–2026 to EUR 81.3 billion (approximately US$ 91 billion) in 2026. Europe is a strong player in the remanufacturing market because of its automotive manufacturing industries as well as its high volume of passenger vehicle sales, and has been estimated to offer the highest opportunity in the global automotive parts remanufacturing market in the future (Persistence Market Research, 2019a; 2019b).

In the automotive remanufacturing sector, some original equipment manufacturers have already established with their own remanufacturing activities, while other large ones are now showing interest in remanufacturing, running studies on introducing remanufacturing, piloting remanufacturing activities and building new kinds of competences and collaboration to support the process. Companies have acknowledged the importance of value-retention strategies, and these are becoming part of their sustainability strategies. At this point, exemplary companies are very important as they can lead the way for others.

Box 3.2 Electromobility solutions and electric vehicles

There is a big technology change taking place in the automotive sector with new drive-train technologies and the move from diesel and petrol-based cars to electric vehicles (EVs). Different studies forecast that in 10 years, 20 per cent of all newly sold cars will be EVs (Casper and Sundin, 2021). The drive-train concept and components of battery EVs are significantly different from cars with internal combustion engines. In principle, remanufacturing is much easier for electric motors compared to internal combustion engines, which opens up totally new opportunities for remanufacturing (Weiland, 2020).

The transition is likely to initially cause a decline in the remanufacturing market, but then offer great opportunities – in case of electric driving motors and lithium batteries the remanufacturing business will start slow, but after five to seven years it is expected to generate higher volumes allowing for economies of scale (Weiland, 2020). Remanufacturing is expected to take an increasingly important role for certain car components, such as electric and hybrid drive units, from 3 per cent today to 16 per cent in the future; as well as electronic components and electronic control units, from 8 per cent now to 12 per cent in the future; and batteries, from 1 per cent to 8 per cent. A decrease is expected for some parts, for example, for combustion engines and parts, from 15 to 10 per cent; and starters and alternators, from 18 to 9 per cent. In total, the growth rate for EV remanufacturing is estimated at 2–5 per cent per year for 2020–2025 (Weiland, 2020). To realising this potential, original equipment manufacturers will need to find new kinds of third-party partners, remanufacturing subcontractors, for dealing with electric power trains and other new technology.

3.4. Electrical and electronic equipment

In the IT industry, remanufacturing is carried out for components and complete products such as routers, switches, network modules, laptops, printers, cartridges and mobile phones. Typical remanufactured electrical parts, in turn, include power distribution conductors, transformers and switch gear. In 2016 Hieronymi estimated remanufacturing is an important business for all IT manufacturers: almost all original equipment manufacturers had remanufacturing programmes for their high-end devices, mainly used in the B2B sector, and were also starting to explore the market of low-/mid-range products. In 2016, however, only a few original equipment manufacturers had been able to establish profitable remanufacturing in the mid segment of the market and the consumer sector (Hieronymi, 2016; Vlaanderen, 2018).

In 2015, the ERN study estimated the EEE remanufacturing market to be worth EUR 3.1billion, driven by ICT and electronics at around EUR 1.8 billion and ink and toner cartridges at EUR 1.3 billion. White goods remanufacturing was estimated to be a very small segment and instead of remanufacturing much of it focused on local repair activities. The intensity ratio of EEE sector was 1.1 per cent in 2015 (Parker et al., 2015). The development of remanufacturing in the sector since then is somewhat unclear: an estimate is that the remanufacturing market in the sector is much larger than has been suggested but some say that the intensity has not changed since the 2015 ERN study. Nonetheless, remanufacturing activities are expected to grow: the Rematec study estimated, for example, an annual increase of 5 per cent in the industrial machines/electronics sector (Rematec, 2020b), driven in part by (the risk of) shortages of raw materials and the strong link to mobility solutions.

Some product segments have evolved further than others. Manufacturers of copiers and cartridges stand out with a rather long history of remanufacturing but it should be noted that it has taken these companies years to build this business and the required ecosystem. Currently, laptop and phone remanufacturing are notably growing businesses with clear development paths, and Europe remains the dominant region in the global refurbished/remanufactured computers and laptops market, with revenues in 2019 estimated at EUR 714 million (approximately US$ 800 million) (Transparency Market Research, 2019), with strong third-party players in Finland, Sweden and the UK. The market is forecast to grow strongly in the future,

with the global refurbished computers and laptops market expected to grow at a compound annual growth rate of 11 per cent in 2019–2027 (Transparency Market Research, 2019).

3.5. Furniture

According to the ERN study, in 2015 the remanufacturing market for furniture was worth approximately EUR 300 million, with an intensity ratio of 0.4 per cent (Parker et al., 2015). At the moment, the furniture sector is not very linked to upcycling activities, and very few companies are involved in remanufacturing. These provide services and products mainly for offices and public spaces, such as restaurants. Furniture products may be considered difficult to remanufacture, but there are also examples of big actors launching takeback schemes, and thus moving towards value-retention activities. Typical remanufactured furniture products include office chairs, desks, tables, shelves and partition walls (Vlaanderen 2018).

Although the sector is comparatively small, it is expected to grow, supported by growing awareness and know-how – architects are, for example, getting more used to specifying remanufactured furniture. Moreover, some European manufacturers have started to pay special attention to furniture design so that remanufacturing can be carried out as efficiently as possible. Furthermore, the business model of offering furniture or whole meeting rooms as service has been introduced in the sector.

3.6. Heavy duty and off-road equipment

The HDOR sector consists of companies that produce equipment and systems used in the commercial trucking, construction, mining, agriculture, and bulk transportation industries. This sector is primarily focused on mobile equipment that is highly durable and of high value. Many of the components in the HDOR equipment parts sector are designed for greater durability and even scheduled overhaul refurbishment and preventative maintenance activities (IRP, 2018).

In 2015, the European remanufacturing market was estimated to be worth EUR 4.1 billion, which includes EUR 850 million of HDOR tyre-retreading activities, with an intensity ratio for the sector of 2.9 per cent (Parker et al., 2015). Germany was estimated to account for 27 per cent of the market, with France, Italy, and the UK and Ireland representing 15, 13 and 12 per cent respectively. This market has a considerable potential and is expected to grow in the future. Steady growth is predicted, for example for the mining remanufacturing components and axle markets: the former is forecast to grow in Germany at a compound annual growth rate of approximately 2.6 per cent in 2020–2027; while for the latter, the global market is expected to grow at compound annual growth rate of 3.7 per cent in 2020–2027, with Europe one of the areas driving that growth (ReportLinker, 2021). Potential is also identified in the agricultural industry where a lot of heavy products that could be remanufactured are currently discarded.

3.7. Machinery

In 2015, remanufacturing of machinery in Europe was worth around EUR 1 billion, of which Germany accounted for a third with Italy, France and UK following at 20, 11 and 9 per cent respectively, and an intensity ratio for the sector of 0.7 per cent (Parker et al., 2015) In 2020, the Rematec study estimated the growth of industrial machines/electronics remanufacturing at 5 per cent a year (Rematec, 2020b). Global material and components shortages affecting Europe may boost local value-retention activities.

Typical remanufactured products include wind, gas and steam turbines. valves, compressors, pumps, heat exchangers, food processing equipment, industrial tools and industrial robots (Vlaanderen 2018). In the future, one interesting product group is wind turbines and their related components. As windmills have only recently established themselves as a significant product group, it is still somewhat unclear which end-of-life solutions will dominate for their components and materials, and what the opportunities for remanufacturing are.

3.8. Marine

In 2015, the marine equipment remanufacturing market was estimated at EUR 76m, which some argue is an under estimate, and the intensity ratio of the sector was 0.3 per cent (Parker et al., 2015). Remanufacturing in this sector is expected to grow at 11 per cent a year (Rematec, 2020b). Typical remanufactured products in the marine sector are components of large diesel engines, such as cylinder covers, pistons and exhaust valves; and cabin components including headboards and surfaces (Vlaanderen 2018).

3.9. Medical equipment

In 2015, the remanufacturing of medical devices in Europe was estimated to be worth around EUR 1billion, and the intensity ratio of the sector was 2.8 per cent (Parker et al., 2015). According to one interviewee, the sector has grown slightly since then; this is also supported by the 2020 Rematec study, which estimated an annual increase of 4 per cent for the health care sector (Rematec, 2020b). As globally the market for refurbished medical devices is expected to grow at a compound annual growth rate of 12.2 per cent in 2020–2026, the remanufacturing market in Europe may increase faster than forecasted by Rematec. Europe is known to have a good market penetration and robust demand for refurbished systems. A key product group in the sector is medical imaging equipment and a significant increase in demand is also expected for, amongst others, mechanical ventilators. Moreover, the increasing interest of original equipment manufacturers in refurbishment/remanufacturing medical devices is expected to stimulate growth in the market (Mordor Intelligence, 2020).

Regulation that allows medical products to be remanufactured is expected to evolve, which will support the growth of the sector. In the UK, for example, the National Health Service (NHS), the UK's healthcare systems, is looking into the possibilities of remanufacturing, and if they were to include remanufactured products into their procurement strategy, it would have a big impact on remanufacturing in the sector. The COVID19 pandemic has, moreover, brought to light risks associated with global supply chains.

3.10. Rail

The remanufacturing market in the rail sector was valued in 2015 at close to EUR 350 million and its intensity ratio was 1.1 per cent (Parker et al., 2015). The business is expected to grow, for example, a Rematec study estimated sector was growing at an annual rate of 7 per cent (Rematec, 2020b). In the future, change in power systems would necessitate a change towards remanufacturing. Decarbonisation in Europe is expected to boost the sector, benefiting not just remanufacturing markets but all value-retention businesses.

A recent example from Portugal demonstrated how lower costs and faster delivery times have encouraged the national train company to buy second-hand carriages and to organise refurbishment and remanufacturing for the carriages and components. In general, typical remanufactured products in rail include locomotive engines, drive motors, axles and traction converters (Vlaanderen, 2018). Some companies offer rail service solutions with which their customers can reduce downtime by replacing a piece of existing equipment with a factory remanufactured unit, returning the original product for assessment of condition.

Box 3.3 Sports goods, a potentially emerging sector

While remanufacturing has an established position in the production of B2B goods, initiatives in remanufacturing of consumer goods are emerging, of which sports goods are a good example. A major sport–goods chain has recently started working on ecodesign, which will also support developing remanufacturing processes and other value-retention activities in due course. Another sports-goods company that manufactures global positioning systems (GPS) watches has piloted a refurbishment process, through which it built both the process and capability for product refurbishment. In the US, several companies are remanufacturing gym equipment, including treadmills and strength machines.

The interest of sport goods companies in remanufacturing can also be seen in research activities, for instance by several textile companies in France (Expert interviews). With the move towards consumer markets, the recovery of used products/parts becomes more challenging as these markets are widely distributed and often involve additional intermediaries.

3.11. Summing up the forecasts

Based on the estimates of the sectors' remanufacturing market sizes (Parker et al., 2015) and the market potential – the base case scenario for 2015 and Rematec 2020 market study – some very rough estimates of the market sizes in 2021 can be made. The annual growth rate estimates range from small growth percentages of 0.5 per cent for the HDOR, machinery and marine sectors to very positive forecasts of 7–11 per cent for the automotive, marine and rail sectors. The sectors with largest remanufacturing market values are aerospace, automotive, EEE, and HDOR equipment. It must be stressed that these figures only give an indication of the current market size.

Table 3.1 Estimates of the remanufacturing market sizes by sectors

Sector (remanufacturing total value/intensity ratio in 2014)	**Estimation of the remanufacturing market size in 2021** **low end – high end** (applied growth rate)	
Aerospace (EUR 12.4 billion/11.5 %)	EUR 15.2 billion (3 %)	EUR 16.3 billion (4 %*)
Automotive (EUR 7.4 billion/1.1 %)	EUR 9.1 billion (3 %)	EUR 11.9 billion (7 %*)
Heavy duty and off-road equipment (HDOR) (EUR 4.1 billion/2.9 %)	EUR 4.2 billion (0.5 %)	
Electrical and electronic equipment (EEE) (EUR 3.1 billion/1.1 %)	EUR 4.4 billion (5 %*)	
Medical equipment (EUR 1 billion/2.8. %)	EUR 1.32 billion (4 %*)	EUR 1.4 billion (5 %)
Machinery (EUR 1 billion/0.7 %)	EUR 1.04 billion (0.5 %)	EUR 1.4 billion (5 %*)
Rail (EUR 350 million/1.1 %)	EUR 430.4 million (3 %)	EUR 562.1 million (7 %*)
Furniture (EUR 300 million/0.4 %)	EUR 422.1 million (5 %)	
Marine (EUR 76 million/0.3 %)	EUR 78.7 million (0.5 %)	EUR 157.6 million (11 %*)

**assuming that the remanufacturing sector grows at the same growth rate after 2015, as is projected for the future (projection from the Rematec report)*

Analysing the remanufacturing penetration in the selected sectors is a challenging task due to the lack of up-to date and comparable information. Currently, the NACE classification ([2]) also fails to represent the

[2] The statistical classification of economic activities in the European Community

share of remanufacturing as, with few exceptions including code 30306030 'Reconditioning of civil aircraft engines', classification of remanufacturing is most likely to fall under manufacturing. In practice it can be assumed that all remanufacturing done by original equipment manufacturers is shown as manufacturing. The same probably holds for remanufacturing by third parties as well, though in this case, a third-party remanufacturer can cut across several manufacturing sectors, for example, HDOR and automotive. Moreover, to get a better understanding of the current penetration of remanufacturing in the studied sectors, the development of the sectors in general, i.e. the current total market turnover, should be examined. Many industries are going through big changes – electrification, digitalisation, etc. – which means that the definitions are also changing. In order to get reliable, up-to-date information about remanufacturing penetration and the value of markets, further study that takes account of the evolving nature of manufacturing sectors and in which more in-depth data collection and statistical analysis are included, is recommended.

4 Principles for monitoring remanufacturing

Previous chapters respectively introduced specificities around the definition of remanufacturing (Chapter 1), discussed its potential (Chapter 2) and actual penetration (Chapter 3). The objective of Chapter 4 is to identify opportunities for monitoring the contribution of remanufacturing to the Europe's transition to a circular economy.

In view of the expansion of EEA indicator set, the ETC/WMGE conducted a gap analysis and exploration of additional indicators for monitoring the circular economy. Monitoring the progress of the transition requires new concepts, new indicators and new ways of gathering data (Vercalsteren et al., 2021). Moreover, the second principle of the previously mentioned Bellagio Declaration indicates that a robust monitoring system for the circular economy transition should include different indicators types:

- "*material and waste flow indicators to monitor changes throughout the material's lifecycle including resource efficiency dimensions;.*
- *"environmental footprint indicators to capture the impacts across the full lifecycle of products and materials, so that spill-over effects are assessed, and planetary boundaries are respected;*
- *'economic and social impact indicators to capture positive as well as negative impacts that may occur during the structural changes of the circular economy transition;*
- *"policy, process, and behaviour indicators to capture the implementation of specific Circular Economy policy measures and initiatives, in particular for key sectors*" (EEA et al., 2020).

Its fifth principle also refers to the importance of a multilevel monitoring. The Declaration mentions that such a monitoring framework should "*capture changes happening across all levels of the economy. It should address both public and private sector stakeholders, and different governance levels from global to local scale*" (EEA et al., 2020). As these levels cannot be considered completely hierarchical or separate. and full value-chain effects need to be considered, the following categorisation was proposed:

- macro (regional: city, country, etc.);
- meso (inter-organisation);
- micro (organisation);
- nano (product).

In line with the Bellagio principles of promoting the development of coherent metrics capturing the multiple dimensions of the circular economy, these opportunities will be particularly discussed according to their types and applicable levels.

4.1. Remanufacturing indicators in existing monitoring frameworks

In January 2021 the EU laid down a common methodology and format for reporting on reuse in accordance with Directive 2008/98/EC. It has been adopted to better monitor the implementation of measures on reuse. As part of the format provided for reporting on the qualitative data on reuse, a description of the measures and a qualitative assessment of their impacts or expected impacts is required. Measures such as *"support to or establishment of accredited repair and reuse-centres and networks or support to new business models such as sharing schemes, repair and remanufacturing*" are affected by this Act (European Commission, 2021). As Member States are also required to report on the implementation of measures related to remanufacturing, a review of existing monitoring frameworks is required for identifying potential existing and/or already proposed indicators related to remanufacturing.

Based on the recent gap analysis (Vercalsteren et al., 2021), in none of the reviewed existing frameworks ([3]) are remanufacturing indicators currently operational. Nonetheless, two examples of possible indicators are identified: the share of citizens who bought a remanufactured product, and the share of remanufacturing business in the manufacturing economy (Vercalsteren et al., 2021).

Drawing on its 2020 report addressing the principles for measuring the circular economy in cities and regions (OECD, 2020), the OECD has recently released an inventory of 474 circular economy-related indicators (OECD, 2021). Furthermore, in distinguishing indicators types, the OECD collected and classified macro-level (city, province, region or country) indicators between 2018 and 2020. Twenty-seven monitoring frameworks, eight at the national level, eight at the regional level and 11 at the local level, were reviewed. While 8 per cent of identified indicators refer to the repair, reuse and share sector, none explicitly addresses remanufacturing. When discussing the main challenges of these existing frameworks, the OECD emphasises this current lack of a systemic approach in circular economy indicators together with a lack of integration between macro, meso and micro levels (OECD, 2020).

The *Fundación COTEC para la Innovación* proposed and assessed the availability of several indicators for monitoring the Spanish transition to a circular economy. The share of remanufacturing business in the manufacturing economy was also identified for monitoring the transition of businesses in adopting circular strategies. The current limited availability of data was, however, stressed (Fundación COTEC para la innovación, 2017). The Finnish Circwaste project (Circwaste, 2020) defined a set of 16 indicators describing the penetration and development of circular business activity in the country. One of them particularly addresses remanufacturing, illustrated using one typical remanufactured product in Finland, heavy vehicles' tyres. Using statistical data, the indicator monitors the value of retreated tyres between 2013 and 2018 (Circwaste, 2020). In France, the key indicator aiming to monitor the extension of product lifetimes refers to household spending per year allocated to maintenance and repair, with no direct reference to remanufacturing (Scribe et al., 2021). A prospective study discussing the circular economy in 2040 in France, however, suggests possible indicators for monitoring the evolution of business activities. Targeting both reuse and remanufacturing activities, the authors recommend monitoring the development over time of corresponding markets, jobs, and collection and resale networks, as well as the number of dedicated platforms and marketplaces (INRS, 2019). Insights from the review of these initiatives are shown in Table 4.1.

[3] CE Monitoring Framework (EU); EU RE Scoreboard; WBCSD CE tool; EEA publication, *CE in Europe – Developing the knowledge base*; EEA indicators based on EEA Discussion paper on CE/SCP/RE indicators (draft 18.01.2019); PBL-framework; Key indicators for monitoring CE (France); Flemish CE indicator set, including proxy indicators from other initiatives; and EASAC Indicators for a circular economy.

Table 4.1: Identified remanufacturing indicators from existing monitoring frameworks, including associated macro-level initiatives

Identified remanufacturing indicators	Type of indicators	Level	Data source	Source(s)
Share of citizens who bought a remanufactured product	Policy, process and behaviour	Macro	One-off survey	Flash Eurobarometer survey, FB 388: Attitudes of Europeans towards Waste Management and Resource Efficiency, conducted in 2013 (European Commission, 2013)
Share of remanufacturing businesses in the manufacturing economy	Policy, process and behaviour	Macro	Proxy data (as in 2016 it was believed that no data were available to create the indicator) Use of statistical data from official sources would be recommended	Possible indicator suggested in the EEA report *Circular economy in Europe – Developing the knowledge base* (EEA, 2016) *Fundación COTEC para la Innovación* proposed and assessed the availability of several indicators for monitoring Spain's transition to a circular economy (Fundación COTEC para la innovación, 2017)
Value of retreaded tyres	Economic	Macro	Finland's statistics on industrial output, using PRODCOM EU classification of industrial products	Set of 16 indicators defined for describing the penetration and development of business activity of the Finnish circular economy. Illustrated with the value of retreading heavy tyres (Circwaste, 2020)
Jobs in remanufacturing	Social	Macro	Possible data source not indicated	Study proposing indicators targeting both reuse and remanufacturing activities to monitor the evolution business activities in France by 2040 (INRS, 2019)
Marketplaces and dedicated remanufacturing platforms	Economic	Macro	Possible data source not indicated	
Collection and resale networks	Economic	Macro	Possible data source not indicated	

Supporting the conclusions from the gap analysis, this first review clearly indicates that there are almost no indicators currently operational at a macro level for directly monitoring the contribution of remanufacturing in the transition to a circular economy.

4.2. Insights from expert interviews

To complete this first review and as part of the conducted interviews, two questions were developed for obtaining the most recent expert views on ways of monitoring the contribution of remanufacturing:

1. what metrics could be used to capture and monitor impacts of remanufacturing activities?
2. what frameworks and initiatives already exist, and/or could be a source of inspiration for defining remanufacturing indicators?

Two interviewees stressed the importance of developing indicators focussing on material retention, considered as the main benefit of remanufacturing activities. As access to resources is an important parameter of the EU's resilience in relation to raw materials, one interviewee explained that indicators could indeed focus on the contribution of remanufacturing in the retention of critical raw materials. Rather than using a business perspective on retaining materials in our economy, the other interviewee mentioned the need to monitor the performance of remanufacturing processes at a micro level. While these indicators would need to be industry and company specific, they are essential for ensuring the optimisation and economic viability of remanufacturing processes.

The availability of data is considered a major challenge. While metrics monitoring the environmental impact of processing and logistics could be beneficial, the experts suggested that the focus should remain on benefits associated with material retention. Monitoring the environmental footprint and emissions at a micro level is important but higher-level (modelling) data sources, rather than investigating efforts in obtaining specific data at product and process levels, could be used for obtaining relevant proxies.

In addition to material retention, an interviewee explained that the retention of functionality (product value retention) should be considered as a main benefit of remanufacturing and adequately monitored. The role of product design to increase durability and easier disassembly, which enables functional retention, would thus be of the utmost importance.

Several interviewees mentioned that monitoring the contribution of remanufacturing in the transition to a circular economy could be facilitated if remanufacturing, including details revenue and market size, were reported as a separate economic activity. Specifically, companies could be mandated to report on the share of their remanufacturing activities. For that and coming back to what was described in Chapter 1, a commonly accepted definition of remanufacturing supported by labels and standards would thus be a pre-requisite for such reporting. One interviewee explained that companies could track their remanufacturing activities by monitoring the number of products that were returned. Another interviewee mentioned that being able to reconcile the specificity of remanufacturing in different sectors, to ensure cross-sectoral monitoring, would be a challenge.

Stressing the outdated data used to monitor remanufacturing, as well as the challenges due to the diversity of activities, some interviewees highlighted the importance of developing indicators for small and medium-sized enterprises (SMEs) and to which they could provide input data. Tracking material at a part level would, however, would be difficult for SMEs.

Resonating with the discrepancies in remanufacturing definitions, one interviewee pointed out that, for engaging consumers in buying/using remanufactured products, remanufactured products should be accompanied by information on performance and durability. Thereby, collecting data for monitoring this engagement would, *per se*, have an informative and supporting spill-over effect.

Two other interviewees mentioned that it could be interesting to monitor the cross-border transport of remanufactured products. While also stressing the difficulty in obtaining such data, they mentioned that it could allow the monitoring of material flows and develop an understanding of the international trade in remanufactured products and the localisation of remanufacturing processes. Moreover, social impact

indicators could be developed for measuring the number of 'greener' jobs as well as trained and educated people.
Relying on his experience in a specific region, an interviewee suggested an indicator set covering the monitoring of circular turnover and benefits (Euros per year); employment numbers; GHG emissions reductions (tonnes per year); number of circular companies and innovation projects, for instance based on EU national and regional fund allocations; and certification; as well as business and consumer circular attitudes and behaviour based on standardised Eurobarometer surveys (Elgorriaga, 2021).

Suggestions from experts' interviews are summarised in Table 4.2.

Table 4.2 Suggested indicators for monitoring the contribution of remanufacturing, insights from experts' interviews

Suggested remanufacturing indicators	**Type of indicator**	**Level**	**Data source**
Use of primary raw materials	Material flows	Micro	Company data
Use of critical raw materials	Material flows	Micro	Company data
Net profit	Economic	Micro	Company data
Remanufacturing process sustainability	Environmental footprint	Micro	Modelling data
Remanufacturing sector sustainability	Environmental footprint	Meso/macro	Statistical data
Product functionality retention	Material flows	Micro	Company data
Cross-border transport	Material flows	Meso/Macro	Statistical trade data
Share of remanufacturing activities in the company	Economic	Micro	Company data
Turnover of remanufacturing activities	Economic	Micro	Company data
Number of cores returning to the company	Material flows	Nano	Company data
Share of remanufacturing business in the manufacturing economy	Policy, process and behaviour	Macro	Statistical data
Share of consumers buying/using remanufactured products	Policy, process and behaviour	Macro	Statistical data
EU investments in remanufacturing activities	Economic	Macro	EU budget data
Jobs in remanufacturing	Social	Macro	Statistical data
Number of educated and trained people on remanufacturing	Social	Macro	Statistical data

While some similarities appeared between insights gathered in possible indicators are identified: the share of citizens who bought a remanufactured product, and the share of remanufacturing business in the manufacturing economy (Vercalsteren et al., 2021).

Drawing on its 2020 report addressing the principles for measuring the circular economy in cities and regions (OECD, 2020), the OECD has recently released an inventory of 474 circular economy-related indicators (OECD, 2021). Furthermore, in distinguishing indicators types, the OECD collected and classified macro-level (city, province, region or country) indicators between 2018 and 2020. Twenty-seven monitoring frameworks, eight at the national level, eight at the regional level and 11 at the local level, were reviewed. While 8 per cent of identified indicators refer to the repair, reuse and share sector, none explicitly addresses remanufacturing. When discussing the main challenges of these existing frameworks,

the OECD emphasises this current lack of a systemic approach in circular economy indicators together with a lack of integration between macro, meso and micro levels (OECD, 2020).

The *Fundación COTEC para la Innovación* proposed and assessed the availability of several indicators for monitoring the Spanish transition to a circular economy. The share of remanufacturing business in the manufacturing economy was also identified for monitoring the transition of businesses in adopting circular strategies. The current limited availability of data was, however, stressed (Fundación COTEC para la innovación, 2017). The Finnish Circwaste project (Circwaste, 2020) defined a set of 16 indicators describing the penetration and development of circular business activity in the country. One of them particularly addresses remanufacturing, illustrated using one typical remanufactured product in Finland, heavy vehicles' tyres. Using statistical data, the indicator monitors the value of retreated tyres between 2013 and 2018 (Circwaste, 2020). In France, the key indicator aiming to monitor the extension of product lifetimes refers to household spending per year allocated to maintenance and repair, with no direct reference to remanufacturing (Scribe et al., 2021). A prospective study discussing the circular economy in 2040 in France, however, suggests possible indicators for monitoring the evolution of business activities. Targeting both reuse and remanufacturing activities, the authors recommend monitoring the development over time of corresponding markets, jobs, and collection and resale networks, as well as the number of dedicated platforms and marketplaces (INRS, 2019). Insights from the review of these initiatives are shown in Table 4.1.

Table 4.1: Identified remanufacturing indicators from existing monitoring frameworks, including associated macro-level initiatives

Identified remanufacturing indicators	**Type of indicators**	**Level**	**Data source**	**Source(s)**
Share of citizens who bought a remanufactured product	Policy, process and behaviour	Macro	One-off survey	Flash Eurobarometer survey, FB 388: Attitudes of Europeans towards Waste Management and Resource Efficiency, conducted in 2013 (European Commission, 2013)
Share of remanufacturing businesses in the manufacturing economy	Policy, process and behaviour	Macro	Proxy data (as in 2016 it was believed that no data were available to create the indicator) Use of statistical data from official sources would be recommended	Possible indicator suggested in the EEA report *Circular economy in Europe – Developing the knowledge base* (EEA, 2016) *Fundación COTEC para la Innovación* proposed and assessed the availability of several indicators for monitoring Spain's transition to a circular economy (Fundación COTEC para la innovación, 2017)
Value of retreaded tyres	Economic	Macro	Finland's statistics on industrial output, using PRODCOM EU classification of industrial products	Set of 16 indicators defined for describing the penetration and development of business activity of the Finnish circular economy. Illustrated with the value of retreading heavy tyres (Circwaste, 2020)
Jobs in remanufacturing	Social	Macro	Possible data source not indicated	Study proposing indicators targeting both reuse and remanufacturing activities to monitor the evolution business activities in France by 2040 (INRS, 2019)
Marketplaces and dedicated remanufacturing platforms	Economic	Macro	Possible data source not indicated	
Collection and resale networks	Economic	Macro	Possible data source not indicated	

Supporting the conclusions from the gap analysis, this first review clearly indicates that there are almost no indicators currently operational at a macro level for directly monitoring the contribution of remanufacturing in the transition to a circular economy.

and Table 4.2, insights from the expert interviews particularly focussed on the importance of defining micro-level indicators. Diving into this level, the Table 4.3 provides more specific suggestions for defining and implementing remanufacturing process sustainability indicators.

4.3. Monitoring the sustainability of companies' remanufacturing processes

Table 4.3 provides an overview of proposed indicators for monitoring the sustainability of remanufacturing processes.

Table 4.3 Identified indicators for assessing companies' remanufacturing process sustainability

Possible indicators for assessing remanufacturing process sustainability	Type of indicator	Level	Data source	Sources
- Overall equipment effectiveness - Remanufacturing process flow - Adequacy of remanufacturing process planning - Availability of machines and tools - Service level - Availability of materials - Complaints level (percentage share of complained products in the total monthly sale) - Local market share (percentage market share of remanufactured diesel particulate filters in province) - New components cost - Core (product)/product value ratio - Core (product)/product ratio - Core (product) class distribution - Core (product) class assessment - Product salvage rate - Component salvage rate - Core (product) disposal rate	Economic	Micro	Assumption that data should be easily accessible within the company, questionnaires filled based on expert judgements	Golinska et al. have defined indicators for assessing the sustainability level of the remanufacturing process (Golinska et al., 2015). Referring to the same indicators, a Sustainability Indicators System for Remanufacturing is proposed (Golinska-Dawson et al., 2018). A set of sustainability indicators in the remanufacturing process for SMEs dealing with a diesel particulate filter was determined (Werner-Lewandowska and Kosacka-Olejnik, 2019). Research aiming to determine a set of sustainability indicators in the scope of remanufacturing process especially for SME (Fatimah and Aman, 2018). PREMANUS project has designed a set of key performance indicators to assist remanufacturers to enhance their business performance (Graham et al., 2015).
- Energy consumption per core - Amount of waste generated - Material recovery rate - Emissions (CO_2, water, sewage) per regenerated core (product) - Material used	Material flows and environmental footprint	Micro/nano		

- Recycled material used - Direct energy consumption - Indirect energy consumption - Water withdrawal - GHG emissions - Total waste by weight					
- Employment change - Staff training - Harmfulness of the remanufacturing process - Average level of comfort at work - Innovation level - Engagement in relation with local community	Social	Micro			

4.4. Monitoring the impact of implemented policy instruments and upcoming initiatives

As described above, a robust monitoring framework defines indicators capturing the implementation and impact of policy measures and initiatives. Several policy instruments have already supported the actual penetration of remanufacturing activities in specific sectors and Elgorriaga et al. (2019) analysed the effectiveness and relevance of these. They have benchmarked their recommendations to policy-makers against those included in other relevant reports – Ihobe´s analysis in the Basque Country (Elgorriaga et al., 2019), Zero Waste Scotland Study (Walsh et al., 2015), ERN (Parker et al., 2015) and International Research Panel (IRP, 2018)) Building on Elgorriaga et al.'s (2019) experience in implementing and evaluating regional instruments in their context, their analysis shows that the following seem to be the most effective instruments for supporting the development of remanufacturing:

- supporting investment in remanufacturing by means of grants or loans;
- Driving research, development and innovation;
- Capacity building and skilling expert personnel;
- Raising awareness of companies (B2B) and consumers (B2C);
- Driving and implementing certifiable remanufacturing standards that increase market confidence.

Monitoring the impact of these particular policy instruments can thus provide relevant insights with regards to the deployment of remanufacturing. During the interviews conducted for this report, some experts shared their views about the relevance of policy instruments in supporting remanufacturing. Several of them referred to the upcoming policy initiative on the right to repair, announced with the release of the new Circular Economy Action Plan. The European Commission has indeed stated its intent to explore possible changes on the role that guarantees can play in adding more circular products to EU consumer law, particularly in the context of the review of the Sales of Goods Directive 2019/771 (European Commission, 2020). Elgorriaga et al.'s (2019) analysis completed with insights from expert interviews are summarised in Table 4.4.

Table 4.4 Policy instruments supporting remanufacturing and assessed relevance.

Comparison between the Ihobe´s analysis in the Basque Country, Zero Waste Scotland (ZWS) Study, ERN for Europe and the latest UNO worldwide study. Considered effectiveness of instruments or *suggested concepts* are scored high (**Dark green**), medium (Medium green) or low (white) by Elgorriaga et al., 2019). Added from expert interviews: medium = mentioned by one expert; high = mentioned by more than one expert; (Red) = not mentioned

	Study type	**Ihobe Basque**	**ZWS Scotland**	**ERN Europe**	**UNO global**	**Experts**

Legal	End-of-life legislation (E End-of-life vehicles, waste EEE, batteries) including extended producer responsibility					
	Removal of Regulatory Barriers					
	Ecodesign Directive (ErP)					
	Circular Economy Action Plan, Right to repair					
Market	Green public procurement					
	Remanufacturing excellence standards					
	Networking local and internationally					
Economic	Fiscal Instruments for B2B					
	Reduced VAT for labelled B2C products					
	Investment financing					
	Financial guarantees for circular models					
Innovation	Research and Innovation support					
	Capacity building					
Capacity building and awareness	Awareness					
Policy	*Targets and comparable data*					
	Clear remanufacturing definitions					

4.5. Opportunities (and challenges) for monitoring the contribution of remanufacturing to the European transition to a circular economy

As explained above, Principle 5 of the Bellagio Declaration refers to the notion of multilevel monitoring. While some opportunities have been identified at macro and micro levels, effective monitoring and capturing the contribution of all stakeholders involved in remanufacturing activities can be a challenge in view of defining relevant indicators. Understanding the full value-chain effects of any measures would thus be key for this. It is important to highlight the diversity of involved stakeholders. Today the European Remanufacturing Council categorises remanufacturing business models into three main groups: independent third parties, approved third parties and original equipment manufacturers in-house (European Remanufacturing Council, 2021a). These stakeholders might have divergent interests and currently not be subject to similar regulatory challenges. Remanufacturing value chains are also global. Monitoring European (quality and quantity) local job creation should use this global perspective, also taking account of job displacement risks. While some clear challenges remain for ensuring holistic multilevel monitoring, identified opportunities presented in Chapter 0 are shown in Figure 4.1.1.

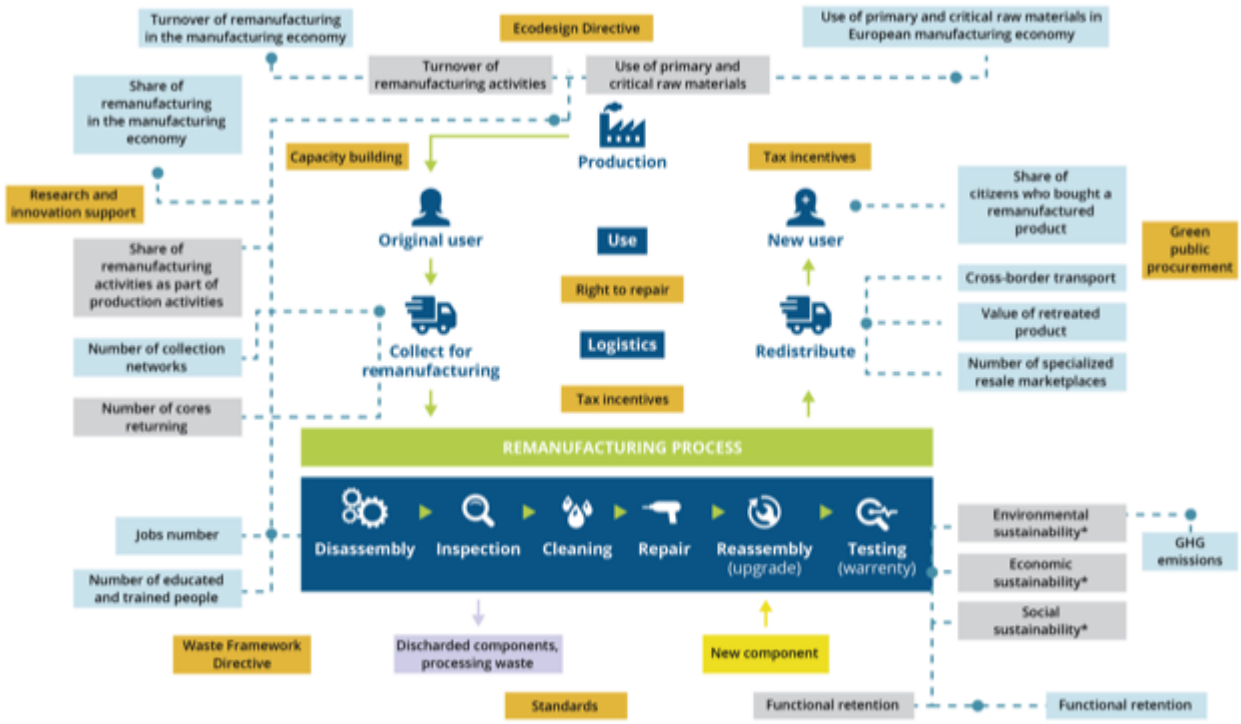

Figure 4.1 Opportunities for a multilevel monitoring of remanufacturing's contribution to the European transition to a circular economy

***see Table 4.3**

Soure: ETC/WMGE

Opportunities shown in Figure 4.1 represent ways of specifically monitoring the contribution of remanufacturing. Both the definition of indicators and their operationalisation, however, relies on a generally accepted definition of remanufacturing, with a clear distinction between other value-retention processes (Chapter 1). Although statistical data and official statistics are, indeed, being considered as relevant data sources for monitoring several of the aspects shown in Figure 4.1.1, this definition is an essential pre-requisite. In the meantime, intermediate data sources can be identified. The European Remanufacturing Council is an industry association representing small and large businesses from all remanufactured product sectors. Their ambition is to increase the value of Europe's remanufacturing sector to EUR 100 billion by 2030 (European Remanufacturing Council, 2021b). To monitor their progress, surveys among their members are planned. While not encompassing all companies performing remanufacturing in Europe, such surveys from industry associations could provide relevant and representative numbers, for example, on the turnover and penetration of remanufacturing. The sales of the European Committee for Standardization (CEN) remanufacturing standard or the number of remanufacturing initiatives reported by Member States in their reporting on reuse activities (qualitative data) could also act as proxy indicators. With regard to material and waste flows, and environmental footprint indicators, it is clear that specific company data would be beneficial. The above-mentioned studies, however, also reflect the complexity and huge efforts associated with gathering this primary information, especially for SMEs. Modelling data, such as for generating an estimated carbon footprint for specific products, if extrapolated can also act as an intermediate data source and provide relevant information at sectoral and company (meso/macro) levels. In coming years and with the digitalisation of manufacturing industry, new data sources could emerge. Digital product passports aiming to track and trace products, could, for instance, enable the monitoring of cores, including their condition, returning to facilities. It could also provide a relevant data source for more easily monitoring cross-border transport.

While this study specifically focusses on identifying ways of monitoring the contribution of remanufacturing, further research is needed before investigating efforts to draft an eventual indicator set solely dedicated to remanufacturing. While a clear definition of remanufacturing is considered beneficial from multiple perspectives, clear challenges can also be foreseen in obtaining a generic and commonly accepted definition that would enable such a cross-sectoral reporting and monitoring. The scope of such a dedicated monitoring system particularly needs to be defined. The possibilities to integrate these identified ways of monitoring remanufacturing with existing and/or potential indicators for other value-retention processes – reuse, repair, refurbishment – should be examined. As mentioned above, among the 474 circular economy-related indicators identified by the OECD, 8 per cent cover the repair, reuse and share sector (OECD, 2021). Defined as part of monitoring frameworks for cities,regions and countries, particularly Paris, Galicia, Spain and Portugal, these operational indicators aim at monitoring aspects such as the volume of objects collected and diverted from recycling centres for reuse or repair, the number of collection points for reuse, the number of places devoted to repair, the ratio of shops offering repair services over the total number of shops, and economic savings for local administrations, etc from the reuse of furniture and equipment. Relying on his experience in a specific region, an interviewee suggested an indicator set covering the monitoring of circular (thus encompassing other value-retention processes) turnover and benefits (euros per year), employment number, GHG emissions reduction (ton per year), number of circular companies and innovation projects, for instance based on EU national and regional fund allocation, and certification, as well as business and consumer circular attitude and behaviour based on standardised Eurobarometer surveys (Elgorriaga, 2021). **Based on similarities and discrepancies between the specific monitoring needs of each of these distinctive value-retention processes, a clear focus on the definition of indicators could thus be recommended: monitoring value-retention in general, specially monitoring each of these value-retention processes, and/or a combination of both perspectives**.

5 Conclusions

Remanufacturing is regarded as a value-retention process position high up the waste hierarchy, implying preservation of product functionality, lifespan extension and minor material losses. It is a term with a number of definitions and many companies are not necessarily aware that they are actually remanufacturing. Moreover, remanufacturing often occurs as an B2B activity and is not well known to the public. A number of definitions have been developed and the border between remanufacturing and other value-retention processes such as refurbishment is somewhat grey. The use of the word remanufacturing also varies in different countries and industrial sectors. In this report, remanufacturing has been discussed in line with the delineation that a remanufactured product should be of at least the same quality as the original product and come with a warranty.

Trends in remanufacturing

Based on interviews with experts and available written reports, it seems that remanufacturing markets have not grown significantly between 2015 and 2021. Nonetheless, there are indications of growing interest in many of the focal sectors and an increasing number of companies are now introducing remanufacturing into their businesses and, for example, setting up pilot projects. Similar positive developments have also taken place in other value-retention activities such as reconditioning.

In recent years, the manufacturing sector has undergone changes that continue to rearrange the sectors and affect the way remanufacturing business develops. These include the increasing understanding of scarcity of supply, risks relating to global value chains, and the evolution of new business models, such as offering products as services and the sharing economy. Digitalisation and major technological developments in the focal product groups, electric vehicles, etc., offer more opportunities for remanufacturing. In many sectors there iare also developments in terms of key players: in the aerospace, automotive and medical equipment sectors, for example, original equipment manufacturers are now reported to be increasingly interested in remanufacturing, promising growth. At the same time, a reluctance to invest in needed new skills, personnel and technical processes, and the fact that remanufacturing involves more complex processes such as reverse logistics, is seen as a hurdle. In the short term, disruptive changes may negatively affect the development of remanufacturing, but in the longer run, the outlook for remanufacturing is positive.

Penetration

This study concluded that current penetration in the focal sectors is around 5 per cent, with the exception of aerospace in which the remanufacturing intensity is estimated to be more than 10 per cent. All sectors contain specific product lines for which remanufacturing is developing rapidly. Collected data and interviews conducted with expert suggest that the biggest sectors by market value, aerospace, automotive, EEE, and HDOR equipment, have, by and large, remained the same. In terms of estimated growth rates, the marine and rail sectors are expected to grow with relatively rapidly in addition to the automotive sector. There is, however, a lack of current, consistent and comparable data on market volumes at all levels – industries (micro), the country level (macro) and the European level.

Monitoring

The work on indicators that could monitor progress towards a circular economy has largely been driven by the development of material resource efficiency and climate impacts. Although these are useful, from both environmental and business perspectives, they are not sufficient for checking the progress of remanufacturing. Obtaining robust data from individual remanufacturing processes and actors is challenging, due to the fact that its definition in business is somewhat grey. The fact that remanufacturing

is done by various actors, both original equipment manufacturers and third parties, also makes the assessment of actual penetration demanding.

Current data on the penetration of remanufacturing in companies has often rather fuzzy edges. To be able to monitor progress and get solid statistics, clear definitions need to be communicated to remanufacturing actors.

While remanufacturing indicators are currently not integrated into existing monitoring frameworks, some opportunities for multilevel monitoring of the remanufacturing process have been identified, categorised and mapped, with the share of remanufacturing in production activities, the number of products being returned for remanufacture and the number of collection networks being mentioned frequently. Challenges in operationalising these indicators have also been discussed, and while most of them involve the paucity of data sources, including a lack of official statistics, intermediate options for gathering these data have been proposed. These include customers' willingness to purchase remanufactured products, sales of products meeting the CEN Standard on remanufacturing, and the number of jobs in the manufacturing sector related to repair, all of which could act as proxies for remanufacturing progress. As part this multilevel monitoring, it should be stressed that some policy instruments have already supported the actual penetration of remanufacturing in Europe. It will thus be important to the capture information on the implementation of upcoming policy initiatives resulting from the new Circular Economy Action Plan.

To obtain the necessary insights into the current penetration of remanufacturing and factors promoting or hindering progress, a comprehensive market study of the European manufacturing sector is needed. In addition to shed light on the actual penetration, such a study, regularly repeated, could guide policy makers towards policies that efficiently enhance value -retention processes in businesses and society.

When looking at the all the elements of remanufacturing as a value-retention process, challenges and large knowledge gaps remain. More robust data are needed on sustainable consumption, such as the sharing economy, in addition to data on repair and reuse. Better descriptive social and waste prevention indicators would also provide greater insights into progress.

References

acatech/Circular Economy Initiative Deutschland and SYSTEMIQ, 2021, *Circular Business Models: Overcoming Barriers, Unleashing Potentials*, acatech (National Academy of Science and Engineering), Munich Germany.

Bauer, T., Mandil, G., Naveaux, E. and Zwolinski, P., 2016, 'Lifespan Extension for Environmental Benefits: A new Concept of Products with Several Distinct Usage Phases', *Procedia CIRP* 47, 430–435.

CarbonTrust, 2014, *Supporting Excellence in UK Remanufacturing. Stakeholder dialogue on opportunities and challenges*, Carbon Trust, London.

Casper, R. and Sundin, E., 2021, 'Electrification in the automotive industry: effects in remanufacturing', *Journal of Remanufacturing* 11, 121–136.

Circwaste, 2020, 'Indicators for the circular economy business' (https://www.stat.fi/tup/kiertotalous/kiertotalousliiketoiminnan-indikaattorit_en.html) accessed 3 September 2021.

EEA, 2016, *Circular Economy in Europe - Developing the knowledge base*, EEA Report 2/2016, European Environment Agency.

EEA, ISPRA and EPA Network, 2020, Bellagio Declaration Circular Economy Monitoring Principles.

Elgorriaga, A., 2021, 'Indicators for policy monitoring: the Basque approach', presentation given at: EEA Webinar on remanufacturing in the circular economy, Online, 11 September 2021.

Elgorriaga, A., Schötz, S., Eguren, J. A. and Quintana, I., 2019, 'Towards an integral remanufacturing support strategy: the first results from the Basque country', conference paper presented at: International Conference on Remanufacturing, Amsterdam, 2019.

European Commission, 2013, *Flash Eurobarometer 388 - Attitudes of Europeans towards Waste Management and Resource Efficiency*, European Commission.

European Commission, 2020, A new Circular Economy Action Plan For a cleaner and more competitive Europe, COM(2020) 98 final.

European Commission, 2021, Commission Implementing Decision (EU) 2021/19 of 18 December 2020 laying down a common methodology and a format for reporting on reuse in accordance with Directive 2008/98/EC of the European Parliament and of the Council (notified under document C(2020) 8976) (Text with EEA relevance), OJ L., 32021D0019.

European Remanufacturing Council, 2021a, 'Case studies for policy-makers' (https://www.remancouncil.eu/case-studies.php) accessed 20 September 2021.

European Remanufacturing Council, 2021b, 'Conseil Européen de Remanufacture | European Remanufacturing Council' (https://www.remancouncil.eu/index.php) accessed 21 September 2021.

Fatimah, Y. A. and Aman, M., 2018, 'Remanufacturing sustainability indicators: An Indonesian small and medium enterprise case study', *IOP Conference Series: Materials Science and Engineering* 403, 012055 (DOI: 10.1088/1757-899X/403/1/012055).

Fischer, S., Benke, J. and Wilts, H., 2017, *Bridging the raw materials knowledge gap for reuse and remanufacturing professionals (ReUK): "Report on ten knowledge gaps"*.

Golinska, P., Mierzwiak, R., Kosacka, M. and Werner-Lewandowska, K., 2015, 'Grey Decision Making as a tool for the classification of the sustainability level of remanufacturing companies', *Journal of Cleaner Production* 105, 28–40 (DOI: 10.1016/j.jclepro.2014.11.040).

Golinska-Dawson, P., Kosacka, M. and Werner-Lewandowska, K., 2018, 'Sustainability Indicators System for Remanufacturing', in: Golinska-Dawson, P. and Kübler, F. (eds), *Sustainability in Remanufacturing Operations*, EcoProduction, Springer International Publishing, Cham, pp. 93–110.

Golinska-Dawson, P. and Kübler, F., 2018, 'Sustainability in Remanufacturing Operations', *Environmental Issues in Logistics and Manufacturing* (DOI: https://doi.org/10.1007/978-3-319-60355-1).

Graham, I., Goodall, P., Peng, Y., Palmer, C., West, A., Conway, P., Mascolo, J. and Dettmer, F., 2015, 'Performance measurement and KPIs for remanufacturing', *Journal of Remanufacturing* 5 (DOI: 10.1186/s13243-015-0019-2).

Gustavsson, N., de Bruijne, E., Frick, F., Berlinghof, T. and Zotz, F., 2021, *Regulatory mapping for remanufacturing of products under EU law*, PM 6/21, Swedish Chemicals Agency.

Gutowski, T. G., Sahni, S., Boustani, D. and Graves, S. C., 2011, 'Remanufacturing and energy savings', *Environmental Science & Technology* 45(10), 4540–4547 (DOI: 10.1021/es102598b).

Hieronymi, K., 2016, 'Remanufacturing and Circular Economy in the IT Industry', in: *Many-New-Again by Remanufacturing, Rebuilding or Refurbishing*, APRA, Binningham, pp. 24.

Ihobe, 2019, *Innovation in the Circular Economy. Materials, Processes and Products. Priority areas and preferential line of funding for the industry in the Basque Country.*, Ihobe - Environmental Management Agency.

Ijomah, W. L., 2008, 'A tool to improve training and operational effectiveness in remanufacturing', *International Journal of Computer Integrated Manufacturing* 21(6), 676–701.

Ijomah, W. L., McMahon, C., Hammond, G. and Newman, S. T., 2007, 'Development of design for remanufacturing guidelines to support sustainable manufacturing', *Robotics and Computer-Integrated Manufacturing* 23(6), 712–719 (DOI: https://doi.org/10.1016/j.rcim.2007.02.017).

INRS, 2019, *Economie circulaire en 2040 - Quels impacts en santé et sécurité au travail? Quelle prévention?*, Institut National de Recherche et de Sécurité.

IRP, 2018, *Re-defining Value – The manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy*, United Nations Environment Programme.

Jansson, K., Vatanen, S., Karvonen, I., Behm, K., Waugh, R., Fitzsimons, D., Sundin, E. and Parker, D., 2017, *D6.3 Targeted Recommendations*, European Remanufacturing Network, Aylesbury, UK.

Karvonen, I., Jansson, K., Behm, K., Vatanen, S. and Parker, D., 2017, 'Identifying recommendations to promote remanufacturing in Europe', *Journal of Remanufacturing* 7(2–3), 159–179 (DOI: https://doi.org/10.1007/s13243-017-0038-2).

Koop, C., Fischer, S., Muller, A., Dibb, S. and Roby, H., 2018, *RemanPath: Market Feasibility Study on learning materials for remanufacturing*, Project Report, EIT Raw Materials.

Mordor Intelligence, 2020, 'Global Refurbished Medical Devices Market - Growth, Trends, Covid-19 Impact, and Forecasts (2021-2026)' (https://www.mordorintelligence.com/industry-reports/global-refurbished-medical-devices-market-industry) accessed 22 August 2021.

Nasr, N., 2020, *Remanufacturing in the Circular Economy: Operations, Engineering and Logistics*, Scrivener Publishing, Austin, TX, US.

OECD, 2019a, *Business Models for the Circular Economy: Opportunities and Challenges for Policy*, OECD.

OECD, 2019b, 'Main Science and Technology Indicators' (http://www.oecd.org/science/msti.htm) accessed 5 August 2019.

OliverWyman, 2017, '2017 – 2027 Fleet & MRO Forecast' (https://www.oliverwyman.com/our-expertise/insights/2017/feb/2017-2027-fleet-mro-forecast.html) accessed 18 August 2021.

Östlin, J., 2008, On Remanufacturing Systems: Analysing and Managing Material Flows and Remanufacturing Processes, The Institute of Technology, Linköping University, Linköping, Sweden.

Parker, D., Riley, K., Robinson, S., Symington, H., Jansson, K., Tewson, J., Ramkumar, S. and Peck, D., 2015, *Remanufacturing Market Study*, ERN.

Parker, D., Riley, K., Robinson, S., Symington, H., Tewson, J., Jansson, K., Ramkumar, S. and Peck, D., 2015, *Remanufacturing Market Study*.

Persistence Market Research, 2019a, 'Automotive Parts Remanufacturing Market' (https://www.persistencemarketresearch.com/market-research/automotive-parts-remanufacturing-market.asp) accessed 19 August 2021.

Persistence Market Research, 2019b, 'Automotive Parts Remanufacturing Market is Estimated to Grow at a Value CAGR of 7.1% Over 2018 to 2026 - Persistence Market Research' (https://www.prnewswire.com/news-releases/automotive-parts-remanufacturing-market-is-estimated-to-grow-at-a-value-cagr-of-7-1-over-2018-to-2026---persistence-market-research-300825943.html) accessed 19 August 2021.

Pulidindi, K. and Prakash, A., 2021, 'Commercial Aircraft MRO Market Size 2021-2027 | Forecasts Report' (https://www.gminsights.com/industry-analysis/commercial-aircraft-mro-market) accessed 18 August 2021.

Rematec, 2020a, 'Global remanufacturing benchmark - Part six' (https://www.rematec.com/news/process-and-technology/global-remanufacturing-benchmark-part-six/) accessed 18 August 2021.

Rematec, 2020b, 'Global remanufacturing benchmark - Part two' (https://www.rematec.com/news/process-and-technology/global-remanufacturing-benchmark-part-two/) accessed 18 August 2021.

Rematec, 2020c, 'Global remanufacturing benchmark: part one' (https://www.rematec.com/news/process-and-technology/global-remanufacturing-benchmark-part-one/) accessed 13 September 2021.

Rematec, 2020d, (https://www.rematec.com/news/process-and-technology/global-remanufacturing-benchmark-part-one/).

ReportLinker, 2021, 'Global Mining Remanufacturing Components Industry' (https://www.reportlinker.com/p06032238/Global-Mining-Remanufacturing-Components-Industry.html) accessed 22 August 2021.

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M. and Topi, C., 2016, 'Implementation of circular economy business

models by small and medium-sized enterprises (SMEs): Barriers and enablers', *Sustainability* 8(11), 1212 (DOI: 10.3390/su8111212).

Scribe, C., Calatayud, P., Gauche, M. and Nauroy, F., 2021, *Key indicators for monitoring the circular economy*, The Data and statistical studies department, French Minister for the Ecological Transition, Paris.

SMMT, 2021, 'Remanufacture, reuse, repeat; sustainability benefits for the CV sector' (http://www.smmt.co.uk/2021/02/remanufacture-reuse-repeat-sustainability-benefits-for-the-cv-sector/) accessed 18 August 2021.

Statista, 2020, 'Aircraft MRO market worldwide' (https://www.statista.com/study/26712/global-market-for-aircraft-mro-statista-dossier/) accessed 18 August 2021.

Statista, 2021, 'Projected global aircraft MRO market in 2021 and 2031, by segment' (https://www.statista.com/statistics/388038/global-aircraft-mro-spend-forecast/) accessed 18 August 2021.

Subramoniam, R., Sundin, E., Subramoniam, S. and Huisingh, D., 2021, 'Riding the Digital Product Life Cycle Waves towards a Circular Economy', *Sustainability* 13(16), 8960 (DOI: https://doi.org/10.3390/su13168960).

Sundin, E. and Bras, E., 2005, 'Making functional sales environmentally and economically beneficial through product remanufacturing', *Journal of Cleaner Production* 13(9), 913–925 (DOI: https://doi.org/10.1016/j.jclepro.2004.04.006).

Sundin, E. and Lee, H., 2011, 'In what way is remanufacturing good for the environment?', Proceedings of the 7th International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Kyoto, Japan, 2011.

Transparency Market Research, 2019, 'Refurbished Computer and Laptop Market' (https://www.transparencymarketresearch.com/refurbished-computers-laptops-market.html) accessed 22 August 2021.

Treat, A., Honnold, V. and Wise, T., 2012, *Remanufactured Goods: An verview of the U.S. and Global Industries, Markets, and Trade*, USITC 4356, United States, International Trade Commission, Washington DC, US.

United States International Trade Commission, 2012, *Remanufactured Goods: An Overview of the U.S. and Global Industries, Markets, and Trade*, Investigation 332–525.

Vercalsteren, A., Borms, L., Christis, M., Geerken, T., Van Pelt, A. and Sequensova, M., 2021, Monitoring CE: Expansion of the EEA indicator set - Gap analysis and exploration of additional indicators, ETC/WMGE Working Paper.

Vlaanderen, T., 2018, *Accelerating growth of the US Remanufacturing Industry: A Stakeholder Guide*.

Walsh, B., Waugh, R. and Symington, H., 2015, *Circular Economy Evidence Building Programme - Remanufacturing Study - Full report*, Oakdene Hollins.

Weiland, F. J., 2020, 'Electric vehicle challenges & opportunities for European manufacturers' (https://www.rematec.com/news/strategy-and-concept/electric-vehicle-challenges/) accessed 22 August 2021.

Appendix 1: CE Monitoring framework

Production and consumption

This area comprises four indicators:

- Self-sufficiency of raw materials for production in the EU;
- Green public procurement (as an indicator for financing aspects);
- Waste generation (as an indicator for consumption aspects);
- Food waste.

Waste management

This area comprises two indicators:

- Recycling rates (the share of waste which is recycled);
- Specific waste streams (packaging waste, biowaste, e-waste, etc.).

Secondary raw materials

This area comprises two indicators:

- Contribution of recycled materials to raw materials demand;
- Trade of recyclable raw materials between the EU Member States and with the rest of the world.

Competitiveness and innovation

This area comprises two indicators:

- Private investments, jobs and gross value added;
- Patents related to recycling and secondary raw materials as a proxy for innovation.

Source: Eurostat
https://ec.europa.eu/eurostat/web/circular-economy/indicators

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