



Circular Economy Evidence Building Programme Remanufacturing Study

Full report

March 2015



Contents

| | | |
|----------|---|-----------|
| 1 | Executive summary | 4 |
| 2 | Background, scope and prior research | 5 |
| 2.1 | Remanufacturing and the circular economy | 5 |
| 2.2 | Definition of 'remanufacturing' | 6 |
| 2.3 | Remanufacturing product characteristics | 7 |
| 2.4 | Remanufacturing company characteristics | 8 |
| 2.5 | Scope of the research | 9 |
| 3 | Findings from previous work | 11 |
| 4 | The Scottish remanufacturing industry by sector | 15 |
| 4.1 | Methodology | 15 |
| 4.2 | Sector identification | 16 |
| 4.3 | Findings by sector | 18 |
| 5 | Summary of the Scottish remanufacturing industry | 68 |
| 5.1 | Market size | 68 |
| 5.2 | Barriers and market failures | 69 |
| 5.3 | Recommendations | 72 |
| 6 | Global best practice | 78 |
| 6.1 | Select country analysis | 78 |
| 6.2 | Academic review: The future of remanufacturing | 81 |
| 6.3 | Exemplar companies | 82 |
| 7 | Future benefits on the Scottish economy | 85 |
| 7.1 | The model overview | 85 |
| 7.2 | Scenario outputs | 86 |
| 8 | Conclusions | 88 |



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1 Executive summary

Circular economy activities cover the whole length of the supply chain, starting with product design, through part and product manufacture, then product use and, lastly, activities at the end of a product's service life. In a circular economy, the maximum value from products is derived by retaining as much of the embedded material, labour, energy and capital both throughout the supply chain and at the end of each service life. Remanufacturing is a key strategy within the circular economy. Remanufacturing is formally defined as "*returning a used product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product*". It maintains the product's form and function leading to both economic and environmental benefits.

This study, for the first time, estimates that the worldwide turnover in remanufactured products is nearly \$110 billion, with the European and US industries being roughly equivalent in size. For Scotland, this study estimates the size of the remanufacturing industry to be £1.1 billion, employing some 19,000 people. Comparatively, remanufacturing is more important to the Scottish economy than it is for the UK as a whole.

The report focuses on 14 sectors. The following are large remanufacturing sectors in Scotland:

Aerospace (maintenance, repair and overhaul - MRO): The industry has a centre of excellence developed around Prestwick and is a key sector; not only due to its current dominance of Scottish remanufacturing, but also because of predictions of healthy growth in the MRO sector.

Automotive: Globally, remanufacturing of automotive components is well-established, and this is no different in Scotland. There is significant growth potential in the automotive market, particularly with respect to interventions from public procurement.

Energy: There is already quite a strong remanufacturing and refurbishment base for the oil and gas and renewable energy sector in Scotland. The decommissioning of North Sea oil platforms provides a great opportunity to increase the amount of remanufacturing undertaken in this sector.

Rail: The UK has a stable demand for regular maintenance of its 12,000 strong rail vehicle fleet and related infrastructure. Scotland is well placed to compete with the rest of the UK for work overhauling rolling stock.

The following two sectors, although currently small, have been highlighted to see significant growth over the next five years:

ICT and mobile electronics: These products are particularly suitable candidates for refurbishment activities largely due to the high value and complexity of items at the end of their first life.

Medical equipment: Previous research has highlighted that medical imaging is an active area of remanufacturing. The largest Scottish market, NHS Scotland, does not currently buy refurbished medical equipment, and this represents a significant opportunity for the sector.

A series of recommendations have been made to encourage growth. These include:

- incentivising core return rates
- increasing access to spares
- sharing best practice
- developing teaching
- developing public procurement practices

Based on the level of intervention by Scottish government - in collaboration with its delivery agencies, other nations' governments and the industry itself - remanufacturing could add another £620 million each year to the Scottish economy by 2020. A full cost benefit analysis would be necessary to fully validate these findings.

This document provides in-depth analysis and background. A summary document is also available that provides the key findings from this document.

2 Background, scope and prior research

2.1 Remanufacturing and the circular economy

Circular economy activities cover the whole length of the supply chain, starting with product design, through part and product manufacture, then product use and, lastly, activities at the end of a product's service life. In a circular economy, the maximum value from product is derived by retaining as much of the embedded material, labour, energy and capital both throughout the supply chain and at the end of each service life. Figure 1 shows the key return flows that characterise a circular economy and reduce the leakage of embedded material, labour, energy and capital to outside the system. The circular economy activities are broadly grouped into four categories:

- **Extension** – Extending the initial and/or subsequent service life of a product will increase the value that can be derived from the product's embedded content.
- **Circularity** – Collecting and diverting products, parts and materials from leaving the product system increases the retained value. The tighter the circle, i.e. the closer the form of the original and retained product, the more value that is retained.
- **Reduction** – Reducing resource inputs either through waste reduction or greater efficiency increases the value derived per unit of resource input.
- **Utilisation** – Increasing the utilisation of a product can reduce the demand for physical products and lead to reduced resource consumption.

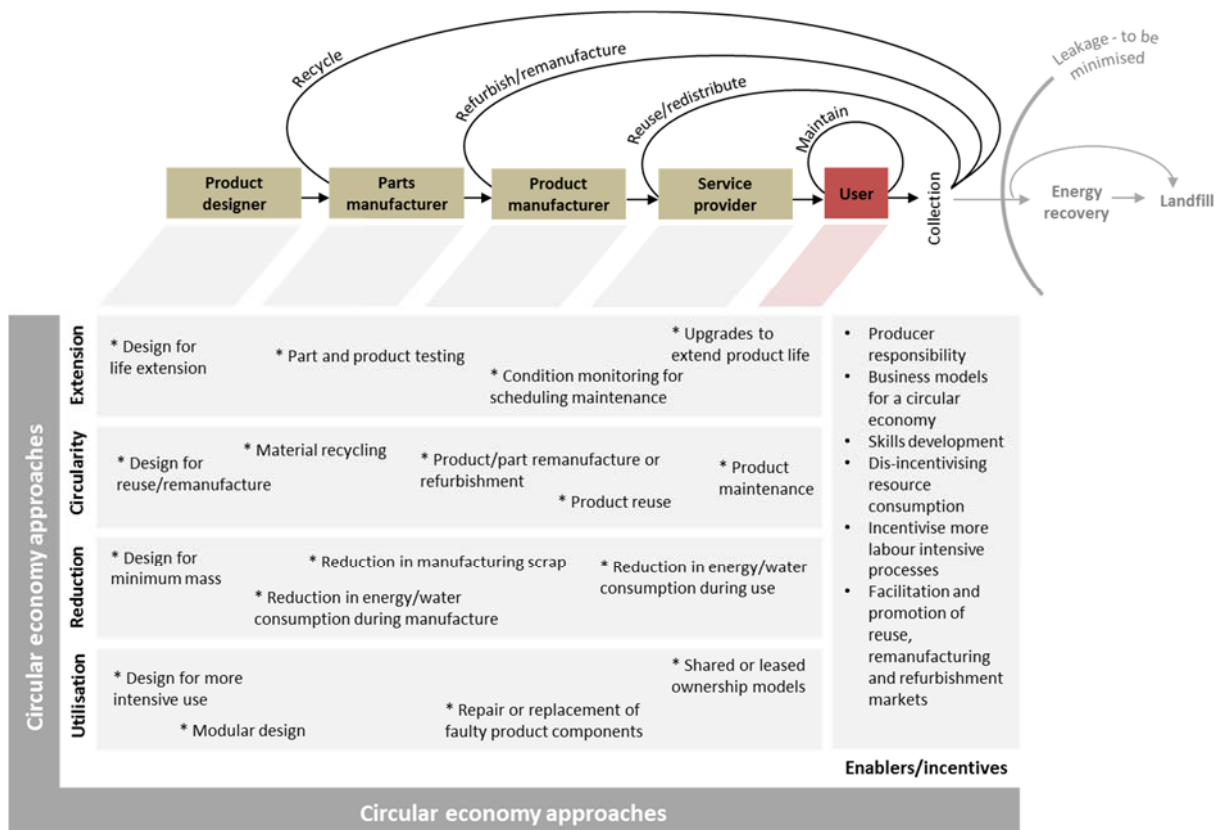


Figure 1 A description of the circular economy

Remanufacturing is a key strategy within the circular economy. It is typically applied to complex manufactured products that possess significant embedded material, energy and labour resources, most of the value of which can be recovered by suitable remediation techniques. From the perspective

of the purchaser or user, the product behaves like new and is backed up by an appropriate warranty from the seller or remanufacturer.

Often, remanufacturers take the opportunity to upgrade the products from old to current performance standards of energy efficiency or productivity. This is one way that they can be differentiated from simple repair items and other end-of-life treatments.

2.2 Definition of 'remanufacturing'

Unlike 'recycling', 'remanufacturing' does not have a universally accepted or recognised definition. This is partly due to its use across a wide number of sectors, where alternative phrases are used that could be interpreted as remanufacturing. Another reason is that there is little European or nationally defined legislation targeting remanufacturing. There have, however, been several attempts to standardise the definition. Probably most relevant to Scottish remanufacturing is the BSI Standard BS 8887-2:2009 that defines a range of end-of-life options for products including remanufacturing. Within this document, remanufacturing is defined as to:

Return a used product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product.

NOTE 1 From a customer viewpoint, the remanufactured product can be considered to be the same as the new product.

NOTE 2 With respect to remanufacture:

— *manufacturing effort involves dismantling the product, the restoration and replacement of components and testing of the individual parts and whole product to ensure that it is within its original design specifications;*

— *performance after remanufacture is expected to be at least to the original performance specification; and*

— *any subsequent warranty is generally at least equal to that of new product.*

NOTE 3 This assumes that remanufacture applies to like-for-like products.

BS 8887-2:2009 also defines refurbishment, reconditioning, repurposing and repair. It was also recently cited by a Chinese proposal for an international ISO standard on remanufacturing.

A similar definition is promoted by the European automotive component trade body, CLEPA:

A remanufactured part fulfils an equivalent or better function as the original part. It is restored from an existing part (core), using standardized industrial processes in line with specific technical specifications. A remanufactured part is given the same warranty as a new part and, it clearly identifies the part as a remanufactured part and the remanufacturer.

This is also endorsed by the European automotive manufacturers association, ACEA, the automotive parts remanufacturing association, APRA, and the European engine rebuilders association, FIRM.

The US International Trade Commission defined remanufacturing as:

An industrial process that restores end-of-life goods to original working condition or better

PAS 3100, a new standard developed in the UK by BSI for an automotive part remanufacturer, defines remanufacturing as:

... part that has been restored to original functionality in terms of fit, form, materials and performance through the application of a sequence of pre-identified process stages to components and assemblies

There are several other international standards that define and reference remanufacturing; these include those provided by the Chinese Standards Office and the Korea Institute of Industrial Technology. Unfortunately, English translations of these documents were unavailable.

2.2.1 Commonalities

All the cited remanufacturing definitions refer to a used component and that the processes should restore the product to the functionality of a new product. There is some division over the use of a warranty. This requirement largely ensures that the product performs the same as a new product and, in effect, reinforces the 'as good as new' definition described by all sources. Some third party remanufacturers do show concern over the requirement for a full warranty because of their limitations in offering a comprehensive warranty. However, the requirement for a warranty should help reduce the risk to procurers and help legitimise the industry. With this in mind, the current BS 8887-2:2009 definition of remanufacturing will be used:

Return a used product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product.

2.3 Remanufacturing product characteristics

It is important to note that remanufacturing is only applicable to a set of products with a key set of characteristics. As a result, only certain product groups are suitable for remanufacturing. Furthermore, certain makes or models of products are suitable for remanufacturing within specific product groups. These characteristics were discussed at length by Parker in 2004¹ and are summarised below.

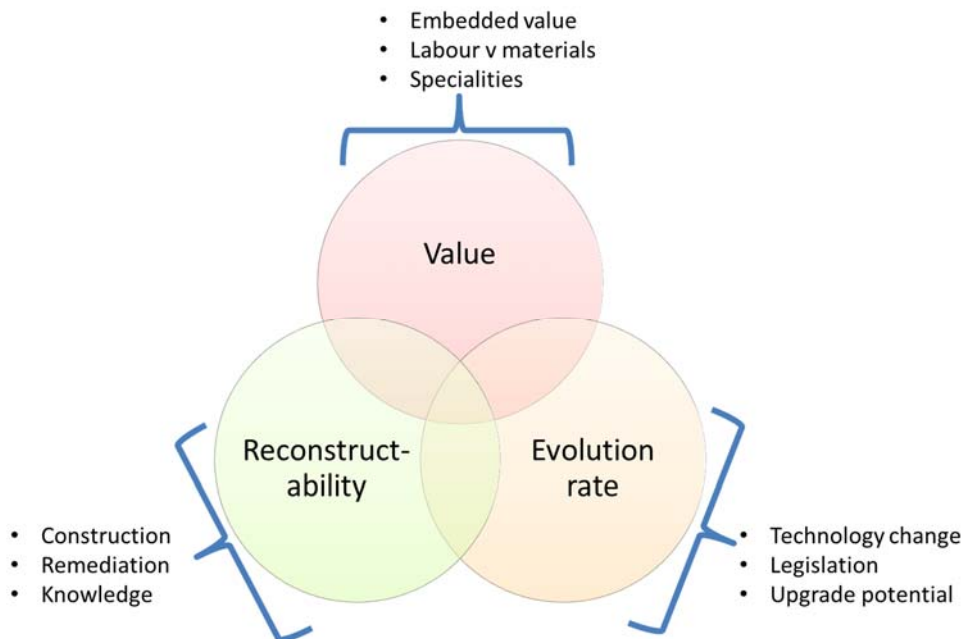


Figure 2 Feasible operating space for remanufacturers

Figure 2 is a simple graphical representation of product characteristics that can determine the remanufacturability of a product. The three areas are described in detail below:

Value implies that more expensive items will naturally lend themselves to remanufacture because of the invested time and resource to achieve a like-new performance. However, this must be moderated by consideration of other factors:

¹ Resource Recovery Forum, Remanufacturing in the UK: a significant contributor to sustainable development? 2004

8 |Circular Economy Evidence Building Programme

- Equipment may be expensive, yet capital expenditure may be low relative to the cost in use.
- The customer may not value durability where this is beyond his planning horizon (such as is the case with many engineering machines and electromechanical systems).
- The balance of labour and materials content prevailing: from a remanufacturer's perspective very high labour costs will negate effects of reclaiming materials.
- Customer perception can override utility value, particularly for consumer and personal goods. There is a strong association of status and self-worth associated with many items: cars, furniture and furnishings, apparel, white and brown goods may be capable of remanufacture to a greater or lesser extent. Issues of branding, trust, liability and warranty prevent this.
- Changes to threats in the business environment can motivate change in perceived intrinsic value. For example, a shortage of a raw material (temporary or permanent), or a penalty on end-of-life disposal could cause a shift to maintaining or increasing the value of a product, biasing towards its recovery or re-use.

Re-constructability: Products which are more easily disassembled and reconstructed are more suited to remanufacture. Again this is a bundle of characteristics that may prevent or assist the physical remanufacturing task:

- Access to used goods. Some industries, because of the setup of the official channels to customers, find it very difficult to source these raw materials. At other times, used goods are widely distributed and users do not appreciate the return value.
- The majority of remanufacturing operations are unlike the initial manufacturing processes. The major difference is in the variability of the raw materials, whilst still being subject to the quality constraint on the finished product. Personnel employed in these operations require both an orientation to hands-on engineering skills, and a facility in problem solving. Remanufacturers report that, within mixed primary and remanufacturing organisations, remanufacturing jobs are seen as more rewarding than straight production.
- The item must be capable of disassembly, diagnosis and reassembly in a reasonable time and whilst maintaining the integrity of the piece. Products that have been re-engineered by designers and users for maintenance, re-use of components and upgrade capability are inherently easier to remanufacture than products that use permanent fixings and are difficult to disassemble.
- Knowledge of product design specification is essential. Without such knowledge, critical engineering components built to incorrect tolerances can fail prematurely. Truly independent remanufacturers have commonly built reverse engineering teams to infer design specifications.

Evolution Rate: Primarily this relates to the change in functionality or capability of goods, features, size, weight, power, economy, emissions and longevity.

- Products subject to very high evolution rates are not suitable for remanufacture because they will generally be obsolete by the end of their first life and not wanted by a customer.
- High evolution systems can justify remanufacture at high value because they are composed of subsystems that can be individually reconstructed and/or upgraded.
- Sectors of zero or very low technological change can also be unattractive. Generally, the products have achieved maturity, and manufacturing costs have been minimised. Products can be long-lived, meaning that refurbishments are few and far between.

2.4 Remanufacturing company characteristics

There are three broad categories of remanufacturers:

- **Original Equipment Manufacturers (OEMs):** Involved in the design, manufacture, sale and remanufacture of a product. They usually have access to all the technical drawings and have the ability to include design upgrades to encourage remanufacturing. In international companies, corporate strategy may be dictated at a remote head-office limiting the ability of the local remanufacture to dictate how it commercially operates. This is common in aerospace and heavy off-road equipment sectors.
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- **Contracted remanufacturers:** Perform remanufacturing on behalf of an OEM. They will usually have access to most of the technical specifications of the product but usually have limited access to designers and have some restrictions on how they operate commercially. They specialise in remanufacturing and offer the service where OEMs see a need but do not want to be distracted from their core business. This is common in the automotive sector.
- **Independent remanufacturers:** Usually directly compete with OEMs with their product. They usually have little formal relationship with the OEMs and have garnered technical information through reverse engineering and understanding of the product. They are usually owner-managed SMEs with total freedom to operate commercially. This is common for ICT equipment and printer cartridges.

2.5 Scope of the research

This research aims primarily to map the size of the remanufacturing industry in Scotland across key sectors. It is important to recognise that different terminology has built up in different industries that could be considered remanufacturing. For example, aerospace and marine use 'overhaul' and 'refit' to indicate remanufacturing activities. In fact, due to the tight regulatory and safety framework surrounding this industry, the term 'remanufacturing' is not used at all. Similarly, medical imaging equipment refers to remanufactured product as 'refurbished'. Added to these clear-cut examples where remanufacturing has a different terminology, less formal use of 'refurbishment' and 'reconditioning' make identification of the appropriate business activities difficult. This is particularly acute in small businesses where the term refurbishment and reconditioning are more prevalent.

There are also many instances of different 'grades' or 'levels' of work being labelled under the same terminology such as refurbishment and reconditioning. As a result, there is a wide spectrum of manufacturing processes on end-of-life products, from very high specification work (particularly in the aerospace industry) through to more remedial activities where safety or quality are less vital.

This ambiguity over terminology means that a strict filter for the term 'remanufacturing' would miss large parts of the circular economy where remanufacturing - or similar - are taking place. Furthermore, in certain industries, such as in ICT, true 'remanufacturing' is probably technically unachievable and therefore a more appropriate examination of less rigorous refurbishment or reconditioning practices will capture a more representative portion of the market. Also, there are cases where it is uneconomic or unnecessary to complete full remanufacturing. These activities are, however, important from a circular economic perspective.

With this in mind, this report will capture a variety of end-of-life practices that extend the life of a product. This will include both refurbishment and reconditioning, as well as overhaul and refit. The project will not focus on straight re-use (where no manufacturing effort has been applied to improve the performance of the product) or repair (where a specific and defined fault is fixed) activities.

As with remanufacturing, this report will use the term 'refurbishment' and 'reconditioning' as defined within BS 8887-2. This standard does not differentiate between these two terms but considers them to:

Return a used product to a satisfactory working condition by rebuilding or repairing major components that are close to failure, even where there are no reported or apparent faults in those components

NOTE:

— *manufacturing effort involves the replacement of worn or broken parts, generally less extensive than required to remanufacture, but more than necessary for repair;*

— *performance after reconditioning is expected to perform its intended role but the overall performance is likely to be inferior to that of the original model; and*

— any subsequent warranty is generally less than new or a remanufactured product but the warranty is likely to cover the whole product (unlike repair); reconditioned products do not require a warranty equivalent to that of a newly manufactured equivalent.

3 Findings from previous work

The following sections summarise a literature review of readily available reports identified and further described in Annex 1. This analysis was used to shape the investigation at the sector level. A detailed list of recommendations for Scottish policy makers can be found in Section 5.3.

3.1.1 Drivers and opportunities

The following major drivers and opportunities that encourage remanufacturing were identified:

- **Economic:** Remanufacturers benefit from the greater profit margins associated with service-based, rather than 'make and sell' businesses, for example product service systems promote remanufacturing rather than replacement.
- **Cost savings:** Remanufactured product is usually lower cost than new products. The cost differential varies from sector-to-sector and also within product lines but, usually, a remanufactured product demands between 50 % and 90 % of the cost of a new product.
- **Access to used product:** Many remanufacturing businesses are supply-constrained, and increasing collection rates will enable growth.
- **Reduced lead times:** Remanufactured products can have a reduced lead times, minimising disruption due to failure of key systems.
- **Alternative businesses models:** These include rental- and service-based offerings which tend to lead to better relationships with customers and a more skilled and adaptable workforce. This can also lead to a reconfiguration of the supply chain to service the new business model.
- **A reduced risk of resource insecurity:** By keeping products 'whole', remanufacturing reduces risks associated with long supply chains.
- **Environmental legislation:** The End-of-life Vehicle Directive poses a problem for recycling but could become an opportunity for remanufacturers when, after 2015, 95 % of a vehicle's material must be recovered.

3.1.2 Barriers

Barriers slowing the uptake of remanufactured products can be separated into those affecting remanufacturers and those affecting consumers/procurers.

Those affecting remanufacturers include:

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

The following are barriers for consumers/procurers:

- **Perception of remanufactured products:** 'Remanufactured' is sometimes considered to be synonymous with 'inferior quality', limiting the appeal of the industry. Low awareness among purchasers is also a major issue.
- **Technology shifts:** Obsolescence of old equipment is a major barrier to remanufacturing in terms of both performance and function, making remanufactured equipment less desirable.
- **Poor understanding by the business community:** Remanufacturing may involve a change of culture and/or business model. This requires buy-in from senior managers who will be enacting change throughout the business.

3.1.3 Approaches to encourage remanufacturing

The following action-orientated interventions were identified as common suggestions from our literature review detailed in Annex 1 and 2. These provide a useful indication of the barriers and enablers to support remanufacturing, prior to the detailed review of Scottish specific circumstances (note that Section 5.3 identifies interventions that are relevant to Scotland):

- **Extending government grants for energy efficiency:** Many government subsidies to improve energy efficiency target new products only, creating a disadvantage for remanufactured products.
 - **Developing an energy rating system** to remove ambiguity over whether a remanufactured product is as environmentally beneficial as a new product.
 - **Develop public purchasing policies and Green Procurement:** Create and develop a sustainable market for remanufactured products through large public sector purchasing. Procurement could also be used to ensure that products can be remanufactured at the end of life, ensuring that they are designed for disassembly and re-use.
 - **Awareness raising:** There are many barriers associated with a lack of understanding of the processes and quality of remanufacturing (or even its existence). Raising awareness would help address this issue.
 - **Develop remanufacturing skills:** There is a need for product designers, engineers and business leaders to be trained in understanding the value of remanufacturing.
 - **Promote design for disassembly:** This could be achieved both through procurement specifications and through direct company and design-house engagement.
 - **Development of take-back schemes:** One of the key barriers for remanufacturers is the lack of access to used products. Take-back schemes could be set at a legislative level or through engagement with end-users in cooperation with remanufacturers.
 - **Remanufacturing standards:** Particularly for public procurement, having a defined set of standards or a certification system will remove purchasing risk and encourage the development of a high-quality remanufacturing industry.
 - **Remove ambiguity over the definition of waste in the context of products which are destined for remanufacturing:** Ambiguity can present barriers and risks to businesses undertaking remanufacturing. Also, where regulatory burden is necessary, it should be minimised to encourage remanufacturing.
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- **Develop a Centre of Excellence for Remanufacturing:** There is currently no single body which offers remanufacturers business, design and technological support. Developing a centre based on current facilities would be relatively low-cost and provide a single point of contact for remanufacturers. (During the finalisation of this report, the Scottish Institute of Remanufacture was launched, which addresses this proposed intervention.)
- **Implement selective landfill bans of products:** This will increase recycling but will also encourage industry to consider remanufacturing and re-use, for example in the automotive industry.
- **Differential VAT rates and tax allowances for businesses involved in remanufacturing:** This could be a clear policy lever to encourage more remanufacturing.
- **Begin international dialogue to tackle non-tariff trade barriers in remanufactured goods and used product:** This could allow access to international markets and also increase the supply of product for remanufacturing domestically.

3.1.4 International and European market size

There are no official trade data on the size of remanufacturing nationally or internationally. There are, however, two reports that detail remanufacturing on a national level that will be used to scale for Europe and the rest of the world. The UK report: *Remanufacturing in the UK, A snapshot of the remanufacturing industry in the UK* by the CRR in 2009 and the *United States International Trade Commission's: Remanufactured Goods, An Overview of the U.S. and Global Industries, Markets, and Trade* in 2012 use similar methodologies to understand the size of their respective remanufacturing markets. This involved market segmentation and then engagement with stakeholders to understand the remanufacturing landscape. Based on these observations from market practitioners and other sources, the market size is determined. (This methodology is similar to that employed within this project and is described in more detail in Section 4.1).

Crucial to this process is how the remanufacturing landscape is divided. Further discussion on the segmentation of the remanufacturing market in Scotland can be found in Section 4.2. However, the segmentation used between the US and UK study were different, but it was possible to re-analyse the UK data to closely match the US findings, providing a good basis for comparison.

European data were extrapolated from the UK data using GDP as a scaling factor (GDP for the EU is seven times that of the UK). Rest of World data were estimated based on comments in the US report which claimed that the 'bulk' of remanufacturing activity was contained within the USA and EU. It was estimated that the rest of the world made up 20 % of the combined EU/US remanufacturing output. These findings are summarised in Table 1.

Using this analysis, aerospace is by far the largest sector in terms of remanufacturing. Also, the USA is the largest single remanufacturing economy but the EU's industry is of a comparable size. The analysis estimates that the global remanufacturing sector is worth \$110bn. This compares well to the only other estimate available. A contribution to the Ellen MacArthur CE100 remanufacturing group estimated the global remanufacturing economy to be approximately \$150bn. Taking this into account, and the fact that the studies used in our analysis are conservative, the global remanufacturing market is likely to range between \$100bn and \$200bn.

| Sector | US ¹ | EU ² | ROW ³ | UK ⁴ | Total |
|-----------------------------|-----------------|-----------------|------------------|-----------------|----------------|
| Aerospace | 13,000 | 22,000 | 7,000 | 3,200 | 42,000 |
| HDOR Equipment ⁶ | 7,800 | 5,500 | 2,700 | 790 | 16,000 |
| Motor vehicle parts | 6,200 | 4,500 | 2,100 | 650 | 13,000 |
| Machinery | 5,800 | 780 | 1,300 | 110 | 7,900 |
| IT products ⁵ | 2,700 | 6,900 | 1,900 | 1,000 | 12,000 |
| Medical devices | 1,500 | 760 | 450 | 110 | 2,700 |
| Re-treaded tyres | 1,400 | 440 | 360 | 64 | 2,200 |
| Other ⁷ | 4,600 | 6,700 | 2,300 | 960 | 14,000 |
| Total | 43,000 | 48,000 | 18,000 | 6,900 | 110,000 |

Table 1 Worldwide remanufacturing activity (Turnover, millions US\$) (2 significant figures)

1 based on United States International Trade Commission Investigation No. 332-525 USITC Publication 4356 October 2012
Remanufactured Goods: An Overview of the U.S. and Global Industries, Markets, and Trade

2 Scaled using GDP ratios between the UK and EU27

3 Calculated as 20 % of the sum of EU and US remanufacturing activity

4 Modified data set from Remanufacturing in the UK: A snapshot of the remanufacturing industry in the UK in 2009, CRR.

5 including printer cartridges

6 Heavy-Duty Off-Road including construction, lifting and earth moving equipment

7 Includes catering, office equipment, pumps and compressors, rail, textiles and white goods.

4 The Scottish remanufacturing industry by sector

4.1 Methodology

A priority list of sectors and products was developed for study. For each sector, a list of contacts was identified through Zero Waste Scotland, Scottish Enterprise, Oakdene Hollins and its subcontractors and internet/web searching. A series of directed conversations were then held to gain comment, opinion and fact on the size of the sectoral remanufacturing industry along with barriers and potential mitigations to encourage remanufacturing.

Analysis of the information collected from interviews and secondary literature sources provided the following outputs:

- **Scale estimates:** the total value in terms of resource savings, sales (turnover) and employment. This was performed by scaling the sample of companies to represent the entire market identified and complemented by existing research reports. Where both remanufacturing and manufacturing occurred within organisations, the scale estimates attempted to disaggregate the remanufacturing activity from the other business activities. It should be noted that the original intent of the report was to examine GVA, however, this information proved difficult to collate and so overall turnover was used as a proxy.
- **Barriers and market failures identification:** These focused on the (potentially negative) impact of the business model in use, design of the product and position in the supply chain, existence of standards, internal influence within the company of Scottish operations (for multinationals).
- **Incentive and opportunity identification:** At both sector level and cross sectoral, key themes were identified and developed into opportunities and interventions that could be taken by the Scottish Government.
- **Growth potential:** An estimate was made of the potential growth in each sector. This was based on the assumption that there would be a level of intervention (locally, nationally and where appropriate at an EU/international level). It was based on a variety of factors including: additional opportunity for remanufacturing to occur (could more remanufacturing be absorbed in the market), current installed manufacturing or remanufacturing base in Scotland (could additional remanufacturing work be committed in Scotland) and competition with imported remanufactured products (is the Scottish economy competitive). The growth potential was set into three bands (low, medium and high) to reflect the uncertainties within the analysis.

Finally, a series of policy recommendations were made along with some analysis indicating the benefit to Scotland. The report was overseen by a steering committee from Zero Waste Scotland, Scottish Enterprise, SEPA and the Scottish Government.

4.1.1 A note on methodology imitations

Oakdene Hollins described in their UK surveys in 2005 and 2009 that remanufacturing is a largely hidden industry. As such, there are no UK wide or Scottish statistics on the size and complexity of the market. There are few comprehensive UK and no Scottish specific databases on companies that are engaged in remanufacturing. Identification of companies and gathering information on remanufacturing activity must occur from first principles. This involves surveying active practitioners and combining this with identifying companies through web searches. This information can then be used to provide estimate on the overall market size.

Clearly with such a paucity of data, any calculation of total market size brings risks of over-simplification of the market and large errors. This report recognises these shortcomings and addresses against such criticism through provision of all the assumptions used to determine figures. It is likely though that any estimation will underestimate the extent of remanufacturing activity because some organisations will not recognise their activities as such, making identification difficult. Even with these limitations, this is the most comprehensive survey of remanufacturing activities of a nation the

size and structure of Scotland and is an important first step towards encouraging remanufacturing uptake.

4.2 Sector identification

Remanufacturing cuts-across many manufacturing sectors. A comprehensive survey of the remanufacturing landscape could be conducted at the Standard Industry Classification level. The 2004 survey used this approach.¹ However, experience has shown that SIC codes alone are a poor method for providing meaningful division of the industry into relevant sectors. Remanufacturing occurs at the product level, and a 'bottom' up approach looking at product would be more appropriate. Unfortunately there are no appropriately detail lists of products from which an investigation into remanufacturing could be performed. Instead, a hybrid system was employed for the 2009 CRR survey and the 2012 USITC survey. This technique used industry classification as the starting point but also recognised that certain product groups (that would not necessarily categorise easily within SIC were also important. For example, SIC code 26200 includes printer cartridge remanufacturing and printer manufacturing. These two products both undergo remanufacturing but by different industry sectors, with different profiles and would be better treated separately.

This study used the following criteria to develop an accurate list of sectors of the remanufacturing and re-use industry:

- Prior indication of high remanufacturing value from previous CRR work.
- Sectors identified in the 2004 survey as having potential for remanufacturing and re-use.¹
- Sectors which did not fall into the previous two categories, but were identified as having high value in the ONS data and believed to be amenable to remanufacture.
- Other sectors identified through a wider literature review performed in Section 3.

This led to the development of a 'long list' of sectors where remanufacturing activity is known to occur. These sectors were then 'graded' to allow research to focus on areas that were likely to have the largest significance to the Scottish economy. The grading process was a mixture of analysis of reports from each of the previous sectors (for different geographic coverage) combined with knowledge of the make-up of the Scottish economy. Table 2 shows a summary of this analysis.

| Product group | Comment |
|-----------------------------|---|
| Aerospace | Significant activity. One of the largest sectors in the UK. Less focus because intervention is currently being undertaken through different support mechanisms. |
| ATM | Well defined and does occur but is difficult to judge due to security |
| Automotive | Significant activity in the area |
| Boilers | Low level activity, may also be environmentally less favourable |
| Carpet tiles | Niche, mainly re-use, little evidence that there is any activity in Scotland. |
| Catering and food industry | Mainly re-use but may be important with whisky production |
| Pumps, fans and compressors | Useful in the context of air conditioning |

| Product group | Comment |
|--|--|
| Construction | Quite niche mainly repair |
| Defence | Significant activity. Scope for expansion or intervention is limited due to being embedded in all current national procurement strategies. |
| Electronics, ICT and business machines | Significant sector |
| Energy | Focus on non-renewables (oil and gas), transmission, wind, PV and wave/tidal |
| Furniture/office furniture | Mainly re-use, small scale remanufacture |
| Games consoles | Niche. |
| Ink and toner cartridges | Significant sector |
| Lifting and handling equipment | Niche |
| Machine tools | Was significant, however the importance has reduced following de-industrialisation. |
| Marine industry | Significant sector |
| Medical equipment | Significant globally, unknown in Scotland |
| Off-road equipment | England base for this activity, unlikely to be significant in Scotland |
| Printing presses | The sector was in decline due to change in technology, unlikely to be significant. |
| Rail industry | Significant sector in the UK, research needed for Scottish contribution |
| Refrigerated display cabinets | Present in England, unknown Scottish activity |
| Textiles | Significant sector, falls outside scope because not technically remanufacture or refurbishment |
| Tyre re-treading | Significant sector |
| Vacuum pumps | Significant worldwide activity, unknown in Scotland |
| Vending machines | Significant activity |

| Product group | Comment |
|---------------|----------------------|
| White goods | Significant activity |

Table 2 Product group sectors

What is clear from these sectors is the disparity between their sizes and make up: the aerospace sector is clearly larger and more complex than the furniture industry. An analysis of how to appropriately group these product groups is discussed in Section 5.1.

4.3 Findings by sector

The section has been ordered to reflect the largest potential gain to the Scottish economy.

4.3.1 Aerospace

4.3.1.1 Introduction

The 2004 and 2009 surveys of remanufacturing in the UK identified aerospace as the largest single remanufacturing sector.^{2,3} However, the word 'remanufacture' is not commonly used in the aerospace industry: most companies use 'overhaul and component repair' to describe the element of their maintenance, repair and overhaul (MRO) activities that falls within the scope of this project. Refurbishment also has particular connotations in the aerospace industry: aircraft cabins are regularly stripped and the interior trim and seats remanufactured as part of a 'cabin refresh'. In the industry, 'remanufacture' more often refers to the process of repairing a faulty component that has not yet been used, i.e. to correct errors in production.

Aircraft such as helicopters and planes consist of a number of distinct components and systems:

| Aircraft component/system | Description |
|---------------------------|---|
| Airframe | The main aircraft structure, which includes the wings, tail section, cabin and fuel tanks. Traditionally made out of aluminium due to its high strength to weight ratio, but an increasing proportion of the airframe is now being made out of carbon fibre composites. |
| Engine | The most expensive component of an aircraft due to its high capital and servicing costs. Gas turbines are the predominant engine type in use and can consist of either jet engine or turboprop technology. Piston engines are a less common engine type, used in small hobby and commuter aircraft. |
| Avionics | Electro-mechanical systems used to provide information to the flight crew and to control the aircraft. These systems include: communication, navigation, flight-control, collision-avoidance and weather-monitoring. The complexity of avionic systems has increased over the years, with modern systems allowing 'fly-by-wire' capability. |
| Hydraulics | Used in a number of aircraft systems, e.g. flap actuators, landing gear and cargo doors. |
| Interior | Includes the seats, cosmetic trim, luggage storage, galley equipment (e.g. food preparation and storage equipment), toilets, medical and safety equipment. |

Table 3 Aircraft components and systems²

² Centre for Remanufacturing and Re-use, 2009, Remanufacturing in the UK: a snapshot of the UK remanufacturing industry

³ Resource Recovery Forum, Remanufacturing in the UK: a significant contributor to sustainable development? 2004

The aerospace industry is a suitable candidate for remanufacturing for the following reasons:⁴

- **Technology evolution rate:** Although aircraft technology does continually evolve - for example in the use of new materials - long technology development times and slow technology uptake (due to the high costs of replacing stock) means that older aircraft with older technology will continue to remain in use for many years. Additionally, the modular nature of aircraft technology allows engine technology and avionics to be updated while preserving the main body of the airframe.
- **Reconstructability:** Because of the high capital costs of aircraft, products are designed for service and repair. This involves designing for ease of inspection and component removal and replacement, and results in highly modular systems. Parts that take a long time to remanufacture may be remanufactured to stock. When an aircraft requires one of these remanufactured components, the existing part is removed as core to be remanufactured at a later time, and a remanufactured component from stock is installed into the aircraft to minimise downtime.
- **Stringent certification and regulation:** The high manufacturing quality required of new and remanufactured aerospace parts and components requires suppliers to adhere to strict certification and test regulations. This presents a barrier to entry for low cost competitors. The historically high cost of parts and components, predicted only to increase with rising energy and material prices, has meant that remanufacturing practices have been well-established in the industry and will likely remain so in the future. Part of the industry regulation centres around component traceability, with systems in place to allow the lifetime of individual components to be documented, giving remanufacturers and customers confidence in the performance of remanufactured components.
- **The suitability of the service model:** The aerospace industry lends itself well to a service-based model, due to the high capital costs of equipment and the clear, measurable service delivered by the product (i.e. time/distance in flight). The transition to a service-based model – for example Rolls-Royce’s ‘power by the hour’ – allows remanufacturers to maintain close links to both the customer and the core.

MRO activities in Scotland are well-established and are considered to be a significant opportunity for growth within Scotland’s aerospace sector.⁵ The industry has a centre of excellence developed around Prestwick, and the ‘aerospace corridor’ between Glasgow and Prestwick includes MRO organisations such as British Airways Maintenance Glasgow, Rolls-Royce in East Kilbride (to be moved to Inchinnan next year) and Spirit Aerosystems in Prestwick.⁵ A list of some of the MRO organisations active in Scotland can be found in Table 4.

| Company name | | | | |
|---------------------------------|--|--------------------------------|------------------------------------|------------------------------|
| A&I Accessory Ltd | ACS Engineering Ltd | Aeropair Ltd | Aerospace Machining Technology Ltd | Aerospace Tooling Ltd |
| Air Service Training Ltd | Aircraft Engineers Ltd | Airframe Components Europe Ltd | Astec UK Ltd | AvilT Ltd |
| Avotek Ltd | BAE Systems Regional Aircraft | BMI Regional Ltd | Bradchem Ltd | Bristow Helicopters Ltd |
| British Airways Maintenance Ltd | Castle Precision Engineering (Glasgow) Ltd | Chromalloy Ltd | Copernicus Technology Ltd | Data Systems & Solutions Ltd |

⁴ Based on Centre for Remanufacturing and Re-use, 2009, Remanufacturing in the UK: a snapshot of the UK remanufacturing industry

⁵ Scottish Development International, Aerospace and defence opportunities in Scotland, 2010 [Link](#) Accessed 25 September, 2014

| Company name | | | | |
|---------------------------------------|---|---|---|------------------------------|
| East Kilbride Engineering Ltd (EKES) | FineUnit | First People Aviation Ltd | Gael Quality Ltd | GE Caledonian Ltd |
| Goodrich Prestwick Service Centre Ltd | Inter-Tec Services Ltd | Jet2 Aviation Ltd | Kimetsan Aerospace & Defence Coatings Ltd | Loganair Ltd |
| Martin Aerospace Ltd | MB Aerospace Ltd | Missiles & Space Batteries Ltd | Ocean Sky Ltd | RD Taylor & Co Ltd |
| Rolls Royce plc | Ryanair/PMAL (Prestwick Aircraft Maintenance Ltd) | Scot Avionics Ltd | Spirit AeroSystems Ltd | Teledyne Ltd |
| Trig Avionics | Turner Access Ltd | Turner Aviation Ltd | Vector Aerospace Component Services Ltd | Vector Aircraft Services Ltd |
| William Lees & Sons Ltd | WL Gore & Associates (UK) Ltd | Wood Group Accessories & Components Ltd | Woodward Aircraft Engine Systems Ltd | |

Table 4 Companies active in the MRO supply chain in Scotland⁶

4.3.1.2 Market size

| Employment | Turnover | % of aerospace sector | Environmental benefits | Growth potential to 2020 |
|---------------|---------------------|-----------------------|--|--------------------------|
| 3,400 persons | £ 440-£ 670 million | 66 % | 11,000 – 16,750 tonnes CO ₂ e avoided | Medium |

Table 5 Market size of aerospace remanufacturing activities

Assumptions:

- The Scottish aerospace sector is reported to employ 5,100 people⁷ in over 160 companies and generate sales of approximately £1.6 billion per year.⁸ In 2006, civil MRO activities in Scotland were reported to account for 66 % of aerospace sales⁵, suggesting a turnover of approximately £1 billion more recently.
- A top-down estimate can also be made based on the global commercial aircraft MRO market, which in 2013 was estimated to be US\$59.2 billion (£37.9 billion⁹).¹⁰ Scotland's share of the global MRO market was estimated in 2006 to be around 4 %⁵, which corresponds to an approximate market size of £1.5 billion now.

⁶ Scottish Development International, MRO in Scotland – It could be your greatest discovery, 2011 [Link](#) Accessed 14 November, 2014

⁷ Scottish Annual Business Statistics, 2012, Scottish Government.

⁸ UK Government, Lifting off – Implementing a strategic vision for UK Aerospace, 2014 [Link](#) Accessed 25 September, 2014

⁹ Using an average exchange rate of \$1 to £0.63953 for 2013 from [Link](#) Accessed 25 September, 2014

¹⁰ Aerospace & Defence Aeroweb, Commercial Aircraft MRO: Total market size and growth, market by region, and market by type of MRO, 2014 [Link](#) Accessed 25 September, 2014

- True remanufacturing will make up a sub-set of MRO activity, which also includes repair. Assuming that £2 billion² of the £4.5 billion² spent on MRO in the UK can be attributed to remanufacturing and refurbishment, this equates to a Scottish market size of £440-£670 million.
- Assuming that the share of MRO employment is the same as the share of MRO activities in aerospace sale¹¹ (66 %⁵), this equates to direct employment of approximately 3,400 employees.
- We assume that the environmental benefits of aerospace remanufacturing activities can be estimated by scaling from the UK 2004 survey, which reported that 50,000 tCO₂e were avoided through re-use activities with a value of £2 billion in the aerospace sector.³ Scaling this to the Scottish remanufacturing aerospace market with a value of £440 - £670 million suggests remanufacturing activities avoid 11,000 – 16,750 tCO₂e.
- The growth rate of the MRO sector has been estimated at 3.7 % compound annual growth rate, which is in line with the general growth of the aerospace industry¹⁰ There are opportunities beyond this in Scotland to win additional work from international competitors; hence a medium growth potential.¹²

4.3.1.3 Trends and barriers

The trends in the aerospace industry have remained largely unchanged since the 2009 survey on remanufacturing. Key trends identified then included:⁴

- The UK and Scottish aerospace MRO markets are well-developed with significant global market share.
- The industry's strong position is reinforced by the presence of large firms who are on the cutting edge of aircraft development and remanufacturing.
- The industry is driven by economics: remanufacturing is the most cost-effective option for the industry due to high capital costs, and this is unlikely to change.
- Growth in the UK and Scottish MRO markets is unlikely to be stimulated by government policy, but rather by the growth in the global MRO market, predominantly from emerging markets like Asia-Pacific and the Middle East.¹³ They are also a potential source of competition, although barriers to entry are high.
- The move to more efficient technology to reduce the environmental impact of aircraft and their components may reduce the environmental benefit of remanufacturing older systems. However, it is not economically feasible to replace all aircraft with newer, more fuel efficient aircraft and so remanufacturing will likely remain an important efficiency strategy, saving material resources and their embodied energy.

The recent study on the aerospace, defence and marine sector in Scotland¹⁴ highlights a number of barriers that currently limit the uptake of circular economy approaches, including remanufacturing:

| Barrier | Description |
|----------------|---|
| Mature markets | The UK's successful input to current generations of aircraft draws heavily on investments made in technological research and development in the 1970s and 1980s. However, recent trends have shown that the UK's input to new aircraft is reducing. The estimated costs and complexity of servicing the components and structures on the newer aircraft will be a challenge to the established repair industry, as new techniques and machines will be needed to service more advanced aircraft, requiring considerable investment in R&D and labour skills in order to remain at the forefront of the MRO markets. |

¹¹ Oakdene Hollins estimate

¹² Note that the global growth in aerospace is projected to double. However, the majority of growth in this sector will occur in Asia and is unlikely to result in a proportionate level of growth within Scotland; therefore the more conservative figure has been used.

¹³ Doan, The Global MRO Forecast 2012–2022, 2012 [Link](#) Accessed 25 September, 2014

¹⁴ Extracts in Table 6 taken from AMEC, Circular economy evidence building programme - sector study on Aerospace–Defence–Marine, for Zero Waste Scotland, 2014

| Barrier | Description |
|----------------------|--|
| SMEs | Whilst remanufacture is carried out mostly by small companies, data is more readily available from larger remanufacturers and most of the case studies focus on the activities of larger airlines and OEMs. Small companies have a less stable turnover and therefore can face added financial difficulties in adopting 'circular' approaches. This is compounded by a lack of access to finance in SMEs looking to adopt more innovative business models and approaches. Larger businesses also benefit from economies of scale and purchasing power. Consequentially, their profits may be higher than those of smaller companies engaged in closed loop activities such as MRO. ¹⁵ A lack of baseline information for SMEs could skew the remanufacturing potential. |
| Linear supply chains | While the aerospace sector has increasing levels of supply chain collaboration and de-lineation, there is still a lack of supply chain visibility. A recent study by KPMG notes that 27 % of respondents in the aerospace and defence sectors cited they had visibility past Tier 1 of their supply chain, compared to 41 % of non-aerospace and defence manufacturers. 9 % admitted to having no visibility at all. Increasing visibility across supply chains is fundamental to increasing the uptake of circular approaches, such as remanufacturing, and to the adoption of supply chain integration measures. |

Table 6 Barriers to increased remanufacturing in the aerospace sector

4.3.1.4 Possible mitigations

Investment in workforce skills

Currently, the UK and Scotland have the skills and capabilities to design and manufacture aircraft, which gives them a distinct advantage compared to other MRO hubs around the world. However, continued effort in recruitment and training of MRO operatives will be needed to maintain this leading position. It is estimated that only 1,200 licensed MRO engineers are aged 20-30, compared to 3,500 aged over 50.⁸ Current employment trends indicate that 3,000 fewer young people will be employed in the aerospace sector in the next eight years than the number of employees retiring.⁸ Action could be taken to address this imbalance, particularly in light of the anticipated increase in the global market.

Research into advanced materials repair technology

Remanufacturing capabilities in Scotland could be enhanced by research into advanced materials repair technology, and may provide opportunities for MRO growth. Joint projects with universities could provide opportunities to research ways to detect and repair faults in the advanced composites and metals increasingly used in aircraft. Examples of initiatives like this already exist, e.g. the Advanced Forming Research Centre¹⁶; however, other remanufacturing-specific initiatives could be developed.

4.3.2 Energy

4.3.2.1 Introduction

The energy sector consists of all industries involved in producing and selling energy, and in related support activities, such as equipment manufacture. In Scotland, key energy producing industries can be disaggregated between the oil and gas industry and the renewables industry (which includes wind, hydro and tidal power generation). The energy sector contributes significantly to the Scottish economy: the oil and gas sector is by far the largest industrial sector in Scotland.¹⁷ The oil and gas sector supports 200,000 jobs within Scotland through 674 operational installations, 74 decommissioned installations and 24 closed installations in the North Sea within the United Kingdom Continental Shelf (UKCS) and Scottish Territorial Waters (inshore and offshore).¹⁸ The current

¹⁵ Gray and Charter, Remanufacturing and Product Design, 2007 [Link](#) Accessed 25 September, 2014

¹⁶ Aerospace, Defence & Marine Industry Advisory Group, Scottish aerospace, defence & marine industry strategy 2009, 2009

¹⁷ Scottish Government, Energy in Scotland: Get the facts [Link](#) Accessed 12 November, 2014

¹⁸ AMEC, Circular economy evidence building programme – oil and gas sector report (working draft), for Zero Waste Scotland, 2014

installed capacity of renewable energy in Scotland¹⁹ is shown in Figure 3; the renewable energy industry in Scotland employs almost 12,000 people.²⁰

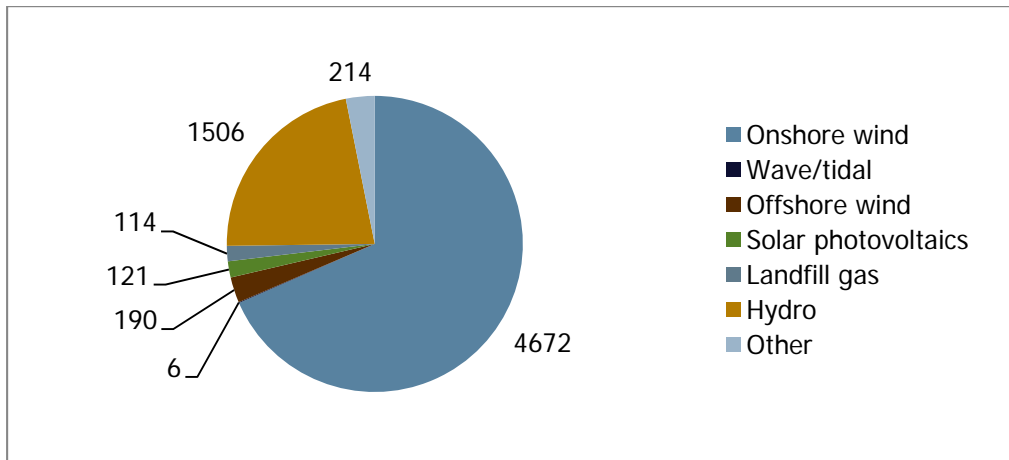


Figure 3 Installed renewable energy capacity in Scotland Q1 2014 (MW)

The energy sector requires the production and maintenance of a wide variety of plant and equipment to convert energy from one form to another. Some of this, such as pumps, turbines, generator sets and transformers, may be suitable for remanufacture. However, remanufacturing is not appropriate for all products, particularly components which have been degraded or fatigued due to the harsh operating conditions of off-shore installations.¹⁸ There is significant activity in repair and refurbishment of off-shore facilities and equipment in Scotland; for example, refurbishment of accommodation and drilling platforms and rigs, and refurbishment of oilfield equipment such as winches and drilling tools (see Table 7). Many of Scotland's docks, quays and ports (e.g. Dundee, Aberdeen, Peterhead and Invergordon) are well-positioned for this type of activity with ready access to North Sea installations, and numerous refurbishment companies have set themselves up around these locations.

There is already quite a strong remanufacturing and refurbishment base for the oil and gas, and the wider energy sector in Scotland. Organisations active in the sector in Scotland vary from large multi-national corporations to specialist SMEs. The remanufacturing activities also cover a wide range of the sector value chain, ranging from remanufacturing as part of ongoing maintenance and overhaul activities, remanufacturing of leased items and remanufacturing of end-of-life products. Examples of organisations operating in the remanufacturing industry are described in the table below:

| Company | Description |
|-----------------|--|
| Clyde Bergemann | Global engineering company that has a division in Glasgow. It operates in energy-related industries, specialising in designing products and systems for improved boiler efficiency. The company is also involved in manufacturing and refurbishment activities; for example, manufacture and refurbishment of soot blowers - devices are used for cleaning heat exchangers in power, waste, biomass, and industrial boilers. The refurbishing process follows a process similar to remanufacturing, whereby the soot blowers are disassembled, parts are repaired or replaced, cleaned and re-greased and reassembled with a 12 month warranty. These operations take place at a factory in Glasgow, with a workforce of 62 people. Turnover is approximately £8 million a year, of which £600,000 accounts for refurbishment of industrial machinery. ²¹ |
| Weir Group | Engineering company that operates in the natural resources and energy industries. It has servicing facilities based across Scotland and provides "re-engineering" services to industrial |

¹⁹ DECC Energy Trends, accessed via Scottish Renewables website [Link](#) Accessed 29 September, 2014

²⁰ O'Herlihy & Co. Ltd., Employment in renewable energy in Scotland, 2013 [Link](#) Accessed 29 September, 2014

²¹ Personal communication, 20 August, 2014

| Company | Description |
|---------------------------|---|
| | products including centrifugal pumps, valves, and hydro turbines. Re-engineering is simply remanufacturing by another name and addresses the same process. These products are re-engineered for use in power plants, refineries, and production plants. Weir has been remanufacturing products for 150 years; it generates revenue of £100 million a year, £50 million of which is generated in Scotland, and has 350 employees in this division of the organisation. ²² |
| Agra Engineering | Originally began operating in remanufacturing of automotive components, such as engines. The company has since diversified into offshore activities and now refurbishes marine engines and gearboxes. ²³ |
| Rolls Wood Group | Joint venture between Wood Group and Rolls-Royce plc. It provides maintenance, repair and overhaul services to operators of Rolls-Royce industrial gas generators oil and gas, power generation, and marine propulsion industries. Its Aberdeen base has 400 employees but it also has operations in USA and Malaysia. ²⁴ Its (global) turnover was around £150 million in 2009. ²⁵ |
| Precision Engine Services | Another automotive engine remanufacturer that also operates in the offshore sector, Precision Engine Services offers complete skid ²⁶ refurbishment services. It is an SME, employing 9 people. ²⁷ |
| Aggreko | Provides a rental service for power and temperature control systems. Its Dumbarton facility conducts servicing and repairs for its global rental fleet, including generators, engines, heaters and air conditioning systems. The site has 50 to 60 employees. While the Dumbarton facility conducts servicing and repair, major overhaul and refurbishment primarily takes place in facilities in Dubai and North America. ²⁸ |
| PD&MS Energy | Specialises in brownfield engineering, including upgrades and modifications to off-shore platforms and rigs. The company was recently recognised for its growth, particularly in overseas sales, with a turnover of £47 million in the 2 years to June 2013. ²⁹ |
| Rigmar | Offers a drilling rig repair service along with a “drilling facility upgrade and reactivation programme”. The company operates in 27 countries, working with both platform and mobile drilling systems and will refurbish rigs, drilling instrumentation, pipe handling equipment, power generation and distribution equipment. ³⁰ |
| Global Energy Group | The company has facilities in Invergordon, Nigg, Evanton, Dunfermline and multiple facilities in Aberdeen. It is involved in rig repairs and upgrades, predominantly of semi-submersible and jack-up rigs operating in Europe and West Africa. The group employs about 3,500 employees worldwide. ³¹ |
| The Saltire Energy Group | Provides an equipment rental service to the oil and gas sector. While some of the rental products offered are maintained by either the OEM or third party companies, the Saltire Pressure Control team has the capability to repair, refurbish and remanufacture pressure control equipment. ³² |

²² Personal communication, 19 August, 2014

²³ Agra Engineering website, Offshore engineering, [Link](#) Accessed 29 September, 2014

²⁴ Rolls Wood Group Website, [Link](#), Accessed 5 November 2014

²⁵ Wood Group Website, [Link](#), Accessed 5 November 2014

²⁶ A skid unit normally consists of a pump, tanks and hose and can be used in applications such as: fire pump, cement pump, diesel driven generators, portable air compressors etc.

²⁷ Precision Engine Services website, Skid refurbishment, [Link](#), Accessed 29 September, 2014

²⁸ Personal communication, 17 September, 2014

²⁹ PD&MS website, [Link](#), Accessed 6 November, 2014

³⁰ Rigmar website, [Link](#), accessed 6 November, 2014

³¹ Global Energy Group website, [Link](#), accessed 6 November, 2014

³² The Saltire Energy Group website, [Link](#), accessed 6 November, 2014

| Company | Description |
|-----------------------------------|---|
| Score Subsea and Wellhead Limited | Based in Peterhead, it offers refurbishment, modification and overhaul services for both subsea and surface 'Christmas trees' (an assembly of valves, spools and fittings used in wells) and wellhead valves. The company has deepwater test pits and hyperbaric test chambers for testing equipment. ³³ |
| Swire Oilfield Services | Involved in the repair and refurbishment of equipment used in onshore and offshore helicopter refuelling. The company has around 1,000 employees around the world. ³⁴ |
| Turbine Services | Specialises in maintenance services for heavy duty General Electric gas turbines, such as those used in power stations. Maintenance services include gas turbine refurbishment and customisation. ³⁵ |
| Turner Engine Power Solutions | Provides maintenance, refurbishment and overhaul services for industrial engines, such as those used for power generation in the oil and gas sector. ³⁶ |

Table 7 Companies involved in remanufacturing and refurbishment in the energy sector in Scotland

Discussions with Perthshire-based Element Engineering, provider of renewable energy services, confirm that there is no remanufacturing of wind turbines in Scotland, and little activity in the UK as a whole.³⁷ Element Engineering reports that wind turbines are not typically refurbished; end-of-life turbines are disassembled and become scrap materials. At present, wind farm developers tend to purchase and install new turbines, and only very occasionally do developers buy second hand turbines for re-use (not refurbishment or remanufacture). There are moves to begin leasing turbines to wind farm operators, which could lead to opportunities to remanufacture; however, this is in an early stage of development.³⁸

While there is significant remanufacturing activity taking place as part of maintenance and overhaul operations for hydro-electric power plants (e.g. by organisations such as the Weir Group), no evidence of appreciable remanufacturing or refurbishment activities in other renewable energy sectors in Scotland (e.g. wave or tidal energy) was identified during this study. This is perhaps to be anticipated as these industries are in their infancy with little end-of-life core available for remanufacturing and with rapidly evolving technology limiting the benefits of remanufactured products over new.

4.3.2.2 Market size

| Employment | Turnover | % of energy sector | Environmental benefits | Growth potential to 2020 |
|----------------|--------------|--------------------|--|--------------------------|
| 10,000 persons | £300 million | < 1 % | 6,600 tonnes CO ₂ e avoided | High |

Table 8 Market size of energy sector remanufacturing activities

Assumptions:

- Of the 200,000 people in Scotland employed in the oil and gas industry, we estimate that around 5 % of jobs could be attributed to remanufacturing and refurbishment.
- We assume that there are currently no remanufacturing or refurbishment jobs in Scotland in the renewable energy sector, with any jobs associated with remanufacturing or refurbishment of hydro-

³³ Score Subsea and Wellhead Limited, [Link](#), accessed 6 November, 2014

³⁴ Swire Oilfield Services website, [Link](#), accessed 6 November, 2014

³⁵ Turbine Services website, [Link](#), accessed 6 November, 2014

³⁶ Turner Engine Power Solutions website, [Link](#), accessed 6 November, 2014

³⁷ Personal communication, 4 September, 2014

³⁸ Private communication, 30 October 2014

electric equipment already being accounted for by companies also operating in the oil and gas industry.

- We assume that the turnover for energy sector remanufacturing and refurbishment activities are dominated by The Weir Group (turnover £50 million in Scotland) and Rolls Wood Group (approx. £100 million in Scotland). Assuming that there are several other large players, comparable to Clyde Bergemann and several other SMEs, we estimate that an additional £150 million turnover may arise from remanufacturing and refurbishment activities in Scotland.
- In 2012, the GVA of the energy sector in Scotland was £23.1 billion.⁵⁰ It is likely, therefore, that the contribution to the sector from remanufacturing activities will be less than 1 %.
- Assuming that 165,000 tonnes of equipment will be available for refurbishment and remanufacturing from the oil and gas sector between 2013 and 2022¹⁸, we assume that 16,500 tonnes of predominantly steel-containing products could be remanufactured each year in Scotland. If refurbishment and remanufacturing displaces the CO₂ emissions of steel recycling (approximately 0.4 tonnes CO₂ / tonne steel³⁹), then this would avoid approximately 6,600 tonnes of CO₂.
- The decommissioning of North Sea oil platforms provides a great opportunity to increase the amount of remanufacturing undertaken in this sector. Therefore the growth potential in this sector is likely to be high.

4.3.2.3 Trends and barriers

Production from the oil and gas industry has declined 38 % from 2010 to 2013¹⁸ and there is an increasing focus in the industry on cost reduction and asset life extension. Remanufacturing can help address both of these drivers and activity in this sector already takes place for some plant and equipment, particularly where remanufacturing skills and tooling is common across other sectors, e.g. automotive. The wind turbine remanufacturing market in the UK is currently very small as the industry is relatively young, with few turbines having reached their end-of-life. However, there is opportunity in the future for remanufacturing to increase in line with growth of the market. The European turbine supply market is further ahead than the UK with the windier EU countries (e.g. Germany, Holland, Denmark) implementing sustainable measures to ensure a thriving energy turbine supply market. Further abroad in the USA they also active in this field.³⁷

As oil rigs are decommissioned and oilfields come to the end of their service life, there is a large opportunity for remanufacturing these complex installations. In particular, there could be opportunities for pumps, fans and valve re-use and remanufacture as the rigs are decommissioned. However, the majority of value and volume for remanufacturing will likely arise from remanufacturing lower value steel structures and pipes, rather than the higher value equipment, which will make up much smaller tonnages of available material.

The barriers faced to increased remanufacturing and refurbishment in the energy sector, are described in the table below:⁴⁰

| Barrier | Description |
|---|--|
| Design for disassembly or remanufacture | Some structures have been in place for 40 years with no or little design to aid disassembly or re-use. Additionally, many offshore installations are unique and reflect local environment and operator design characteristics. This reduces inter-changeability between installations. |
| Liability issues and concerns | The industry has strong health and safety and quality assurance requirements for all equipment and materials; there may be a natural favour of new items over re-used and remanufactured alternatives. Warranties and assurance may be harder to attain with re-used and remanufactured equipment. |

³⁹ IEA Clean Coal Centre, Profiles – CO₂ abatement in the iron and steel industry, [Link](#) Accessed 2 October, 2014
⁴⁰ Extracts from AMEC, Circular economy evidence building programme – oil and gas sector report (working draft), for Zero Waste Scotland, 2014

| Barrier | Description |
|---|---|
| End-of-life drivers | Key drivers at end-of-life for many operators are swift, cost-efficient and safe removal; de-construction and disassembly <i>in situ</i> could be slower, costlier and more energy intensive even factoring re-use of equipment. Potential savings of re-using or remanufacturing equipment are relatively small in the context of installations operating and de-commissioning costs, so not a major incentive for operator. |
| Efficiency and lifetime of used items | Materials and equipment may become obsolete during their lifetime as newer designs emerge; efficiencies of equipment may be lowered beyond point of remanufacture by time spent in service and age. |
| Bureaucracy caused by maintaining documentation | The need to maintain documentation accompanying all equipment (e.g. certification) can lead to higher levels of bureaucracy. |
| Lack of re-use targets | The lack of targets for re-using plant and equipment can make it difficult to pass on motivation to remanufacture equipment to other actors. |
| Reduced margins | The margin available from remanufacturing can be reduced if significant cleaning and/or processing is required. |
| Attitudes towards remanufacturing | Attitudes and use of language which devalues remanufacturing; constant reference to waste, re-use and recycling reduces the likelihood that materials and equipment can be viewed automatically as 'resources'. |
| Reducing new manufacturing demand | Remanufacturing of equipment and materials can impact on first-time manufacturing jobs. |
| Barriers to cross-sector working | Higher fees commanded by supply vessel operators for oil and gas contracts – little incentive for cross-sector working with offshore renewables which has been proven to be a viable option. |

Table 9 Barriers to increased remanufacturing and refurbishment in the energy sector

4.3.2.4 Possible mitigations

Policy incentives leading to growth in renewables

Scottish, UK and European policy is promoting the growth of the renewables industry; for example, the 'Renewables Obligation' requires the UK to source increasing proportions of its energy from renewables, with targets for electricity generation from renewables now in place until 2037.⁴¹ This growth in the industry will, in time, lead to the greater availability of end-of-life products, e.g. wind and tidal turbines, that will be available as core for remanufacturing. The increased demand for renewables may also increase the demand for remanufactured products for smaller-scale installations.

Opportunities from cross-sector collaboration ¹⁸

Cross-sector collaborations could increase the market for remanufactured products in the energy sector. For example, decommissioned and remanufactured platforms for substations could be used by the offshore wind industry. Cross-sector collaborations could therefore increase the supply of remanufacturing core and increase demand for remanufactured products, while reducing the capital costs of equipment.

⁴¹ UK Government, National Renewable Energy Action Plan for the United Kingdom, 2010 [Link](#) Accessed 30 September, 2014

Examining options for decommissioning

The oil and gas industry are at the start of a decommissioning of offshore platforms process that will last for at least 20 years. There is an opportunity to maximise the value of that process by remanufacturing useable equipment (either for use in the oil and gas industry or for other uses). Increasing remanufacturing in this area could be achieved through engagement with industry bodies such as Decom North Sea in the development of pilot project or research projects.

Strong remanufacturing skills base ¹⁸

There is already a strong remanufacturing skills base built up around manufacturing activities in the oil and gas sector. This base could be developed and supported through demand for remanufacturing of plant and installations decommissioned from the oil and gas and renewable energy industries.

Potential for refurbishment of microturbines ⁴²

Microturbine refurbishment is a potential opportunity for activity in the energy sector. In contrast to larger wind turbines, microturbines - which can be installed on walls or roofs of domestic housing - benefit from low maintenance costs, ease of instalment and simple transport logistics. These features could attract new entrants to this market.

4.3.3 Automotive

4.3.3.1 Introduction

Globally, remanufacturing of automotive components is well-established. Remanufacturing takes place for a number of different automotive components and systems, and the main remanufacturing categories are described below:

Engines

Engine remanufacturing is well-established, primarily its suitability for remanufacture characterised by its complexity, value and function.⁴³ Remanufacturers operate in both the private and the commercial sectors. Some Scottish engine remanufacturers are dedicated to remanufacturing automotive engines while others also remanufacture a range of automotive components (e.g. gearboxes) and others still have remanufacturing operations diversified across a range of sectors (e.g. marine, off-shore). In addition to complete engine remanufacturing, there are some organisations that are active in component remanufacturing; for example, remanufacturing of cylinder heads.

Only one OEM has been identified as remanufacturing engines in Scotland (Diesel ReCon UK, a division of Cummins); the remaining engine remanufacturers identified are independent companies. While localised remanufacturing operations may be beneficial for some customers (e.g. private individuals looking for a local supplier), other factors such as lead time may be more important for others. One supplier of remanufactured components to the fleet industry reported that its remanufacturing facilities were based in England, but that its garages in Scotland fitted approximately 10 remanufactured engines per week.⁴⁴ They suggested that, by remanufacturing at scale, there were few companies that could compete for large volume fleet contracts.

Transmission and drivetrain components

Remanufacturing of transmissions and drivetrain components (which include clutches, gearboxes, differentials and axles) is considered to be a well-established and high-value remanufacturing activity.⁴³ These parts are often suitable for remanufacturing as - while a few key components have a

⁴² Personal communication, 1 October, 2014

⁴³ Centre for Remanufacturing and Re-use, 2009, Remanufacturing in the UK: a snapshot of the UK remanufacturing industry

⁴⁴ Personal communication, 9 September 2014

finite lifetime, due to wear and fatigue in normal use -other components (e.g. structural components) do not degrade during use and can be retained in a remanufactured product.

Several remanufacturers of transmission components operate in Scotland. The largest remanufacturer is Mackie Automatic & Manual Transmissions, which is reportedly the sole supplier of remanufactured transmissions to vehicle manufacturers including Subaru, Isuzu, Hyundai, Nissan and Chevrolet.⁴⁵ Other independent remanufacturers also offer transmission remanufacturing services.

Rotating electrics and ignition parts

Remanufacturing in this sector (which includes remanufacturing of components such as alternators, dynamos, starter motors and ignition coils) is also well-established. During remanufacturing, the external casing of the component is re-used as it does not degrade during use. The internal brushes may also be re-used and the copper wire solenoid rewound. Other components, such as the magnets and brushes, are replaced as necessary.⁴³ While remanufacturing is commonplace, it is not without its challenges. The relatively low cost of new parts and the high labour intensity of remanufacturing mean that, for remanufacturing to be profitable, the remanufacturing process must be as efficient as possible; for example, through economies of scale.

Turbochargers

Turbochargers are complex and high performance parts which need to work reliably at spin rates of 15,000 rpm or higher. These characteristics mean that turbochargers are of a high build quality, e.g. with narrow tolerances, but are also liable to fail.⁴³ For these reasons, turbochargers are candidates for remanufacture; however, there are relatively few examples of turbocharger remanufacturers in Scotland. One turbocharger remanufacturer stated that specialist equipment is required to remanufacture a turbocharger and reported that only five companies in Scotland possessed this capability.⁴⁶

Air conditioning

Air conditioning systems are now commonplace in vehicles, and consist of a compressor, radiator, expansion valve and evaporator.⁴³ Remanufacturing of air conditioning systems is less well-established than other remanufacturing activities in the automotive sector and, where it occurs, it is predominantly focused on remanufacturing the compressor. This is because the compressor is a high value item and frequently wears out during use, therefore making it a good candidate for remanufacturing.⁴³ No examples of compressor remanufacturers operating in Scotland could be identified. This was supported by discussions with Compressortech, a large supplier of remanufactured air conditioning compressors based in Warwick.⁴⁷ Compressortech distributes some of its remanufactured products into Scotland, but was not aware of any compressor remanufactures operating in Scotland.

Electronics

Electronic systems in cars are increasingly prevalent, and include electronic control units (ECUs) for engine management, traction control and airbag deployment.⁴³ Previous UK-based research found that electronics remanufacturing is limited to a few Tier 2 companies.⁴³ Remanufacturing of engine ECUs is the most common electronics remanufacturing activity as the components are well-established and familiar to remanufacturers. Remanufacturing of some ECUs - such as airbag deployment and immobiliser systems - is more challenging due to specific safety and security concerns. Glasgow-based E.S. Alternators has diversified from alternator remanufacture and now also works in automotive electronics.⁴⁸ However, the company reports that its activities are repaired-based rather than remanufacturing or even refurbishment, and stated that it was not aware of any automotive

⁴⁵ Mackie Automatic & Manual Transmissions website, 2014 [Link](#) Accessed 11 September 2014

⁴⁶ Personal communication, 11 September, 2014

⁴⁷ Personal communication, 3 October, 2014

⁴⁸ Personal communication, 18 September, 2014

electronics remanufacturing taking place in Scotland. This was corroborated by discussions with a representative from ATP, an automotive electronics remanufacturer with approximately 25 % of the UK market share.⁴⁹ ATP also reported that it was not aware of any electronics remanufacturing occurring in Scotland.

4.3.3.2 Market size

| Employment | Turnover | % of automotive sector | Environmental benefits | Growth potential to 2020 |
|-------------------|-------------|------------------------|--|--------------------------|
| 650 - 900 persons | £35 million | < 1 % | 4,100 tonnes CO ₂ e avoided | High |

Table 10 Market size of automotive remanufacturing activities

Assumptions:

- Direct employment for the automotive sector is estimated to be the sum of employment for remanufacturing engines (200-300), transmission and drivetrain components (125), rotating electrics and ignition parts (300-400) and turbochargers (30-60).
- We assume that there is no direct employment arising from remanufacturing automotive air conditioning or electronics in Scotland.
- In the engine sector, we estimate that there are approximately 20 companies operating in Scotland. The Federation of Engine Remanufacturers has 108 members (including supplier members) and estimates that it has approximately 50 % membership in the sector.⁵¹ We estimate that the Scottish engine remanufacturing industry makes up approximately 9 % of the UK industry.
- We found little data to estimate the turnover of remanufacturing in the automotive sector. The total value of remanufacturing and re-using of engines, transmissions and drivetrain components, rotating electrics and turbochargers - as reported in the 2009 UK survey - was £375 million.² If we assume that the proportion of remanufacturing activity occurring in Scotland the same as for the engine sector (9 %), this corresponds to a value of approximately £35 million. However, this is a crude estimate.
- The turnover of wholesale and retail trade and repair of motor vehicles and motorcycles in 2010 in Scotland was £6.9 billion.⁵⁰ This suggests that remanufacturing activities made up less than 1 % of the value of the sector.
- We assume that the environmental benefits of automotive remanufacturing activities can be scaled by value from the CO₂e emissions savings reported in the UK 2009 remanufacturing survey for the sector. The UK 2009 survey reported that 48,000 tCO₂e were avoided through re-use activities, with a value of £408 million.² Scaling this to the Scottish market with a value of £35 million suggests remanufacturing activities there avoid 4,120 tCO₂e.
- There is significant growth potential in this market, particularly with respect to interventions with public procurement. Although the likely benefit from any increase in procurement of remanufactured components is likely to increase remanufacturing activity across the UK, it can be assumed that Scottish remanufacturers will take a fair proportion of an increase. Based on this assessment, a high growth potential has been predicted.

Engines

The Federation of Engine Remanufacturers has eight members listed in Scotland and estimates that it represents approximately 50 % of engine remanufacturing companies.⁵¹ This corresponds well with estimates of the market size from individual engine remanufacturers: one estimated that there would be no more than about 20 engine remanufacturing companies operating in Scotland.⁵² Most engine

⁴⁹ Personal communication, 18 September, 2014
⁵⁰ The Scottish Government, Scottish annual business statistics, 2012 [Link](#) Accessed 2 October, 2014
⁵¹ Personal communication, 8 September, 2014
⁵² Personal communication, 10 September, 2014

remanufacturers are small enterprises, with fewer than 10 employees⁵²; an exception to this would be Diesel ReCon UK which employs about 100 people at its Cumbernauld plant.⁵³ Based on these figures, an estimate for the direct employment in the engine remanufacturing sector would be 200-300 people. There will be additional personnel involved in fitting engines in Scotland that have been remanufactured outside of the country and in other indirect activities.

No clear estimate could be found for the number of companies remanufacturing engine components, such as cylinder heads, particularly as many organisations involved in this activity may also be involved in remanufacturing other automotive components such as turbochargers or gearboxes.

Transmission and drivetrain components

Mackie Automatic & Manual Transmissions employs over 25 staff for its remanufacturing activities.⁴⁵ Desk-based research identified several organisations reportedly involved in transmission remanufacturing with many more being involved in transmission rebuilding and repair activities. We estimate that there might be around 20 further organisations involved in transmission and drivetrain component remanufacturing and refurbishment in Scotland, with a total direct employment in Scotland of approximately 125 people. The market for transmission and drivetrain component repair would be significantly larger than this.

Rotating electrics and ignition parts

Desk-based research has identified many remanufacturers in this sector. Shandon Electrical Ltd⁵⁴ has seven employees and reports that its competitors are mostly smaller businesses.⁵⁵ Shandon remanufacturers approximately 100 units per month for a wide range of customers, including councils, haulage companies, and taxis; however it was unable to provide an estimate of the total market size in Scotland.⁵⁵ Without further data to quantify the size of the market, we estimate that there might be around 100 businesses involved in remanufacturing and refurbishing rotating electrics and ignition parts, and approximately 300-400 people might be directly employed in these activities.

Turbochargers

One turbocharger remanufacturer, The Turbo Guy, reported that there were only five 'true' turbocharger remanufacturers operating in Scotland. While the company employs six people to undertake remanufacturing on a production line basis, it suggests that the remaining remanufacturers are smaller, with only one or two employees.⁴⁶ Another source estimated that there may be up to 25 turbocharger remanufacturers operating in Scotland⁴⁴; however, some of these may be involved in refurbishment rather than full remanufacturing. Based on these figures, an estimate for the direct employment in the turbocharger remanufacturing sector would be 30-60 people.

The Turbo Guy reported an annual turnover in 2013 of £0.5 million, of which over 90 % arose from sales of remanufactured products. The company technical and sales director estimates that the market for remanufactured turbochargers in Scotland is £2-3 million per year; however, he believes that most of the market is serviced from products produced in England.⁴⁶

Air conditioning

This study has to date found no evidence of remanufacturing of automotive air conditioning components. Previous UK-based research found that remanufacturing in this area is less well-established than in other automotive sectors.⁴³

Electronics

This study has to date found no evidence of automotive electronics remanufacturing taking place in Scotland. Previous UK-based research found that remanufacturing in this area is limited compared to

⁵³ Personal communication 18 September, 2014

⁵⁴ Shandon Electricals Ltd, 2014 [Link](#) Accessed 18 September 2014

⁵⁵ Personal communication, 12 September 2014

other automotive sectors.⁴³ ATP estimated that less than 5 % of its remanufactured components were distributed to Scotland.⁴⁹ Assuming that ATP has a 25 %⁴⁹ market penetration, this equates to approximately 40 to 50 remanufactured ECUs being purchased in Scotland per week.

4.3.3.3 Trends and barriers

Trends and barriers across the automotive sector are generally independent of component type. One common trend observed by engine and alternator remanufacturers has been a decrease in the size of the market: the number of remanufacturers operating in Scotland has decreased significantly over the last ten years while remaining remanufacturers have chosen to diversify into new areas (e.g. offering new products, remanufacturing a range of components, remanufacturing for a range of sectors) to stay in business.

The decrease in business has been attributed to a number of barriers explored below:

| Barrier | Description |
|--|---|
| Increasing product complexity | <p>For some products, an increase in complexity is making remanufacturing more difficult. For example, the electric variable value unit in a turbocharger has reportedly become more complex and therefore harder to remanufacture.⁴⁶ Alternators have also seen an increase in complexity, which Shandon Electrical Ltd believes is driven by OEMs wanting to make it harder for companies to copy their products.⁵⁵ The increase in product complexity - for example smaller, more powerful engines - may also necessitate the use of more expensive, specialised tooling, which may be difficult for independent remanufacturers to purchase or replicate.⁵¹</p> <p>Whilst the increase in technical complexity can make remanufacturing more difficult, it may also present an opportunity for remanufacturers. For example, Shandon Electrical Ltd reports that there is an increasing prevalence of computer coding linking a specific alternator to a specific vehicle.⁵⁵ This would make it difficult for a new, non-OEM part to be fitted to the vehicle, but remanufacturing the original unit to replace in the vehicle would be possible.</p> |
| Competition from low-cost new and used parts | <p>The aftermarket is reported by some remanufacturers to be price-driven; this can be one of the key advantages of remanufactured products, but imports of low-cost new products, predominantly from the Far East, presents a challenge particularly to starter and alternator remanufacturers. Additionally, companies offering repaired or reconditioned (i.e. not fully remanufactured) parts can offer lower price products which can compete against remanufactured products. However, this also represents a reputational risk: these used products might not perform as expected and, without a good understanding of remanufacturing compared to re-use, remanufactured products may also - by association - be considered second-hand and second-rate products.</p> |
| High speed of technology innovation | <p>This barrier was identified by an engine remanufacturer who felt that engine technology is changing very quickly, perhaps every 2-3 years, primarily as a response to increasingly stringent emissions regulations. In combination with the increasing reliability and operating life for engines, this remanufacturer anticipates that obtaining component parts for remanufacturing from the original suppliers will be an increasingly expensive and challenging task.</p> |
| Core availability | <p>Core availability can be a barrier to remanufacturing, particularly if there is a wide range of product models available. Diesel ReCon is planning to expand the range of products it remanufactures, but this will place increasing demands on sourcing and storing core.⁵³ Part exchange (i.e. where a remanufactured part is exchanged for the existing part) is often a good source of core; however, this is not always reliable: some parts may be unsuitable for remanufacture or customers may be unwilling to return the old product. Core can also be sourced from brokers, which may allow remanufacturers to build up a range of stock. For remanufacturing operations where availability is a key selling point, (e.g. Diesel ReCon⁵³) ensuring a reliable supply and stock of core is crucial.</p> |

Table 11 Barriers to increased remanufacturing in the automotive sector

4.3.3.4 Possible mitigations

Differentiation of remanufacturing

Currently the terminology used to describe remanufacturing is inconsistent across the sector and poorly understood by customers. The industry has seen a shift in terminology away from 'reconditioning' to 'remanufacturing'⁵²; however, it is not clear whether organisations reportedly undertaking 'remanufacturing' are performing true remanufacturing or refurbishment as defined in this report, or whether they are undertaking lesser, re-use activities. Conversely, some companies advertising 'rebuilding' or 'reconditioning' activities may actually be performing activities to the same standard as remanufacturing or refurbishment but not advertising these as such. An accepted definition of remanufacturing and refurbishment terminology would allow customers to recognise and trust the performance of remanufactured products and would allow companies to differentiate their processes from other, less rigorous, re-use activities.

Promoting remanufacturing advantages

While one of the key advantages of remanufactured products is their low price compared to buying new, another advantage of remanufactured products that could be leveraged is availability. For products whose lead time for purchasing new can be quite long, remanufactured products - particularly products that have been remanufactured to stock - can have a significant advantage over new. This is more likely to be a mitigation strategy for larger and more expensive products, e.g. large diesel engines and their components.

Automotive policy

Automotive policy represents an opportunity to promote remanufactured automotive products; however, as it currently stands, the End-of-life Vehicles Directive does not distinguish between 'remanufacture' and 'reuse'. Therefore, while remanufacturing end-of-life automotive components contributes towards the targets, there is no incentive for remanufacturing to be the preferred option for end-of-life parts. Additionally, it is important that changes to existing legislation do not unintentionally penalise remanufacturers. For example, current modifications to legal guidelines from the United Nations, with the intention to prevent hazardous electronic waste being shipped to developing countries to be landfilled, should not unintentionally prevent the movement of core, e.g. for automotive electronic remanufacture.⁵⁶

Procurement

Procurement policy can be a valuable tool for promoting the remanufacturing market. For example, in the USA a bill was introduced to Congress in February which would require all vehicles in the Federal fleet (about 588,000 vehicles) to be repaired and maintained using remanufactured parts - unless it can be demonstrated that to do so would be more expensive, take longer or be of lower quality. An equivalent approach for public procurement in Scotland could help increase demand for remanufactured products and stimulate the industry.

4.3.4 Rail industry

4.3.4.1 Introduction

Rolling stock within the rail industry can be split into five main groups:

- traction units (vehicles to provide motive power to pull either passenger or freight trains)
- passenger carriages
- self-propelled passenger vehicles
- freight vehicles
- infrastructure maintenance vehicles.

⁵⁶ Bartel, P., "The missing word..." page 34, ReMaTecNews, August 2014, No. 4, Volume 14

The body of the vehicle and interior fittings usually require refurbishment at the half-life refit, assuming no damage occurs from misuse or a collision. The running gear will require more frequent remanufacture, and is normally serviced at a fixed mileage interval. Heavy overhaul is usually carried out at between 400,000 and 900,000 miles, depending on the vehicle. This involves removal of the bogies for complete strip down and remanufacture of all systems. The engine or motor and transformer will also need to be removed and remanufactured at similar intervals.

At 5-8 years most vehicles will receive a major overhaul, during which systems such as doors and electronics will be serviced, possibly replaced, to bring the vehicle up to current standards and avoid issues of obsolescence. An even more comprehensive service will be undertaken at 15-20 years (half-life), at which interiors will be completely replaced.

The UK has a stable demand for regular maintenance of its 12,000 strong rail vehicle fleet. Separating Scotland's fleet from the rest of the UK is difficult, particularly with intercity trains operating across borders. The majority of rail services in Scotland are operated by the ScotRail franchise for day services and by the Caledonian Sleeper franchise for overnight services between Scotland and England. From April 1st 2015 the day services will be operated by Abellio ScotRail and the overnight services by SERCO Caledonian sleeper.

In the United Kingdom, there are a number of organisations that own railway traction units and carriages which are leased to passenger train operating companies (TOC) that actually operate the trains. In addition, there are also some direct leasing agreements with the manufacturer, which includes a complete maintenance and overhaul package. Some vehicle owning and financing organisations that are active in the UK are⁵⁷

- Angel Trains Ltd
- Porterbrook Leasing Company Ltd
- Eversholt Rail Group
- Beacon Rail Leasing
- Macquarie European Rail Ltd
- Qw Rail Leasing Ltd,
- SMBC
- Lombard

There are five companies active in building passenger trains for the UK market: Alstom Power, Bombardier Transportation, Hitachi Europe Ltd, CAF of Spain and Siemens Transportation Systems Ltd.⁵⁷ The vehicle owners are ultimately the customers of any refurbished rolling stock and actively engage in refurbishment activities. For example, in September 2014, Eversholt Rail awarded Alstom with a contract to overhaul Scottish suburban trains. The two year contract, worth £36.1 million, is to improve the passenger environment and reliability of the 40 ScotRail trains that operate services between Helensburgh – Airdrie - Bathgate - Edinburgh. Work is due to start in early 2015 and will be led by Alstom's Modernisation team in Preston, with support from the Glasgow Traincare Centre in Polmadie and the Manchester Traincare Centre.⁵⁸

Some of the refurbishment works being undertaken as part of this contract include:⁵⁸

- overhaul of saloon and cab doors
- fitting full passenger saloon heating, ventilation and air conditioning
- installation of 230v at seat sockets
- preparing carriages for future WiFi, by installing an Ethernet backbone

This investment is the third fleet upgrade for Scotland by Eversholt Rail. As a point of note, Alstom manufactured the trains in the early 2000s, suggesting that the rail manufacturers build in remanufacturing and refurbishment into their business activities.⁵⁸ As part of this contract, Alstom is

⁵⁷ Office of Rail Regulation website, Rolling stock companies, [Link](#) Accessed 1 October, 2014

⁵⁸ Alstom website, Eversholt Rail awards Alstom with contract to overhaul Scottish suburban trains, 24 September, 2014 [Link](#) Accessed 1 October, 2014

reported to be investing £500,000 at the Glasgow and Manchester depots, including a 22 m shed extension in Glasgow.⁵⁹

Other major rail refurbishers in Scotland include:

| Company | Description |
|---|---|
| Wabtec Rail Scotland | Based in Kilmarnock, the company contains a100,000 sq. ft. overhaul facility. It has been involved in the rail industry and engineering for 170 years, becoming part of the Wabtec Rail Group in 2011. It focuses solely on supporting rolling stock owners and train operators in Scotland and North England. The company is considered the second largest rail engineering company in Scotland (turnover £20 million), behind Knorr-Bremse RailServices. Alstom Transport and Brodie Engineering are also competitors. In total these four companies make up the rail maintenance sector in Scotland. ⁶⁰ |
| Knorr-Bremse RailServices (formerly Railcare Ltd) | A specialist train service, maintenance, overhaul and upgrade division, the company operates from two sites: Springburn in Glasgow and at Wolverton near Milton Keynes. ⁶¹ The establishment of the company followed the acquisition of Railcare Ltd in 2013. ⁶² |
| Brodie Engineering Ltd | Offers a range of overhaul and refurbishment services, including heavy maintenance, interior refurbishment and re-paint/re-livery. The company's main facility is based in Kilmarnock, Ayrshire and employs 70 staff. ⁶³ |

Table 12 Other companies involved in remanufacturing and refurbishment in the rail sector in Scotland

During 2013/14, the Scottish Government published their Invitation To Tenders for both the ScotRail and Caledonian sleeper franchises following public consultation during 2012. The ITT requested improvements in the passenger facing elements on existing rolling stock, demonstrating public acceptance of the refurbishment of trains on a number of routes.

In addition to refurbishment of rolling stock, track components, such as sleepers, rail track and ballast can be re-used with or without repair, however, these activities fall outside the scope of the research, as defined in section 2.5.

4.3.4.2 Market size

| Employment | Turnover | % of UK rail sector | Environmental benefits | Growth potential to 2020 |
|-------------|-------------|---------------------|--|--------------------------|
| 160 persons | £35 million | 3.5 % | 4,100 tonnes CO ₂ e avoided | Medium |

Table 13 Market size of rail industry remanufacturing activities

Assumptions:

- Assuming that the rail maintenance companies have approximately 100 employees each,⁶⁴ except Brodie Engineering which employs 70 staff,⁶³ the total employment in this sector is estimated to be 370 people. We assume that 44% of the maintenance activity by expenditure includes remanufacturing and refurbishment activities – the same proportion assumed for the aerospace sector. This gives an estimated employment size of 160 people.

⁵⁹ International Railway Journal website, Alstom to refurbish Scottish EMUs, 1 September, 2014 [Link](#) Accessed 1 October, 2014

⁶⁰ Personal communication, 25 September, 2014

⁶¹ Knorr-Bremse website, Knorr-Bremse RailServices, [Link](#) Accessed 1 October, 2014

⁶² Railway Gazette, Knorr-Bremse buys RailCare from administrators, 27 August, 2013 [Link](#) Accessed 1 October, 2014

⁶³ Brodie Engineering website, Overhaul & refurbishment, [Link](#) Accessed 1 October, 2014

⁶⁴ Oakdene Hollins estimate

- The turnover for Wabtec Rail Scotland was reported to be £20 million.⁶⁰ Assuming this is the average for this sector, the total sector turnover is estimated to be £80 million. This corresponds well with the total infrastructure maintenance expenditure in Scotland in 2012-2013, which was £89 million.⁶⁵ Not all of the expenditure in Scotland will be realised by Scottish companies and, similarly, some of the expenditure in the rest of the UK may be realised by Scottish maintenance companies; nevertheless this is a useful reference. It is also likely to be an overestimate as maintenance expenditure includes other activities in addition to remanufacturing and refurbishment. We assume that 44% of the maintenance expenditure includes remanufacturing and refurbishment activities – the same proportion assumed for the aerospace sector. This gives an estimated market size of £35 million.
- Because of the integrated nature of the rail network, the percentage of the sector is calculated as a proportion of the national expenditure on infrastructure maintenance, which was £1.01 billion in 2012-13.⁶⁵
- The environmental benefits of rail industry remanufacturing can be scaled by monetary value from the figures in the 2009 UK survey, which reports 12,390 tCO₂e avoided through £105 million re-use activity.²
- Scotland is well placed to compete with the rest of the UK for work overhauling rolling stock. However, the market is largely saturated therefore any growth will come at the expense of English and Welsh competition, which is inherently more difficult than growth through new markets. Therefore the expected growth potential is medium.

4.3.4.3 Trends and barriers

| Barrier | Description |
|-----------------------------|--|
| Initial capital costs | Initiating new remanufacturing activities in this sector may require significantly large capital costs. This may be a barrier to extending remanufacturing into new areas or technologies, and for smaller companies that want to enter the remanufacturing sector. ² |
| Safety | The extensive testing requirements for new, refurbished and used equipment, specified by the Railway Industry Supplier approval scheme is an additional burden for remanufacturers; however, this requirement is not unique to remanufacturers. ² |
| Technology | The continued development of modern rail equipment, particularly the increased integration of electrical systems into rail parts and systems, may increase the complexity of remanufacturing operations, requiring the development of specialist electronics skills. However, this may also represent an opportunity for the industry to develop new markets for their remanufacturing and refurbishment activities. ² |
| Insufficient capacity | Demand for refurbishment is reported to be growing, particularly in the EU as a whole, but there is insufficient capacity to keep up. Across Europe there are not enough overhaul sites to facilitate the rising volumes of rolling stock requiring maintenance. ⁶⁰ |
| Market uncertainty | The market for complete vehicle remanufacture can be unpredictable. The size of this sector is defined annually by only a handful of contracts, and thus its value will fluctuate dramatically from year to year. This is far more dependent on economic stability and confidence than the overhaul market. Operators will choose to run on old stock without carrying out a programme of expensive upgrades if confidence in passenger or freight growth is not good: Most vehicles will undergo one complete remanufacture at their half-life. ROSCOs or TOCs may choose to carry out this process more regularly in times of high rail confidence to improve passenger perception of the service. |
| Fixed route operating costs | By fixing the cost at which the TOC must operate a train route, there is an indirect barrier that can be imposed as to the amount that a TOC can spend on rolling stock. The Scottish and/or UK government can influence this decision to a certain extent with the franchise agreement issued |

⁶⁵ Office of Rail Regulation, GB rail industry financial information 2012-2013, 2014 [Link](#) Accessed 1 October, 2014

to a particular route.

Table 14 Barriers to increased remanufacturing in the rail sector

4.3.4.4 Possible mitigations

A growing market for refurbishment

The overall level of UK-based refurbishment of rolling stock is likely to grow in line with passenger numbers and miles travelled. But the growth is unlikely to be significantly beyond this because it is a well embedded and widely used practice within the industry. There are, however, further opportunities within Scotland to attract a larger share of this market. With four major maintenance and overhaul sites based within the Central Belt, there are sufficient skills, knowledge and equipment to further develop this industry for Scotland.

If a marked increase in rail travel is seen in the future then remanufacturing will benefit, as more vehicles will be required, all of which will require regular maintenance and overhaul. Conversely, if passenger numbers fall, TOCs will run fewer services, resulting in fewer vehicles miles, and less need for overhaul. Any such change will be as a result of prolonged changes in rail usage, as timetabling and delays in procuring vehicles acts as a buffer against short term demand fluctuations. Changes in vehicle type will also have little effect as even new vehicles require routine overhaul.

Reports from industry suggest that the refurbishment market is increasing, for example, due to requirements for rolling stock owners and train operators to comply with more stringent industry regulation for e.g. C4 and C6 classified repairs and refurbishment, which requires increased maintenance on rolling stock. This growth presents an opportune time for new entrants to join the industry and for existing rail engineering companies to expand or build new facilities.⁶⁰

Cost-effective mechanism for improving customer experience

After punctuality, the way a train looks and how comfortable it is will be the major factor in how satisfied a customer is with her rail experience. A complete refit can be a cost effective way for TOCs to extend the life of their vehicles, and still provide customers with up to date cabin equipment and comfort levels. Similarly, freight operators will refit wagons to fulfil the needs of a particular customer.

4.3.5 Marine industry

4.3.5.1 Introduction

The 'marine industries' in the UK manufacture and provide support services in the leisure, naval, commercial, offshore renewable energy and other subsectors. The UK represents approximately 3 % of the estimated global marine sector by sales.⁶⁶ This section will focus on leisure, naval and commercial shipping remanufacture and refurbishment to remain consistent with previous reports in the circular economy evidence building programme. Offshore energy is discussed in Section 4.3.2; however, it can be difficult to separate offshore from marine activities as companies active in the marine sector are often also involved in offshore services, for example, overhaul of floating production, storage and offloading vessels used in the oil and gas industry, could fit in either the marine or offshore sectors.

The Scottish shipbuilding sector contributes almost 33 % of the UK total sales, reflecting Scotland's particular strength in complex, high value naval shipbuilding.⁶⁷ The contribution of the commercial marine sector is much smaller. The British Marine Federation estimates that the leisure, super-yacht and small commercial industries generate revenues of roughly £2.9 billion for the UK (GVA of £950 million), and Scotland is estimated to have a 2.8 % of the UK total.⁶⁸ There are 282 companies

⁶⁶ <http://www.ssa.org.uk/about/our-industry>, Accessed October 2014

⁶⁷ Scottish Aerospace, Defence & Marine Industry Strategy 2009

⁶⁸ Personal communication, 2 October, 2014

employing nearly 1,500 people in Scotland, based on British Marine Federation figures.⁶⁸ The marine leisure industry has been in steady decline since 2008, with revenues dropping 18 % from £100 million to £82 million.⁶⁸ This industry is largely supported through a vibrant - although small - boating tourism industry.

In addition to the revenue generated by small commercial marine, large commercial shipping activities will contribute to the impact of the sector. A report for Maritime UK reported that the Scottish maritime services sector directly employed 41,600 workers in the ports and shipping industries and contributed £2.2 billion to Scottish GDP.⁶⁹

The term 'remanufacture' or 'refurbishment' are not usually associated with ships. The most common and closest terminology is 'refitting'. Refitting includes a variety of operations from basic maintenance and refresh to repurposing and fully upgrading a ship for a different use.

Most ships are refitted during their lifetime. There is considerable time and cost benefits associated with refitting. For example, while a typical cruise ship overhaul can take from 15 days to 1 month, to build a new cruise ship (from design to launch) takes about 3 years (depending on its size, special features, owner, etc.). Although usually significantly longer, naval vessels also benefit from a reduction in refit time compared to new build. In most cases, 'refurbish' is synonymous to 'maintenance and repair' and 'freshen up'. This will cost the company between US\$10-40 million per ship although some refits may cost up to US\$50 million⁷⁰ - this is compared to approximately US\$375-900 million to buy a new ship depending on size.

Particularly for naval vessels, through-life maintenance and support are often of a greater cost than the original build cost (a portion of which will include refit). The sums involved can be significant; for example, major upcoming contracts will be for the two Queen Elizabeth Class carriers, which will provide work for 50 years and are likely to cost upwards of £6.2 billion.⁷¹

Naval remanufacturing operations

There are two major companies in Scotland operating naval shipyards (note that this excludes Faslane, which operates the UK's nuclear submarine fleet). Both are key partners for the MOD:

1. **BAE Systems Maritime** manufactures surface warships and offers through-life support for the UK Ministry of Defence and for other countries. The shipyards at Scotstoun and Govan in Glasgow offer a ship design facility and a steelwork centre of excellence. They employ 3,500 people in Scotland, including 500 design engineers and naval architects. It is also Scotland's largest private sector employer of Modern Apprentices.
2. **Babcock Marine**, the largest division of Babcock International plc, provides engineering and support services to the Royal Navy and specialised commercial markets. The company operates Rosyth dockyard in Fife where its current workload includes a mix of MoD ship refit and repair contracts and civil engineering contracts. Refitting work makes up the 'base load' of many ship yards from which further business is built. At the Rosyth dockyard, HMS Portland, one of the Type 23 frigates, recently spent 50 weeks being refitted in Fife at a cost of £27 million.⁷¹

Until recently, Babcock refitted 75 % of UK surface fleet. This was split between their Devonport (Plymouth) and Rosyth facilities. However, earlier this year, the MOD made a strategic decision to focus on 'new build' ship building in Scotland with the majority of the maintenance and refit activities being undertaken in Plymouth. There are good operational and financial reasons for the maintenance and overhaul activities to be conducted at the home port of a vessel. Therefore, along with BAE Systems – Maritime, the scale of the refit industry in Scotland is being reduced and will have a dramatic effect on the amount of refit work undertaken in Scotland. Although this is likely to be

⁶⁹ Oxford Economics, The economic impact of the UK maritime services sector in Scotland, 2013, [Link](#), Accessed September 2014

⁷⁰ Sector Study on Aerospace-Defence-Marine, AMEC, 2014

⁷¹ UK Parliament website, Scottish Affairs, 3 Refit and maintenance – Rosyth [Link](#), Accessed September 2014

compensated for with an increase in new build ship orders, it appears that the lack of refit 'base-load' may have an impact on shipbuilding in Scotland. This reduction in activity is a continuation of the slow and long decline of shipbuilding in Scotland. In particular, in relation to naval shipbuilding, this decline can be seen as largely precipitated through changes in government policy rather than any commercial or economic factors.

Commercial remanufacturing operations

In addition to activities at naval shipyards, there are a wide range of refurbishment and remanufacturing activities taking place in the marine sector. Several companies active in the naval sector are also involved in commercial activities, for example, Rosyth docks also undertake commercial refits, such as the refit of Bibby Offshore's Polaris Dive Support Vessel.⁷⁰ A range of companies are active in the market ranging from large multi-nationals to SMEs, reflecting the range of scale, complexity and price of marine vessels and their components that are available for remanufacturing and refurbishment. Examples of companies involved in these types of activities in Scotland are shown in the table below:

| Company | Description |
|---------------------------------|---|
| Ferguson Marine Engineering Ltd | The last commercial shipbuilder on the Clyde, recently emerged from administration. They have recently undertaken some refit work on a small vessel and it remains a viable opportunity for the company. |
| Turner Engine Powered Solutions | Involved in refurbishment of diesel engines for marine applications. ⁷² |
| PD&MS Energy | Has been involved in the maintenance and refurbishment of lifeboats and supporting infrastructure (e.g. the davits used to lower the boats into the water). ⁷³ |
| Global Energy Group | Operates ship repair services and vessel upgrades. The type of ships the company works with includes floating production storage and offloading (FPSO) vessels, used in the offshore energy industry, and subsea construction vessels, such as pipelay vessels. ⁷⁴ It can be difficult to clearly separate the marine activities in the offshore industry (e.g. FPSO upgrade) with indirect offshore activities (e.g. pipelay vessel upgrade). |
| Red Rooster Industrial | Involved in the sale, repair and rental of equipment, including ship winches. After the end of each rental contract, the equipment is refurbished before being returned to the rental equipment pool. ⁷⁵ |
| Briggs Marine | The company refurbishes around 220 buoys each year. Refurbishment activities include blasting and painting, steelwork repairs, pressure testing and electrical and lighting repairs. ⁷⁶ |
| Co-at marine | Offers HVAC refurbishment services for passenger vessels and naval ships, as well as offshore platforms, tankers, drilling rigs and FPSOs in the energy sector. ⁷⁷ |
| Macduff Ship Design Limited | Offers design services for a wide range of commercial vessels, including tugs, research vessels, pilot boats, work boats, dredgers, ferries and fishing vessels. As well as offering design services for new builds, the company offers design services for vessel conversions, including re-engining, change of use, fitting new deck machinery, fitting additional |

⁷² Turner Engine Powered Solutions website, [Link](#), accessed 12 November, 2014

⁷³ PD&MS Energy website, Lifeboat compliance, [Link](#), accessed 12 November, 2014

⁷⁴ Global Energy Group website, [Link](#), accessed 12 November, 2014

⁷⁵ Red Rooster Industrial (UK) Ltd website, [Link](#), accessed 12 November, 2014

⁷⁶ Briggs Marine website, [Link](#), accessed 6 November, 2014

⁷⁷ Co-at marine website, [Link](#), accessed 12 November, 2014

accommodation blocks, fitting new structures (e.g. ballast keels and stability tanks), and vessel lengthening. These services may be aligned with refurbishment and refit activities.⁷⁸

| | |
|------------------------------|--|
| Mackay Boat Repair | Based in Inverness, the company offers modification and refit services for yachts, motor sailor and motor boats and refurbishment of wooden hulls. ⁷⁹ |
| Forth Estuary Engineering | A member of the Forth Group, the company offers major refits and conversions, and repairs to hulls, diesel engines, boilers and ancillary machines, for offshore contracts, the MOD and commercial shipping. The company makes use of two dry docks in the Forth Estuary, with the smaller Edinburgh dock handling the majority of commercial vessels. ⁸⁰ |
| Garvel Clyde Limited | Another member of the Forth Group, Garvel Clyde Limited offers similar services to Forth Estuary Engineering, but operates out of the dry docks at Greenock and Troon on the Firth of Clyde. ⁸⁰ |
| Grangemouth Ship Repairs Ltd | This third member of the Forth Group operates out of Carron dry dock and offers similar services to Forth Estuary Engineering and Garvel Clyde Limited. ⁸⁰ |

Table 15 Other companies involved in refurbishment and remanufacturing activities in the marine sector

4.3.5.2 Market size

| Employment | Turnover | % of marine sector | Environmental benefits | Growth potential to 2020 |
|-------------|-------------|--------------------|------------------------|--------------------------|
| 650 persons | £34 million | 1.5 % | Estimate not possible | Low |

Table 16 Market size of marine industry remanufacturing activities

Assumptions:

- We have excluded naval activities.
- The British Marine Federation estimates that boat repair and servicing contribute £17 million to the Scottish economy for the leisure, super-yacht and small commercial sector.⁶⁸ It is assumed that 20 % of this could be considered maintenance and overhaul.⁸¹
- If the same proportion of expenditure on repair and servicing applied to large commercial vessels as to the leisure, super-yacht and small commercial sector, this would suggest £163 million is spent on vessel repair and servicing. It is assumed that 20 % of this could be considered maintenance and overhaul.⁸¹
- If the proportion of employees working on marine maintenance and overhaul scales with revenue, this equates to 1.5 % of sector employees (20 % of 7.4 %).
- The total size of the leisure, super-yacht, small commercial and large commercial marine sector is estimated to be £2.3 billion.
- It is difficult to estimate the environmental benefits of marine industry remanufacturing activities, as the mass of material displaced from disposal or recycling will vary from project to project.
- Commercial ship building and refitting activities have been in decline for many years. This may be somewhat mitigated with growth in specialist shipbuilding but overall the growth potential for ship refitting is expected to be low.

⁷⁸ Macduff Ship Design Limited website, [Link](#), accessed 12 November, 2014

⁷⁹ Mackay Boat Repairs website, [Link](#), accessed 12 November, 2014

⁸⁰ Forth Group website, [Link](#), accessed 12 November, 2014

⁸¹ Oakdene Hollins estimate

4.3.5.3 Trends and barriers

There appears to be a good opportunity to increase the level of refit and refurbishment of vessels in Scotland. Particularly on the banks of the Clyde and Forth, the installed shipbuilding base enables the further development of refit activities. Unfortunately, the largest potential client, the MOD, has focused priority on new shipbuilding in Scotland. Commercial ship building and maintenance appears to be significantly less important in Scotland. Specialist equipment refit, in particular for the oil and gas industry, does occur and will remain important.

| Barrier | Description |
|---|--|
| Lack of capacity | Particularly within commercial shipping, the UKTI identifies the lack of capacity as a key barrier to growth in refitting activities. Without a significant manufacturing base it is very difficult to build a global customer base. |
| National policy toward MRO of naval vessels | BAE Maritime – Naval highlighted that at present it services 100 % of its naval MRO contracts from Portsmouth. This is to suit the logistical needs of their key client the Royal Navy. |

Table 17 Barriers to increased remanufacturing in the marine sector

4.3.5.4 Possible mitigations

There is the capacity, skills and facilities available within Scotland to provide world class refit services, particularly to the naval and specialist sectors. However, the move of MRO services to the Solent may have a detrimental effect on the overall industry. The major shipbuilders rely on MRO as a base load to keep skills and employment relevant. Without major contracts from the MOD, further decline in Scottish shipbuilding may occur. Areas where refit could play a role in increasing role in Scotland are as follows:

- Focus on working with the national trade representatives to develop markets beyond the UK.
- Refocus Scottish shipbuilding on commercial and specialist projects. In particular, there is the opportunity to emulate the industry in the Solent where most of the UK's big super-yacht and small commercial marine manufacturers are based. Conversations with experts suggest that there is some movement to regenerate the Scottish marine industry around the Clyde but there was uncertainty over how advanced they were.⁶⁸
- Look to expand work servicing of the oil and gas industry's fleets. Looking to capture the value of MRO and establish a baseline from which to grow the sector in Scotland.

4.3.6 ICT and mobile electronics

4.3.6.1 Introduction

The ICT and mobile electronics product group includes desktops, laptops, servers, tablets and mobile phones. These products are particularly suitable candidates for refurbishment activities largely due to the high value and complexity of items at the end of their first life. The complexity of the product group means that most of the sector's activities are limited to refurbishment, repair and straight re-use. Additional drivers include: the increasing requirements for responsible disposal of electronic products and the frequent rate of product replacement which often not due to technical failure. Frequent replacement for ICT is driven within the business community on three year cycles and every 18-24 months with mobile phone contracts and upgrades.

The barrier to entry at a basic level (electronically and physically clean and test) is low but increases rapidly because a clean room becomes necessary to undertake more advanced servicing and repair. The most significant barrier to growth and entry into the market is obtaining sufficient high quality used components. Good quality end-of-life ICT equipment has a high value attached to it. ICT refurbisher

Remploy E-cycle estimates the industry can pay up to £75 for a computer (approx. £5,000 per tonne) and still make a margin on resale as either a refurbished item or as parts.⁸²

There is potentially plenty of scope for expansion in the industry: it is claimed that over 80 % of companies dispose of old ICT equipment as waste. Many larger ICT waste management companies offer a complete ICT service package including new installation, life-time upgrades and off-site backups. Re-use then forms just one adjunct of their operation. There is even profit in the waste generated by the refurbisher, as components that cannot be used are segregated to a high degree and sold to an authorised treatment facility for rendering to materials and recycling. Almost every company that operates in the ICT sector alludes to re-use as part of its green credentials.

Mobile phones undergo rapid replacement cycles driven by mobile phone network's contract renewals. There is a ready market both in the UK but particularly overseas for high-quality smartphones. Due to their inherent value, there is also scope for some refurbishment activity, mainly to repair damaged screens and replacement of batteries, prior to resale; however the majority of units are sold without modification (although a data wipe is usually performed to remove user data). As with many other reuse sectors, the market is constrained by supply. The main barrier to increasing supply is in convincing users to sell their old phones quickly after an upgrade.

| Company | Description |
|----------------------------|---|
| Sims Recycling Solutions | Its facility located near Glasgow primarily recycles end-of-life IT equipment, mobile devices and tablets. Other services at the facility include repair and refurbishment of phones and tablets, but only in small volumes. ⁸³ |
| TES-AMM | Global electronics waste recycler with facilities in Irvine, North Ayrshire. The company offers repair, refurbishment and resale services. ⁸⁴ |
| Redeem Limited | An e-waste recycling company that also trades second hand electronic devices and offers refurbishment and repair services. It has production facilities based in Bathgate and Falkirk with a combined total of 100 employees. The two facilities in Scotland generate an annual turnover of £35 million; of which 10 % is attributed to refurbishment of electronics. ⁸⁵ |
| Datec Technologies Limited | Kilwinning-based electronics recycling facility jointly owned by Belmont Trading Company and Sipi Metals Corporation. ⁸⁶ Activities include: recycling end-of-life electronic devices; processing and disposing of IT and telecom e-waste; disassembling electronic devices for re-use of components (e.g. metal recovery); repairing electronic devices; and re-servicing hard drives, computers and laptops. The company has 70 employees operating in Scotland and 20 % of the site's £6 million turnover accounts for product recovery, repairs, and re-use. ⁸⁷ |
| Regeneris | Provides IT aftermarket services to a range of clients, including: equipment and device manufacturers, retailers, insurance providers and satellite and cable TV companies. It has facilities world-wide, with two in Scotland: Glasgow and Glenrothes. ⁸⁸ |
| CCL (North) | Provides WEEE and IT hardware recycling services, including refurbishment of equipment including: monitors, computers, laptops, networking equipment, servers and telecoms equipment. It is an accredited Microsoft Registered Refurbisher and is based in Irvine. ⁸⁹ |

⁸² Oakdene Hollins, private sector report.

⁸³ Personal communication, 23 September, 2014

⁸⁴ TES-AMM website, Regional page for TES-AMM Irvine [Link](#) Accessed 26 September, 2014

⁸⁵ Personal communication, 29 August, 2014

⁸⁶ Belmont Trading Company website, Datec Technologies Limited [Link](#) Accessed 26 September, 2014

⁸⁷ Personal communication, 3 September, 2014

⁸⁸ Regeneris website [Link](#) Accessed 26 September, 2014

⁸⁹ CCL (North) website [Link](#) Accessed 26 September, 2014

| Company | Description |
|-----------------|---|
| Hewlett Packard | HP has a Technology Renewal Centre in Erksine which offers a range of IT management and recovery services such as reverse logistics, refurbishment, remarketing and recycling. HP is partnered with Sims Recycling Solutions and uses its facilities to recycle or dispose of end-of-life products unsuitable for refurbishment. HP process 5,000 IT assets a week ⁹⁰ at its renewal centre. |
| Retronix | Retonix in Coatbridge provides refurbishment services for integrated circuits, e.g. lead straightening, re-tinning and verification tests. ⁹¹ |
| Re-Tek | Has a large facility in Glasgow that is dedicated to the re-use and resale of IT equipment. It focuses on corporate clients, providing a full removal and disposal service, and promotes its security credentials for disposal of sensitive information. ⁹² |

Table 18 Companies involved in remanufacturing and refurbishment of electronics and ICT in Scotland

4.3.6.2 Market size

| Employment | Turnover | % of electronics /ICT sector | Environmental benefits | Growth potential to 2020 |
|-------------|-------------|------------------------------|--------------------------------------|--------------------------|
| 700 persons | £19 million | 0.6 % | 630 tonnes CO ₂ e avoided | High |

Table 19 Market size of electronics and ICT refurbishment activities

Assumptions:

- In 2012, overall turnover in the Scottish manufacturing industry amounted to £32.7 billion.⁹³ Turnover generated in the 'computer, electronic and electrical equipment' was approximately £2.9 billion, whilst GVA stood at £952 million.
- Using employment figures for Redeem Limited and Datec Technologies Limited, assuming all of the remaining companies are large organisations with approximately 100 employees, with the exception of Retronix, which is assumed to have around 20 employees, the number of direct employees in this sector is approximately 700 people.
- Using turnover figures for Redeem Limited and Datec Technologies Limited for their refurbishment and repair activities, assuming that the remaining companies have a turnover of approximately £2 million⁹⁴ (the average of Redeem Limited and Datec Technologies Limited), the total turnover from refurbishment for this group of companies is estimated to be £18.7 million.
- The environmental benefits of remanufacturing are scaled by value from the values reported in the 2009 UK survey (20,000 tCO₂e saved from total re-use with £192.45 million value²). This gives an estimated environmental benefit of 626 tCO₂e avoided.
- The continued move towards portable electronics means that there will be a growing supply of re-usable products entering the marketplace over the coming years. This is likely to increase as wearable electronics and other innovations become available.

4.3.6.3 Trends and barriers

Barriers to the increased uptake of remanufacturing and refurbishment activities identified by stakeholders include:

⁹⁰ Hewlett Packard website, Erskine virtual tour [Link](#) Accessed 26 September, 2014

⁹¹ Retronix website, IC Repair [Link](#), Accessed 26 September, 2014

⁹² Re-tek website, [Link](#), Accessed 31 October, 2014

⁹³ The Scottish Government website, Scottish annual business statistics – key facts, [Link](#), Accessed 26 September, 2014

⁹⁴ Oakdene Hollins estimate

| Barrier | Description |
|--|---|
| Availability of parts | Parts may not be readily available for refurbishment activities. For example, Apple has authorised service providers and parts can only be obtained through them. As a consequence, refurbishers usually rely on harvesting spares from other core. |
| Lack of general standards | The lack of standards for the refurbishment of electronics and ICT equipment results in a range of product performance. It may therefore be difficult for a genuine refurbisher to compete on price against other companies that reportedly sell equivalent products but have undertaken less rigorous processing. |
| Data security | The removal of information and data during the refurbishment process is critical. Without reliable and perhaps even certified data-wiping processes, users may not be willing for their end-of-life products to be used as core for refurbishment and remanufacturing and instead mandate physical destruction of the device. |
| Companies requesting 'new' equipment | Companies' requirement for new equipment limits (either as outright purchase or through a leasing system) the market for remanufactured products. It is usually impractical for large organisations sourcing large volumes of identical equipment; however, smaller organisations could benefit from refurbished products. |
| Illegal activity of electronics waste disposal | The illegal export and sale of unfit electronics equipment reduces the competitiveness of genuine refurbishers because illegal exporters can reduce their overall costs of disposal. |
| User behaviour | Particularly with mobile phones, convincing users to trade in or reuse their mobile phones is difficult. Many users treat their mobiles as 'spares' or the lack of perceived incentive to trade in their old phones prevents reuse. |

Table 20 Barriers to increased remanufacturing and refurbishment in the electronics and ICT sector

4.3.6.4 Possible mitigations

Promotion of the Transform initiative

The Transform Compliance Scheme could be used as a platform to disseminate further information about electronics and ICT refurbishment. It currently encourages companies within the electronics sector to responsibly dispose of e-waste and reduce or eliminate any environmental impact. Measures to achieve this include: increased collection, re-use, recycling and refurbishment of end-of-life electronics or e-waste.

Increasing market for core/spares

Engage with manufacturers to help improve availability of spare parts. With the wide variety of devices and models on the market, an increased access to core and spares will help enable refurbishers to meet the demand for particular products.

Sales to emerging markets

Emerging markets are a large market for remanufactured and refurbished electronic and ICT products. It is important to ensure that any legislation regarding the trade and movement of electronic goods does not penalise the trade of remanufactured or refurbished products, or the movement of electronic core.

4.3.7 *Pumps, fans and compressors*

4.3.7.1 Introduction

This section details the remanufacture of pumps, fans and compressors for use in all applications except where they are used in the oil and gas or renewables sectors. Remanufacture in these industries are described in section 4.3.2.

Pumps

At a simple level, pumps are rotational equipment designed to propel liquid or a liquid-solid mix at a certain rate and pressure. They have applications in a wide range of industries and environments. Pumps operating in a relatively benign environment - such as in freshwater pumping stations - may last for up to 70 years. Those operating in more demanding environments may only last for 12 months before a complete refurbishment is required. It is difficult to describe every type and application of pump available, but there are a number of common elements that may be identified on virtually every pump – see table below.

| Part | Description |
|-------------------|--|
| Chassis or casing | This serves to contain the rotating components of the pump and also acts as a guide to direct the liquid in the desired direction. Depending on the liquid, the chassis will usually be cast from iron or stainless steel. Other more specialised materials are available for highly corrosive or reactive environments. The casing may also be coated with thin film technology to increase its resistance to chemical attack or mechanical wear. Together with the motor, it represents the bulk of a pump's mass. |
| Motor | This drives the rotational elements of the pump and may be either electrical (usual in industrial environments) or internal combustion (for more remote or temporary installations). The motor is usually housed on the chassis but slightly removed from the main body of the pump to enable servicing. A significant proportion of the mass of the pump is in the motor. The manufacturer of the pump will purchase motors from companies such as ABB. Motors are often remanufactured or refurbished, either by the OEM or a specialist facility. |
| Bearings | These are fitted to enable the free rotation of the pump. Once worn, these must be replaced with new, and the old bearings recycled. These will be purchased by the pump manufacturer from a specialist bearings manufacturer. |
| Impeller(s) | This is the rotational element of the pump which actually forces the medium through the pump and provides the motive force. They take a variety of forms and may consist of a single impeller or a pair. Impellers are constructed from a wide range of materials including aluminium, stainless steel and engineering plastics. The impeller is often coated with thin film technology to increase its resistance to chemical attack or mechanical wear. |
| Shaft | This connects the impeller(s) to the motor. It is usually constructed from stainless steel or a similar corrosion-resistant material. The shaft is in constant contact with the bearings and thus may wear over time, and require refinishing or replacing. |

Table 21 Generic components of a pump

Fans

There are no dedicated fan remanufacturers operating in the UK. We did identify one company, Ritmac, that provides fan repair maintenance, but generally intake for maintenance or remanufacture of fans is very low. In most cases the fan casing and impeller rarely require maintenance. Only the motor and bearings could be potential targets for replacement and upgrade.

Where very large heavy duty units do exist, which are embedded in a complex plant and cannot be removed, existing agreements with a service organisations are in place to maintain the fans. Most of the new fan market is now concentrated in smaller or less robust units for ventilation of factories. There is also a market in equipment cooling and for use in scientific equipment. Although regular servicing of the bearings and motor is important, true remanufacture or refurbishment is a niche activity.

Compressors

Compressors are found operating in a large range of industrial and domestic environments, as well as in the automotive, aerospace and oil and gas sector (which are addressed separately). By their very nature, compressors are designed for regular service and renewal of high wear components. This means that they must be easily disassembled and re-assembled, normally with basic workshop tools. They are therefore ideal candidates for remanufacture.

The domestic market is dominated by low value products that are considered uneconomical to remanufacture, and hold little or no resale value. The demand for large industrial compressors has decreased due to the fall in number of large factories. There is however steady demand from pharmaceutical companies and blue chip firms for lab based equipment. The growing globalisation of

the equipment market has brought about entry in some sectors from cheaper Asian brands, forcing UK manufacturers to exit from certain low spec markets.

Compressor OEMs play little or no part in the remanufacturing of their products and see that selling new as their primary business. There are a number of small, independent companies and OEM distributors in Scotland carrying out refurbishment and servicing of compressors, particularly when associated with offering leasing models. Although none of these claims to remanufacture, many do state that compressors will be returned to full manufacturer's specifications upon refurbishment.

HVAC

Compressors are integral to heating, ventilation and air conditioning (HVAC) systems. Remanufacture of HVAC units is limited almost exclusively to the larger plant (> 50 kW) because the lower power markets are dominated by low price competition. Low capacity compressors are also hermetically sealed making remanufacture more difficult; in essence, these units are designed to be thrown away at the end of their useful life.

Although cost is the primary reason for remanufacturing, other factors are also important. Company lease agreements may require that at the end of the tender the building is handed back with working AC. To achieve this, the company can use remanufacturing to significantly increase the lifetime of the AC without requiring a new installation. Another issue with cost is not simply the capital investment in plant, which will only make up approximately 50 % of the overall cost of a new unit; there are significant consultancy fees for recommending new equipment and installation cost can be extremely high. The logistics of installing bulky, heavy equipment on the roof of a working building can lead to prohibitive costs. In addition to these costs is the (less quantifiable) cost of disruption to the workforce occupying the building while the installation is being performed. This makes the remanufacturing option more attractive.

In Scotland, the following companies have been identified as being active in refurbishment of pumps, fans and/or compressors:

| Company | Description |
|--------------------|---|
| Ferrier Pumps | Supplies pumps to a number of different industries. A large part of its operation is devoted to repair and refurbishment of equipment. It has bases in Edinburgh, Glasgow and Aberdeen. ⁹⁵ |
| Ritmac | Specialist manufacturer and supplier of pumps, located in Glasgow. It also provides consulting and maintenance services, including maintenance services for compressors and fans. ⁹⁶ |
| Howden Compressors | Global business that specialises in the manufacture of fans, compressors and heaters. Howden Compressors, based in Glasgow, offers service operations including maintenance, repair, and re-build. Re-build can take the form of a full overhaul of a compressor unit, approaching what would be considered remanufacturing. ⁹⁷ |
| EDC | Electronic Drives and Controls is based in Erskine and specialises in the manufacture of drives, motors and control equipment for air compressors. It provides repair and refurbishing services throughout a product's lifespan. EDC has a small production facility in Erskine (Renfrewshire) that consists of fifteen staff, but its sister company Central Group has larger facilities located in England where most of maintenance is performed on drives, controls and power generators. ⁹⁸ |

⁹⁵ Ferrier Pumps website, [Link](#) Accessed 3 October, 2014

⁹⁶ Ritmac website, [Link](#) Accessed 3 October, 2014

⁹⁷ Howden Group website, Howden Compressors Ltd, [Link](#) Accessed 3 October, 2014

⁹⁸ Personal Communication, 29 September, 2014

| Company | Description |
|---------------------|--|
| Airmac-Gdi | Small engineering company based in Glasgow that specialises in the manufacture, maintenance and refurbishment of air compressors. The company consists of five employees and has been in operation for four years. ⁹⁹ |
| Kerr Compressors | Large player in the Scottish compressors market. ⁹⁹ It manufactures and services compressor units, vacuum pumps, and blowers. |
| Scot Industrial Air | Supplies industrial compressors and associated equipment. This company is located in Aberdeen and Glasgow, and also provides maintenance and refurbishing services to used or end-of-life compressors. ¹⁰⁰ |
| Griffin Air Systems | Specialists in the manufacture of compressors, it also provides maintenance, refurbishment and design services. ¹⁰¹ |
| Speck and Burke | A supplier of compressors and pumps based in Alva, Clackmannanshire. It also reconditions and sells gas compressors, generators and vacuum pumps. ¹⁰² |
| Plenty Pumps | Located in Glasgow and specialises in the manufacture, maintenance, and remanufacture of pumps. It is owned by the OEM, SPX, a global manufacturing and industrial equipment supplier. ¹⁰³ |

Table 22 Companies involved in refurbishment of pumps, fans and/or compressors in Scotland

Energy efficiency

When considering the suitability for remanufacturing of energy consuming industrial equipment such as pumps, fans and compressors, it is important to consider the energy in use, not just the initial production energy. The chart below shows the cost of running an air compressor over its lifetime.¹⁰⁴

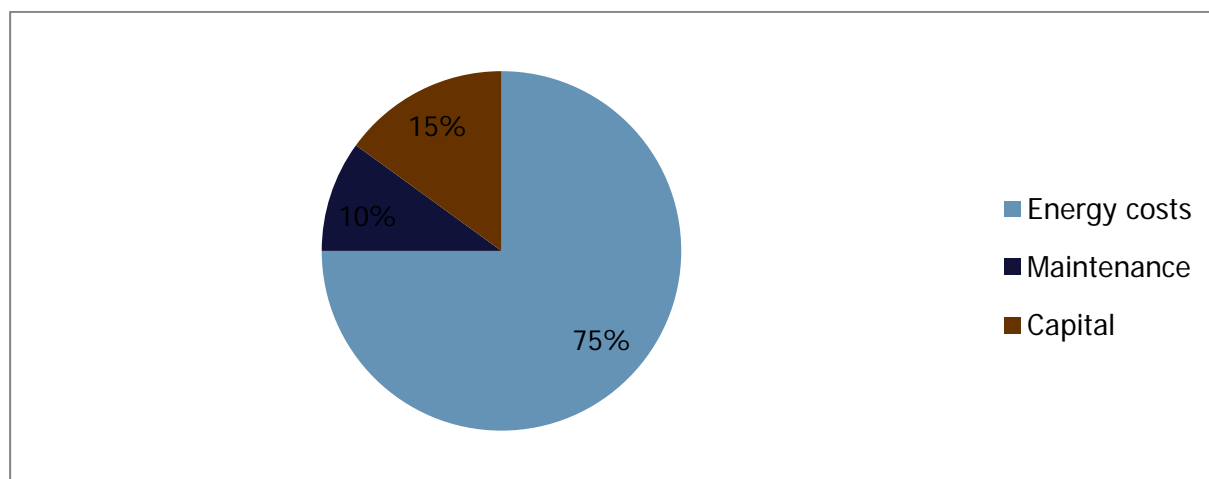


Figure 4 Compressing air costs

With 75 % of the overall cost attributed to operating energy, the purchasing cost and thus embodied energy of the product (15 %) becomes a secondary consideration. Where a more efficient new product is available (for example the recent move to variable drive technology), it may make economic and

⁹⁹ Personal communication, 2 October, 2014

¹⁰⁰ Scot Industrial Air website, [Link](#) Accessed 3 October, 2014

¹⁰¹ Griffin Air Systems website, [Link](#) Accessed 3 October, 2014

¹⁰² Speck and Burke website, [Link](#) Accessed 3 October, 2014

¹⁰³ SPX website, Plenty, [Link](#) Accessed 3 October, 2014

¹⁰⁴ ETSU, Good practice guide 241, Energy savings in the selection, control and maintenance of air compressors, 1998 [Link](#) Accessed 3 October, 2014

environmental sense to recycle the old unit and install a new one. The data for pumps and fans also highlights the operating energy to be a major factor in the remanufacture / recycle decision. This situation can be mitigated where energy efficiency upgrades can be incorporated during the remanufacturing process. It is therefore necessary to evaluate each case individually.

4.3.7.2 Market size

| Employment | Turnover | % of pumps, fans and compressors sector | Environmental benefits | Growth potential to 2020 |
|-------------|-------------|---|--|--------------------------|
| 360 persons | £30 million | 9 % | 3,500 tonnes CO ₂ e avoided | Low |

Table 23 Market size of pumps, fans and compressors remanufacturing activities

Assumptions:

- We estimate that 12 companies make up the compressed air manufacturing and maintenance in Scotland. Total turnover for the sector is reported to be £50 million⁹⁹ of which approximately 30 % arises from refurbishment activities.
- Equivalent data for the pumps subsector has not been identified, so we assume that it is the same size as the compressor subsector, i.e. £15 million.¹⁰⁵
- We assume there is negligible remanufacturing activity in the fans subsector.
- Assuming that the 24 compressor and pump remanufacturing companies employ 15 people, on average,¹⁰⁵ we estimate that 360 people are employed in this area.
- We estimate that the total turnover arising from pumps and compressor remanufacturing activities is approximately £30 million.
- High level figures for the market size of the pumps and compressor industries report that the revenue for manufacturing pumps in the UK is £3 billion¹⁰⁶ and the revenue for manufacturing compressors is £553 million.¹⁰⁷ No comparable data for fans could be found. Scaling this revenue from the UK to Scotland using GDP, gives an estimated total market size of £320 million (Scottish GDP: £148 billion;¹³⁷ UK GDP: £1,650 billion¹³⁸). Therefore, remanufacturing activities represents about 9 % of the sector activity.
- The environmental benefits of pump and compressor remanufacturing can be scaled by monetary value from the figures in the 2009 UK survey, which reports 30,680 tCO₂e avoided through £260 million re-use activity.²
- The potential growth in pump sales is relatively modest because the market is largely saturated. There appears to be little market for remanufactured fans. There does, however, appear to be some potential increase in compressor remanufacturing, but the overall prospects for increased sales in this area are low.

4.3.7.3 Trends and barriers

| Barrier | Description |
|---------|--|
| Costs | Refurbishing a compressor can be a costly option. For instance, the value of remanufactured compressors is 75 % of a new unit. Only compressors of over £1,000 are considered for remanufacture. Therefore, general maintenance - such as repairs and replacement of components - is more common in order to maximise a compressor's lifespan before considering end-of-life options: refurbishment or new purchase. |

¹⁰⁵ Oakdene Hollins estimate

¹⁰⁶ Ibis World website, Pump manufacturing in the UK: market research report, [Link](#) Accessed 3 October, 2014

¹⁰⁷ Ibis World website, Compressor manufacturing in the UK: market research report, [Link](#) Accessed 3 October, 2014

| Barrier | Description |
|------------------------------------|---|
| Attitude of OEMs towards old units | Some OEMs offer an exchange service on old parts which are then generally scrapped and recycled. With a large network of distributors and service agents, there is a ready means of recovering old cores, possibly on an exchange basis. |
| Heavy industry decline | A reduction in demand for heavy-duty fans has mirrored the decline in heavy industry, particularly mining. |
| Regulation (trend) | One EDC employee observed that the Scottish sectors where remanufacturing activity primarily takes place is in electronics and oil and gas sectors because they are highly regulated. In these sectors product design, maintenance and waste management are generally areas of focus for new or amended regulation. Upgrading product specifications tends to follow regulatory changes, and refurbishment or overhaul is considered a cheaper alternative to the manufacture of new products. Although this trend is reactionary to regulation, it is indirectly promoting remanufacturing activity. |

Table 24 Barriers to the increase of pumps, fans and compressors remanufacturing activities

4.3.7.4 Possible mitigations

Purchaser transparency

Introduce a rating system for new equipment that describes its suitability for remanufacture and upgrade. This will help promote the procurement of equipment which is more suited to remanufacturing as a planned maintenance operation.

Promotion

Produce promotional material aimed at operations managers of small to medium sized facilities, clearly describing the benefits of using remanufactured compressors.

4.3.8 Ink and toner cartridges

4.3.8.1 Introduction

Ink and toner cartridges are used in the two dominant printer technologies: ink cartridges are used in inkjet printers and toner cartridges used in laser printers. Inkjet cartridges may either consist of a separate print-head and ink reservoir, or of a unified print-head cartridge (a cartridge that contains both an ink reservoir and a high precision print-head). Unified cartridges are regularly remanufactured whereas the lower cost of the separate print-head and reservoir cartridges prohibits their remanufacture. Toner cartridges are higher value than ink cartridges, containing a large aluminium print head and more than 100 moving parts, meaning they are widely remanufactured.

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

The cartridge remanufacturing industry has historically been in conflict with OEMs manufacturing new cartridges. The OEM's business model is to use printer sales as loss leaders and make a significant margin on the sale of new cartridges. Competition in the cartridge market from remanufacturers is seen by OEMs as a significant threat; however, the rise in import and sale of 'compatible' cartridges is perhaps more pressing, due to copyright infringements and the fact that compatible cartridges can undercut both new and remanufactured cartridges.

The 2009 UK remanufacturing survey estimated that there were approximately 400 cartridge remanufacturers in the UK.² However, very little remanufacturing activity was identified in Scotland. Edinburgh-based company Proprint sells remanufactured cartridges; however, it does not remanufacture the cartridges itself.¹⁰⁸ Smart Cartridge, another Scottish retailer of remanufactured cartridges, has no remanufacturing facilities in Scotland; these facilities are primarily based in England.¹⁰⁹ Both Proprint and Smart Cartridges were only able to identify one cartridge remanufacturer active in Scotland: Effective Consumable Solutions (EDC), acquired cartridge remanufacturer Tinto Laser in March 2014, which remanufactures toner cartridges at its facilities in Bellshill, near Glasgow.¹¹⁰ The company has undergone a brand change and now trades as Green Agenda and employs 30 people.

4.3.8.2 Market size

| Employment | Turnover | % of ink and toner cartridge sector | Environmental benefits | Growth potential to 2020 |
|------------|--------------|-------------------------------------|-------------------------------------|--------------------------|
| 30 persons | £6.6 million | 11 % | 88 tonnes CO ₂ e avoided | Low |

Table 25 Market size of ink and toner cartridges remanufacturing activities

Assumptions:

- Assume that there is only one cartridge remanufacturer whose remanufacturing operations take place in Scotland.
- Based on the employment data in the 2009 UK survey the average size of a cartridge remanufacturing organisation is 5 employees.² Assuming there is only one of 30 employees is active in remanufacturing activities in Scotland, the approximate turnover of the sector can be estimated based on the value of the UK remanufacturing sector in the 2009 UK survey (£435 million from 400 companies). This gives an estimated value of £6.6 million.²
- Over 65 million printer cartridges are estimated to be sold each year in the UK.¹¹¹ Assuming the average price of a printer cartridge is £10, this gives an estimated UK market size of £650 million. Scaling this revenue from the UK to Scotland using GDP gives an estimated total market size of £58 million (Scottish GDP: £148 billion¹³⁷; UK GDP: £1,650 billion¹³⁸). Therefore, remanufacturing activities represents about 11 % of the sector activity.
- The environmental benefit of cartridge remanufacturing is scaled from the value of the whole UK remanufacturing sector in the 2009 UK survey (6,287 tCO₂e). This gives an estimated environmental benefit of saving 88 tCO₂e.
- Remanufacturing in Scotland appears to be declining and moving either to England or overseas. As a result, the expected growth potential in this area is expected to be low.

4.3.8.3 Trends and barriers

Trends identified by printer cartridge stakeholders in Scotland include the observation that the cartridge remanufacturing industry in Scotland has been declining¹⁰⁸ with many remanufacturers either leaving the industry or moving their remanufacturing operations to England. In the past two years, three UK remanufacturers went into liquidation: Phoenix Printer Solutions Ltd., Green Cartridges Ltd., and Tanark.¹¹² Additionally, cartridge retailers have noticed a recent trend in rising demand for DIY ink filling kits, which are cheaper and easier to supply than remanufactured products.¹⁰⁸

¹⁰⁸ Personal communication, 29 August, 2014

¹⁰⁹ Personal communication, 9 September, 2014

¹¹⁰ The Recycler, ECS acquires Tinto Laser, 19 March, 2014 [Link](#) Accessed 30 September, 2014

¹¹¹ The Recycling Factory website, [Link](#) Accessed 3 October, 2014

¹¹² The Recycler, Tinto Laser placed in liquidation, 16 January, 2014 [Link](#) Accessed 30 September, 2014

| Barrier | Description |
|-----------------------------------|---|
| Competition from low cost imports | In China, there is a large manufacturing industry of compatible ink and toner cartridges which have eaten in to Scottish remanufacturing businesses. Some of these compatible cartridges may infringe OEM IP and patents. Such illegal items reduce the available market for genuine remanufactured cartridges. This is the main barrier to increased remanufacturing in the ink and toner cartridge sector. |
| Core availability | Remanufacturing activities for printer cartridges rely on remanufacturers being able to obtain the cartridge core. For inkjet cartridges (mainly for personal use), remanufacturers with walk-in shops may collect core based on an exchange basis. Other collection schemes may rely on postal schemes, in which customers can send off their core in special pre-paid envelopes, or through charity collections. For the larger and more expensive toner cartridges more commonly used in businesses, remanufacturers may offer special collection services. Core may also be purchased on the market. However, most inkjet cartridges are currently landfilled, and there is scope to improve the core recovery rate. |
| Microchips | Most ink and toner cartridges manufactured by major corporates are increasingly complex to disassemble and have installed sophisticated microchips which add extra functionality e.g. indicating ink levels or number of pages printed. However, allegations from the remanufacturing sector claim these chips are designed to prevent remanufacturing; for example, preventing it from printing after a certain number of pages or after it has been removed and re-inserted into the printer. These issues can be overcome by substituting the OEM chip with a third-party smart chip, which will add cost to remanufacturing. Although technically possible, hacking the chip to overcome this barrier is a breach of the OEM's intellectual property. |
| Public perception | The public generally perceive remanufactured cartridges to be inferior to new, branded OEM cartridges. This may be because the public are not aware of the difference between refilled cartridges, which are likely to be of a lower quality, and remanufactured cartridges, which will have undergone print tests and generally have a low return rate. |
| IP and patents | Remanufacturers must be careful that their use of compatible components does not infringe any of the IP or patents of the OEM. This also applies to compatible ink design. OEMs have been known to take legal action against remanufacturers, which can be a significant disincentive, even if the remanufacturer is cleared of any infringement. |

Table 26 Barriers to increased remanufacturing in the ink and toner cartridge sector

4.3.8.4 Possible mitigations

Improve core return rates

Improving the core return rate for inkjet cartridges could help growth the remanufacturing industry, either for sale in Scotland and the UK or overseas. Uncollected cartridges will end up in landfill. Remanufacturing represents an established and effective way to divert waste from landfill while creating value.

Distinguish between remanufacture and re-use

There are clear differences between the processing of remanufactured and refilled cartridges, which lead to differences in the product quality. Educating the public to differentiate between remanufacture and simple re-use will help customers understand, value and trust the remanufactured brand. The UK Cartridge Remanufacturers Association (UKCRA) permits licenced members to use its logo, the UKCRA rosette, to identify the company as a licenced and practising remanufacturer.¹¹³

¹¹³ United Kingdom Cartridge Remanufacturers Association website, [Link](#), Accessed 30 September, 2014

Eliminating compatible cartridges from the market

Eliminating from the market compatible cartridges that currently infringe the copyright of OEMs would likely increase the market for remanufactured cartridges, as remanufactured cartridges currently compete with compatible cartridges on price.

4.3.9 Medical equipment

4.3.9.1 Introduction

The term 'medical devices' covers some 8,000 different types of products.¹¹⁴ The market is a relatively stable one, largely insulated from the economic cycle. Government spending on healthcare tends to remain the same or increase year on year, as to do otherwise would be unpopular with the general public. In Scotland, the annual expenditure on medical equipment is £45 million (this does not include capital expenditure)¹¹⁵ and the replacement value of NHS Scotland medical devices is estimated to be £760 million (Figure 5).¹¹⁵ Previous research has highlighted that medical imaging is an active area of remanufacturing and will be the focus of this section. This makes up over a quarter of total expenditure on medical equipment by NHS Scotland.

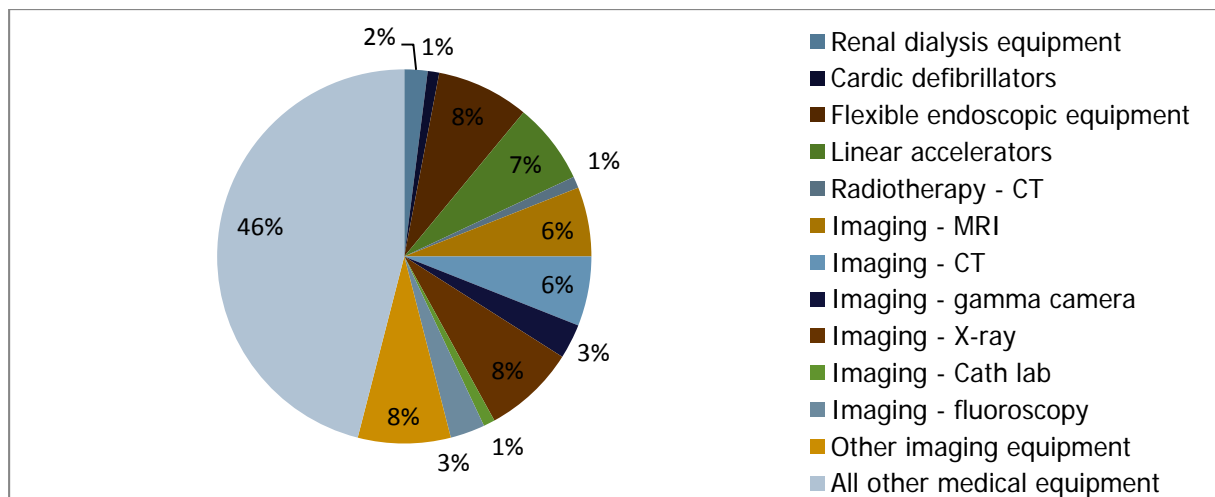


Figure 5 Replacement value of all medical equipment (£760m) in 2013

The market is a global and highly competitive one, with a high emphasis placed on continuing research and development.¹¹⁶ Such a focus, while ensuring that improved devices are constantly entering the market, also means that equipment can date quickly, and health organisations find themselves under pressure to update to and use the latest equipment. As a consequence, working yet older equipment is consistently replaced.

The ready availability of older high quality equipment enables a strong refurbishment industry in the USA and Europe. It is important to note that the words 'remanufacture' and 'refurbish' have significantly different meanings when applied to medical devices within the EU. This difference is defined within EU Regulations. When a medical device is 'refurbished' it is repaired, cleaned and updated to relevant safety standards. Such procedures take it back to the original state and scope of the device when it was placed on the market as a new item: i.e. it is of the same standard as a new item. Thus its conformity, as defined under EU Regulations, is ensured and it retains its CE marking.

A medical device is 'remanufactured' when the repairs and updates take the scope and state of the device beyond its original position i.e. it is 'better' than a new device. At this point it essentially

¹¹⁴ Enterprise and Industry EU website, [Link](#) Accessed September, 2014

¹¹⁵ The Scottish Government, Annual state of NHS Scotland assets and facilities report for 2013, 2013 [Link](#) Accessed 2 October, 2014

¹¹⁶ Keynote report, Medical Equipment Market Report, 2003

becomes a different device and must reapply for conformity and for a CE marking. Remanufacture as defined in the Medical Device Directive is rare in Europe, while refurbishment is well established and is a growing area.

There are two distinct groups that refurbish medical devices. In the first group refurbishment is performed by the OEM. Such refurbished products are generally offered back into the medical institutions of the developed world. The second is when refurbishment is carried out by a separate third-party, and the devices are often sold into veterinary medicine, or to medical institutions in developing countries.

Many of the large medical manufacturing companies offer refurbished imaging systems. Such systems are ideal for refurbishment as they are non-invasive, involve a considerable capital outlay to purchase and represent a significant manufacturing investment. Leading medical device manufacturing companies that advertise refurbished systems in their literature are Siemens, GE and Philips.

Internationally there is also an active third party remanufacturing industry. These organisations provide a range of activities from genuine refurbishment through to brokerage. The warranties provided ranged between thirty days and one year for the companies identified through this work. This best practice is voluntary as no industry standards exist for this work.

OEM refurbishing programmes aim to supply the higher end of the medical device market, focusing on publicising the quality of the products and the quality of the service to the purchasers. At the same time they stress that purchasing such items from third party refurbishers may not yield the same quality of product.

COCIR is the European Coordination Committee of the Radiological, Electro-medical and Healthcare IT Industry. Its green paper entitled *COCIR Good Refurbishment Practice (GRP)* was written by those of its members with refurbishment programmes and was released for consultation in November 2007.¹¹⁷ The aim of this guide is to identify and outline good refurbishment practice. COCIR intends this guide to help healthcare providers distinguish well refurbished devices from poor quality ones, to inform governments about GRP for their regulatory work and to motivate industry to improve the safety and effectiveness of used medical equipment by creating process standards. COCIR is also engaged in discussions with the Chinese to promote refurbished medical devices that are of an appropriate standard and covered by adequate warranties.

The worldwide market for refurbished medical systems is estimated to be worth over a billion dollars annually, with an expected growth rate of 10 % each year.¹¹⁸

The market for refurbished devices in the UK is largely restricted to private hospitals and vets' practices. Much of the refurbished equipment produced worldwide is sold to developing countries. The largest Scottish market, NHS Scotland, does not buy refurbished medical equipment, although some equipment may be refurbished on site and some repairs may involve refurbished parts. This does not appear to be explicit policy but a consequence of the procurement practices within the NHS. Our desk-based research did not identify any companies active in the remanufacturing or refurbishment of medical devices in Scotland.

Further work is being undertaken on this area by Zero Waste Scotland and Scottish Enterprise and has shown that Scotland has an active medical equipment manufacturing industry which would suggest that there are significant opportunities in this area for growth.

¹¹⁷ COCIR Green Paper: Good Refurbishment Practice for Medical Electrical Equipment, November 2007.

¹¹⁸ Frost and Sullivan market research quoted in Siemens Press Release, Medical Solutions, 2005.

4.3.9.2 Market size

| Employment | GVA | % of medical equipment sector | Environmental benefits | Growth potential to 2020 |
|------------|-----|-------------------------------|------------------------|--------------------------|
| N/A | N/A | N/A | N/A | High |

Table 27 Market size of medical equipment remanufacturing activities

Assumptions:

- There is no remanufacturing activity taking place in Scotland in the medical equipment sector.
- There is a significant opportunity to grow this sector with the establishment of procurement specifications within NHS Scotland.

4.3.9.3 Trends and barriers

Siemens reports that it has experienced an increase in demand for refurbished systems; in 2006/2007 over 800 refurbished systems were purchased¹¹⁹ whereas in 2002 only half as many were sold.¹²⁰ Although these figures are encouraging, use of refurbished medical devices varies greatly worldwide. OEM and third party refurbished devices are common in the USA, with its privatised health care system. In Europe, Germany has the largest incidence of using OEM refurbished devices, in part facilitated by a state payment system that pays a set fee per activity performed, irrespective of the equipment used to perform it. The activity of brokers is also particularly strong in Germany. Some use of OEM-refurbished devices occurs in France, also in Spain and Italy. In the UK no specific examples of use of OEM-refurbished devices in NHS hospitals were identified. Although the chances for increasing remanufacturing in Scotland are low, there are opportunities to reduce costs through the purchase of remanufactured imaging equipment, particularly for NHS Scotland.

| Barrier | Description |
|--------------------------------|---|
| NHS Scotland purchasing policy | <p>NHS Scotland dominates all medical related markets in Scotland. Current funding patterns within NHS Scotland mean there is no long-term, centrally agreed replacement programme for imaging equipment. Therefore when the opportunity to replace equipment arises, a Trust often seeks to purchase the most advanced system available within the budget. This may be over-specified initially, but can go some way to 'future-proofing' the equipment. Advanced equipment can also be a positive draw when trying to attract new staff members or research opportunities.</p> <p>There is also a preconception that refurbished medical devices would be sub-standard and do not provide the best patient care. This, combined with a lack of incentive to for procurers to save money, has resulted in the exclusive purchase of new medical imaging systems.</p> |
| End-of-life disposal routes | <p>When a medical device reaches the end of its useful life there are various disposal options. One possibility is to exchange the old system with the OEM as part of the purchase of a new system. Another is to sell old systems to a third party for refurbishment and onward sale. Both of these options allow the residual value of the item to be realised and retained by the hospital. There are many occasions when neither of these options occurs, as there is strong concern in the UK that refurbished medical equipment would be traceable to the original hospital, and some responsibility would be retained should the device malfunction. Therefore end-of-life medical devices may often be sold to auction houses to prevent traceability, or sold as scrap. Such an arrangement means that the NHS retains very little of the market value of these items. Sale for scrap also reduces the number of units available for refurbishment by OEMs or third parties.</p> |

¹¹⁹ Siemens Healthcare, EHS report 2008, [Link](#) Accessed 2 October, 2014

¹²⁰ Siemens Press Release, Medical Solutions, 2005.

| Barrier | Description |
|--------------------|--|
| Lack of incentives | While there are no specific restrictions against the import and sale of refurbished medical devices in the UK ¹²¹ there appears to be little activity to encourage it either centrally or from equipment manufacturers. A combination of the above barriers combined with low levels of promotion means that very few refurbished medical devices are used in UK hospitals. In general public healthcare systems are less receptive to refurbished medical devices than private healthcare systems. Private healthcare institutions often operate on smaller budgets that are more flexible than public ones and a saving made through the purchase of a refurbished system can be used elsewhere in the institution. |

Table 28 Barriers to increased refurbishment in the medical devices sector

4.3.9.4 Possible mitigations

Core availability

The most significant driver in the field of medical devices is developing new technology. The pace of advancing technology in this field is rapid. The intervals between the purchasing of superior systems are shortening, and a greater number of devices with significant use periods still remaining are being returned to the OEMs or bought by third parties to sell on. There are therefore increasing numbers of devices available for refurbishment containing technology that is still relatively advanced.

Education and awareness

The environmental benefits of medical device refurbishment could be promoted to help invigorate the market. Purchases of refurbished non-critical equipment could demonstrate to users the quality and functionality of refurbished equipment. Once sufficient understanding and trust in products has been established, procurers will be more willing to consider other refurbished devices. Education and awareness building may be most effective via OEMs who refurbish equipment as they can demonstrate how the quality of their new equipment is equivalent to the quality (but perhaps not functionality) of their refurbished equipment.

NHS purchasing policies

As the largest user of medical devices in Scotland, developing purchasing policies in NHS Scotland that promote greater use of refurbished medical equipment could help grow the market, and encourage OEM and third-party refurbishers to develop operations in Scotland.

4.3.10 Tyre re-treading

4.3.10.1 Introduction

There are two different remanufacturing processes performed on used tyres:¹²²

- **Re-grooving:** New tread is cut into a specifically designed bald tyre. This is common practice for truck and bus tyres, with estimates as high as 60 % of all tyres going for re-grooving before re-treading. This practice is illegal for car tyres.
- **Re-treading and re-moulding:** Re-treads and re-moulds involve applying new rubber to the tyre to extend its life. Re-treading involves gluing a pre-vulcanised rubber tread onto a bald tyre casing, whereas re-moulding involves injection moulding rubber onto a tyre casing to form a new tread, then vulcanising the rubber tread *in situ*. Within the industry, re-moulding is considered to produce a higher quality product. Both terms are regularly interchanged and industry statistics are not available to differentiate between the two processes. Therefore the term 're-tread' will be used to encompass both re-treading and re-moulding.

¹²¹ Global import regulations for pre-owned (used and refurbished) medical devices, US Department of Commerce, 2006

¹²² Definitions taken from: Centre for Remanufacturing and Re-use, Product group report: tyres, 2009

Used tyres arise from three sources: cars, trucks/bus and specialist sources including aircraft and off-road equipment. The majority of arisings by number are car tyres. By weight, approximately one-third of all arisings are from trucks, with only a small fraction from specialist sources. In contrast, the fraction of re-treading in these categories is reversed: Due to their cost and traceability, virtually all specialist tyres (in particular aerospace tyres) are remanufactured at least once, with truck and bus tyres undergoing an initial re-groove followed by a remould. In contrast, the percentage of car tyres remanufactured is very low.¹²³

The British car re-treading industry disappeared in the 1990s after the market was flooded with Chinese imports. This situation is now being mirrored in the higher value UK truck tyre re-treading industry. Anecdotally, re-treaded truck tyres are higher quality and longer lasting when compared with Chinese tyres, but this is a difficult message to convey to an industry that is very cost competitive and largely looks at up-front cost. However, the Tyre Industry Federation notes that rising raw material prices may challenge this price advantage, making re-tread more competitive.¹²⁴

In 2010, the latest year for which data are available, 8 truck tyre re-treads were sold for every 10 new truck tyres in the UK.¹²⁴ The higher inherent value of truck tyres (and therefore the used casings) incentivises remanufacturing. Large fleet operators are more value-conscious than other purchasers, and have traditionally under-pinned this sector. This has also led to a thriving tyre leasing model where fleet operators are charged per mile rather than per tyre.

Major retreaders in Scotland include:

| Company | Description |
|-----------------------------|---|
| Alba Tyre Management (Alba) | Specialises in truck tyre re-treading and has been operating in Scotland since 2004. The SME sized company consists of 27 employees, and produces up to 22,000 re-treads a year. Operations at Alba consist of 97 % truck tyre re-treading and 3 % tyre repairs. ¹²⁵ |
| Caledonian Tyres | Production reported at 20,000 re-treads a year. ¹²⁶ |
| Redpath Tyres | An independent tyre company and specialise in earthmover and truck tyre re-treading and vulcanised tyre repair. The company is mostly Scotland based with facilities in major cities (Edinburgh, Aberdeen and Stirling) and its main office is located on the Scottish border in Duns. ¹²⁷ |

Table 29 Scottish re-treading companies

4.3.10.2 Market size

| Employment | Turnover | % of sector (by volume) (truck tyres only) | Environmental benefits | Growth potential to 2020 |
|------------|--------------|--|-----------------------------------|--------------------------|
| 50 persons | £3.5 million | 45 % | 2.7 million litres of oil avoided | Medium |

Table 30 Market size of tyre re-treading activities (truck market only)

Assumptions:

¹²³ Centre for Remanufacturing and Re-use, Product group report: tyres, 2009

¹²⁴ Tyre Industry Federation, Factbook 2011, A guide to the UK tyre industry from manufacture to end of life reprocessing, [Link](#), Accessed 1 October, 2014

¹²⁵ Personal communication, 10 September, 2014

¹²⁶ Personal communication, 11 September, 2014

¹²⁷ Redpath Tyres website [Link](#) Accessed 4 November, 2014

- The Scottish truck tyre re-treading industry produces approximately 40,000 re-treads annually.^{125,126}
- The turnover of the Scottish truck tyre re-treading industry is approximately £3.5 million.
- Assuming 8 out of every 18 truck tyre sales are re-treads, the percentage share of the re-tread industry for truck tyres by volume (not turnover) is approximately 45 %.¹²⁴
- Retreading a truck tyre uses 68 litres less oil than manufacturing a new tyre and re-treading a car tyre uses 20 litres less oil than manufacturing a new tyre.¹²⁸
- Assume a saving of 68 litres of oil per tyre as the majority of the retread industry is for truck rather than car tyres.¹²⁹
- Specialist and truck/bus tyres are retreaded as a normal part of the product lifecycle; conversely, car tyres are probably too low-cost to be economically viable. There is, however, an opportunity to retread light commercial vehicle tyres for delivery vehicle fleets. Therefore, the likely growth potential will be medium.

4.3.10.3 Trends and barriers

There are several contributory factors for the small percentage of re-tread activity in the car sector:

| Barrier | Description |
|----------------------|---|
| Public perception | The public perceives that re-treads are poor quality, and therefore unsafe. |
| OEM lock-in | Tyre distributors have a tendency to favour certain OEM makes or they will not offer re-treaded tyres as an option to the customer. This is largely due to perceived rolling resistance savings from these particular tyres that can drive fuel efficiency savings. |
| Poor availability | For car tyres, the low usage rates mean that in some regions, there is a poor availability of re-tread distributors. |
| Low cost competition | The cost-conscious budget tyre market is extremely competitive compared to the cost of remanufactured tyres. |

Table 31 Barriers preventing the expansion of car and light commercial vehicle re-treading.

4.3.10.4 Possible mitigations

Examine re-treading possibilities on light commercial vehicles

Re-treading of truck/bus and specialist tyres happens as a matter of course. The car tyre market is the biggest potential market for re-treaded tyres. Safety concerns could now be counteracted with examples from the truck and aerospace industry that show re-treading produces high quality, high performance tyres and that there is little technical reason why these practices could not be implemented throughout the road vehicle sector. However, at present, the marginal cost difference between retreaded tyres and budget new tyres means that an increase in this market is unlikely in the near term. A more appropriate market which could be further encouraged through trials and action research would be with light commercial vehicles. For example, home delivery fleets, NHS and delivery vans for regional manufacturers or distributions centres could use re-treaded tyres.

4.3.11 White goods

4.3.11.1 Introduction

The remanufacture and refurbishment of white goods is a well-established industry due to their modularity, ease of repair, abundance and relatively high cost. They are not regarded as a being subject to fashion or rapid innovation. Indeed, the prevalence of fitted kitchen units with embedded

¹²⁸ Retread Manufacturers Association website, Why use a retread, [Link](#), Accessed 1 October, 2014

¹²⁹ Oakdene Hollins estimate

white goods that have replaceable fascias is reducing the perceived requirement to replace these units until they become uneconomic to repair. Repair and remanufacture of these units, therefore, is generally commercially unviable. In the case of fridge freezers, the arisings of working units is further reduced because old working fridges are generally retained as secondary units for cooling drinks.

The resale and re-use of older white goods (greater than five years) is dominated by social enterprises where margins are relatively low and the end product is usually destined for secondary markets (for example, low income households and social housing). These goods are usually sourced through donations direct from the public or from Household Waste Recycling Centres (HWRC). However, due to the poor condition of white goods at HWRCs, only 1-2 % of goods are suitable for re-use/ remanufacture.

There are approximately 35 social enterprises within the Community Resources Network Scotland (CRNS) that accept and sell white goods. In addition to this umbrella organisation, charities such as the British Heart Foundation also have a presence in Scotland. As well as providing low cost white goods to disadvantaged households, these schemes give employment for the long term unemployed and socially disadvantaged by providing skills and training programmes as well as raising funds for various good causes.

More valuable used white goods are sourced from households that want to exchange old white goods when buying new. This usually requires contracts with white goods retailers. The retailers themselves want to minimise cost but also ensure that their reputation remains undamaged (either through inappropriate disposal or poor customer experience). As a result, these markets are usually restricted to large, well organised charities and commercial operations that can operate over a large geographical range.

There is also an active market selling returned, damaged and end of line goods. As most appliances are imported, there is little infrastructure in Scotland for repairing and returning damaged goods to customers. Cosmetic damage, such as scrapes and scuffs during transport, are difficult to repair as the damage can be to panels welded to the chassis. Mechanically, the units maybe in perfect working order; however, they cannot be sold 'as new' and are not wanted by customers. Although there is an infrastructure to repair and return certain appliances back to the customer, it is common practice to replace faulty equipment with new. There is a competitive market for factory seconds both from the private sector companies and social enterprises. Agreements between retailers or manufacturers and re-use organisations have been developed to resell these units. Products are sold through a variety of outlets including on-line auction sites and retail discount centres.

The amount of true remanufacture undertaken within this sector is relatively low. Most activities ensure that the product is functioning with some small remediation undertaken where faults are found. Therefore any estimates over the size of the remanufacturing and refurbishment market should take into account that most of the activity within this sector is more akin to straight re-use.

Verifying that a reconditioned appliance is in full working order requires a live test. This means every washing machine has to be connected to electrical power, water and drain and run through an extended cycle not only the check basic operation but also verify the absence of defects such as weeps and drum imbalance. While straightforward, undertaking this type of testing in volume requires a large space, appliance moving machinery and an installed plugs, water and waste to do live tests.

Commercial refurbishers of white goods were not found in Scotland. Their bases were mainly in England and Northern Ireland, suggesting that either English-based re-users would ship units from Scotland or that the market was completely served by social enterprises.

4.3.11.2 Market size

| Employment | Turnover | % of white goods sector | Environmental benefits | Growth potential to 2020 |
|------------|--------------|-------------------------|--|--------------------------|
| 70 persons | £1.1 million | <1 % | 1,400 tonnes CO ₂ e avoided | Medium |

Table 32 Market size of white goods remanufacturing activities

Assumptions:

- In addition to CRNS members, the Furniture Re-use Network has several representatives in Scotland along with ‘national’ charities such as the British Heart Foundation. We estimate that there are 70 organisations in Scotland that can refurbish white goods.
- Each organisation will employ a relatively low number of dedicated staff to the refurbishment of white goods; we estimate the equivalent of 1 person is engaged with the activity per organisation.
- 2.4 million homes in Scotland replace a fridge freezer and washing machine every 10 years, this equates to 480,000 items of white goods sold in Scotland each year. If 10 % are suitable for re-use and 3 % are refurbished, this equates to 14,400 items per annum. The average value of a second hand appliance ranges from £50 to £100. Assuming an £80 ticket item, the value to the Scottish economy is approximately £ 1.1 million.
- High level figures for the market size of the electrical appliance manufacturing industry report that the revenue for manufacturing electrical appliances in the UK is £2 billion.¹³⁰ Scaling this revenue from the UK to Scotland using GDP gives an estimated total market size of £180 million (Scottish GDP: £148 billion;¹³⁷ UK GDP: £1,650billion¹³⁸). Therefore, remanufacturing activities represents less than 1 % of the sector activity.
- The environmental benefits of white remanufacturing can be scaled by monetary value from the figures in the 2009 UK survey, which reports 46,970 tCO₂e avoided through £37.4 million re-use activity.²
- There is an active market to refurbish white goods but interventions to increase supply through partnerships to improve reverse logistics could help this supply constrained industry. Due to their bulky nature, refurbished white goods will only serve the local market, limiting the potential growth in this product group. As a consequence, the potential growth for this industry is medium.

Although this is a relatively low turnover, this is to be expected from a charity sector-type activity.

4.3.11.3 Trends and barriers

The companies that sell refurbished white goods are experiencing significant growth. Processing washing machines and dishwashers requires investment in test facilities to provide power, water and a drain. Recycling fridges requires investment in de-gassing equipment and fire suppression equipment. The highest quality source material comes from retailer returns (warranty returns or new-for-old take back) necessitating B2B supply contracts. All of these represent barriers to new entrants. The lack of a competitor in Scotland limits appropriate interventions towards the charity sector.

| Barrier | Description |
|---|---|
| Access to good quality used white goods | The industry is supply constrained. Most refurbishers and re-users report that they can sell more but supply is always limited. |
| Access to spare parts | Spare parts for these products can be difficult to find or come as part of larger assemblies which can add additional costs. |

¹³⁰ Ibis World website, Electrical appliance manufacturing in the UK: market research report, [Link](#) Accessed 3 October, 2014

| Barrier | Description |
|-------------------------------|---|
| Sparse population | Due to their size, transport costs are a major factor. This is particularly important in sparsely populated areas such as the Highlands. |
| Difficulties with disassembly | Although some units are designed with modularity in mind, certain components and sub-assemblies are not designed for disassembly leading to an increase in the number of units that are scrapped. |

Table 33 Barriers to increased remanufacturing in the white goods sector

4.3.11.4 Possible mitigations

Partnering with distribution companies

As with most remanufacturing operations, the key to expansion is supply of core. Of specific relevance to Scotland is the need to develop effective and low cost ways of collecting used items from remote regions of the country. This could be in conjunction with white good delivery companies.

4.3.12 Catering and food industry

4.3.12.1 Introduction

Industrial food processing equipment (IFPE) is machinery involved in the preparation and processing of food products and beverages. The wide variety of food products available - from ready meals to canned drinks - requires a large range of industrial equipment. Each food processing subsector requires bespoke equipment for processing and conditioning the food product into a food which is convenient, safe, attractive, labour saving, economic, appetising and packaged to maximise sales of the product and to raise its impact above that of a competitor's product.

To provide an illustration of this wide diversity of food & drink processing machinery, the table below lists some of equipment used in the food industry.¹³¹

| Operation | Equipment |
|--------------------------|---|
| Raw material preparation | Washers, sieves, screens, sorters, graders, crushers, grinders, choppers, pitters, corers, slicers, squeezers, cutters, dicers, trimmers, peelers, de-rinders, skimmers, eviscerators, formers |
| Ingredient handling | Soakers, submergers, steamers, marinaders, dehydrators, homogenisers, strainers, coagulators, mixers (horizontal, vertical, rota-table and static), separators, blenders, filters, kneaders, provers |
| Moulding | Dough rounders, stampers, presses, moulders, de-moulders, sheeters, depositors, cutters, extruders, formers |
| Thermal processing | Dryers, ovens (roasting, direct, convection, impingement, radiant cyclotherm, radiant, hot plate, searing, radio frequency, infra-red, microwave), heat exchangers (plate, coil, falling film, scraped surface), evaporators, blanchers, boilers, cookers, pressure cookers, vacuum coolers, temperers, smokers |
| Low-temperature | Refrigerators, coolers, chillers, freezers (tunnel, processing, spiral, belt, plate, air blast, cryogenic, fluidised bed, carton, multibelt) |
| Finishing | Conchers, applications (chocolate, sugar, cream, salt, batter, coating, batter, breading, tempura, dusters) |

¹³¹ Centre for Remanufacturing and Re-use, Product group report: industrial food processing equipment, 2009

| Operation | Equipment |
|-----------|---|
| Packaging | Boxing, shrink wrapping, gas flushing, check weighing – for fill and seal, vacuum, liquid and solid filling |

Table 34 Equipment used in the food industry

There is little recorded remanufacturing of food equipment activity in Scotland, mirroring the UK position.¹³² For example, Falcon Foodservice Equipment - a manufacturer of cooking equipment - has offices in Stirling but no longer refurbishes or disposes of its own products. Instead the company subcontracts approved waste companies based in England to collect and, if necessary, refurbish end-of-life units.¹³² Discussion with the Scotch Whisky Association highlighted a small amount of refurbishment activity in distillery equipment; however, re-use and recycling activities are more prevalent in the industry.¹³³ Distillation refurbishment work is undertaken by metal fabricators such as Forsyths, based in Rothes.¹³³

The catering equipment market was estimated to be worth £686 million in 2011¹³⁴ and the industry is currently recovering from the 2008 recession, with the latest reports predicting growth in the sector for the next five years.¹³⁵ Despite a lack of remanufacturing activities, re-use has historically been a significant activity (in a 2009 report, approximately 15 % (€90 million) of the UK IFPE market was devoted to the sale of second hand equipment¹³¹). Re-use is limited to components made from stainless steel, intricately fabricated components and equipment for processing meat (for example); bakery (excluding ovens due to gains in energy efficiency); and oil, fat and dairy production (tanks and heat exchangers).

There were reports over a decade ago of companies examining remanufacturing packaging line equipment.¹³¹ Such equipment is suitable for remanufacturing, as packaging is not food-specific but rather process-specific such as box stuffing, lidding, thermo-forming, form fill and seal. While the versatility of the plant should support the sale of remanufactured equipment, companies found the cost of the labour to fully remanufacture these lines was close to that of purchasing new plant.¹³¹ Therefore, there was little incentive for the food producer to invest in remanufactured rather than new or even good quality second hand equipment.

As with most energy-using products, the major environmental burden of IFPE is likely to be from its energy consumption during the use phase. However, the relatively low evolution rate of the plant suggests that the energy efficiency of new equipment is not markedly different from older IFPE. Therefore remanufacturing this older equipment is unlikely to generate an overall negative impact on the environment. However, environmental emissions - while significant and important - attract little attention from project investors and accountants at this time; but, if energy prices increase further, project decisions may well change in favour of remanufacturing.

4.3.12.2 Market size

| Employment | Turnover | % of catering and food sector | Environmental benefits | Growth potential to 2020 |
|-------------|--------------|-------------------------------|--------------------------------------|--------------------------|
| 350 persons | £1.0 million | 2 % | 210 tonnes CO ₂ e avoided | Low |

Table 35 Market size of catering and food industry remanufacturing activities

¹³² Personal communication, 4 September, 2014

¹³³ Personal communication, 23 September, 2014

¹³⁴ AMA Research, Non-domestic catering equipment market report – UK 2012-2016 analysis, press release [Link](#) Accessed 3 October, 2014

¹³⁵ Catering Insight website, Report predicts five-year catering equipment recovery, 26 September, 2014 [Link](#) Accessed 3 October, 2014

Assumptions:

- Only a small amount of remanufacturing of catering and food industry equipment takes place in Scotland. We estimate that there are approximately 30 small companies with around 10 employees each working in this sector.¹³⁶
- There is a small amount of refurbishment activity taking place for distillery equipment, estimated to employ approximately 50 people.
- The proportion of remanufacturing and refurbishment in Scotland is approximately the same as in the UK. The whole catering and food remanufacturing and refurbishment industry (excluding straight re-use) was estimated to have a value of £11 million in the 2009 UK survey² compared to the catering equipment market of £686 million in 2011¹³¹. This is approximately 2 % of the industry by sales value.
- The size of the catering equipment remanufacturing and refurbishment industry in Scotland can be scaled using GDP to give an estimated market size of £1.0 million (Scottish GDP: £148 billion¹³⁷; UK GDP: £1,650 billion¹³⁸).
- The environmental benefits of catering equipment remanufacturing and refurbishment can be scaled by value from the CO₂e emissions savings reported in the UK 2009 remanufacturing survey for general catering equipment. The UK 2009 survey reported that 4,473 tCO₂e were avoided through re-use activities with a value of £21 million.² Scaling this to the Scottish market with a value of £1 million suggests remanufacturing activities avoid 213 tCO₂e.
- Due to the modest market size for food equipment and the perceived barriers for growth, the increase in the market for refurbished and remanufactured equipment is likely to be low. There is, however, potential to increase the amount of re-used equipment.

4.3.12.3 Trends and barriers

The prevailing trends for this sector are that remanufacturing of products is not common practice, and refurbishment activities are limited.

| Barrier | Description |
|-------------------------|---|
| Equipment | Much of this equipment is relatively simple and cheap to produce, and refurbishment is enough to extend its lifespan almost indefinitely. This favours re-use and refurbishment over remanufacturing. More complex equipment - including hot beverage machines or industrial fridges - may offer opportunities for aspects of remanufacture, though other factors inhibit this. |
| Cost of remanufacturing | Despite being relatively simple equipment, the cost of remanufacturing often precludes it as a purchasing option. Purchasers of pre-owned equipment are more content buying pre-owned refurbished equipment at a lower price than buying a higher cost, remanufactured item. Comparison with the new equipment market indicates that remanufactured alternatives do not fare well, as purchasers favour buying new equipment. This is further reinforced as many pieces of equipment will cost the same to buy new as they would if remanufactured. |
| Attitudes | As remanufacturing is poorly understood in this industry, purchasers are unwilling to consider remanufactured items even if competitively priced. |

Table 36 Barriers to increased remanufacturing in the catering equipment sector¹³⁹

¹³⁶ Personal communication, 3 October, 2014

¹³⁷ The Scottish Government website, Economy statistics – Gross Domestic Product (GDP), [Link](#) Accessed 2 October, 2014

¹³⁸ Office for National Statistics website, Key economic time series data, [Link](#) Accessed 2 October, 2014

¹³⁹ Taken from Centre for Remanufacturing and Re-use, Remanufacturing in the UK: a snapshot of the UK remanufacturing industry, 2009

4.3.12.4 Possible mitigations

Promoting the benefits of remanufacturing over new and second-hand equipment

Remanufactured equipment could be promoted to the wider industry to gain recognition by executive company policy makers, to establish a mind-set with a focus on remanufacturing. This promotion could not only look at actively encouraging the life extension or replacement of old plant, but remanufacturing could also be considered for new plant investment.

Certification of equipment remanufacturers

A scheme could be initiated to provide certification for competent remanufacturers. The scheme may bring confidence to food manufacturers to purchase quality remanufactured equipment. Such a scheme may be more appropriate on a UK or possibly EU level, as the relatively small amount of remanufacturing within Scotland may not justify a Scotland-specific certification scheme.

Trade association engagement

The IFPE trade associations could also be engaged to place remanufacturing on the agenda for the industry. These trade associations would likely operate at a UK or European level.

4.3.13 Furniture

4.3.13.1 Introduction

The British Furniture Confederation reports that furniture and furnishings manufacturing contributes £9.4 billion to the UK GDP,¹⁴⁰ of which approximately £680 million arises from the office subsector.² Items of office furniture include: seating, desks and pedestals, steel or wooden storage units, and other items, such as partitions. Most of this has a long service life of around 9-12 years, but is often replaced for reasons other than damage or other loss of function.² It is common practice to replace an entire office suite, for example, in an office move or corporate rebranding exercise, rather than individual items unless severe damage has occurred to a particular piece.² This practice means that there is generally a good supply of remanufacturing core.

Direct re-use of office furniture is a relatively active market with many smaller companies serving local needs. However, there are relatively few operations in the UK active in office furniture remanufacture even though many office furniture products are well-suited to remanufacturing, due to their durable design, configurability and low rate of technology evolution.

Remanufactured office furniture items are attractive for customers either for their environmental credentials (remanufacturing displaces large volumes of material from landfill) and/or for the economic value: remanufactured office furniture may cost up to 50 % less than purchasing equivalent new items.¹⁴¹

The market for office furniture remanufacturing is a nationwide market, with remanufacturers operating in England selling products into Scotland. Only one office furniture remanufacturer was identified as operating in Scotland: Ogilvie Ross. Ogilvie Ross is a consultancy with marketing and technical knowledge of furniture remanufacturing. They have a small amount of in-house labour for prototyping and small-scale projects but, for larger projects, specialist contractors with the appropriate industrial machinery will be commissioned.¹⁴¹

Demand for remanufactured office furniture is typically from the public sector, for example, councils and government bodies. Several local councils have policies in place whereby they do not to buy new furniture, e.g. Perth and Kinross, Dundee, Edinburgh and Fife.¹⁴¹ These customers are generally

¹⁴⁰ The British Furniture Confederation website, About the furniture industry, [Link](#) Accessed 2 October, 2014

¹⁴¹ Personal communication, 3 September, 2014

looking for mid-range products or require an audit trail; therefore competition from cheap, imported furniture does not have a negative impact, unlike in the domestic furniture sector.¹⁴¹

4.3.13.2 Market size

| Employment | Turnover | % of office furniture sector | Environmental benefits | Potential growth to 2020 |
|------------|----------|------------------------------|--------------------------------------|--------------------------|
| 20 persons | £250,000 | <1 % | 100 tonnes CO ₂ e avoided | Medium |

Table 37 Market size of office furniture remanufacturing activities

Assumptions:

- Ogilvie Ross is the only organisation involved in office furniture remanufacturing to be based in Scotland.
- The equivalent of approximately 20 full-time staff may be employed in office furniture remanufacturing activities.
- The turnover from office furniture remanufacturing by Ogilvie Ross is approximately £250,000.
- Scaling the estimated office furniture for the UK (£680 million) based on GDP, the size of the office furniture sector in Scotland is estimated to be £61 million (Scottish GDP: £148 billion;¹³⁷ UK GDP: £1,650 billion¹³⁸).
- The environmental benefits of office furniture remanufacturing can be scaled by monetary value from the figures in the 2009 UK survey, which reports 15,200 tCO₂e avoided through £37.4 million re-use activity.²
- There is a good opportunity to grow re-use of office furniture but remanufacturing and refurbishment is probably going to make a smaller portion of the marketplace. In particular, there is an opportunity to re-use and refurbish office furniture throughout the public sector (including agencies such as SEPA and the NHS Scotland). Therefore, the overall growth potential for refurbished and remanufactured office furniture is medium.

4.3.13.3 Trends and barriers

| Barrier | Description |
|--|--|
| Lack of public understanding | Mainstream understanding of remanufacturing and re-use (and recycling) is often confused, making differentiation unclear. Remanufacturing is viewed as a low-skilled cottage industry and the output products are considered to be low value and low quality. However, remanufacturing has the potential to produce high value and high margin products, providing there is sufficient demand. |
| Exaggerated claims of remanufacturing from manufacturers | There are concerns that furniture manufacturers' claims of incorporating remanufacturing into their activities are exaggerated. ¹⁴¹ This is eroding market differentiation for genuine remanufacturers. |
| Lack of necessary skills within OEMs | OEMs struggle to reconfigure industrial machinery for reverse processing, or may not own the necessary machinery to carry out remanufacturing. Limited knowledge of remanufacturing is another barrier. |
| Fragmented market | Unlike in the USA where there are only 4 or 5 large furniture manufacturers, there are hundreds of furniture manufacturers operating in the UK. Therefore, remanufacturing equipment cannot be manufacturer-specific and flexibility is required to cope with variations in demand and in the characteristics of the furniture core inputs. ¹⁴¹ |

Table 38 Barriers to increased remanufacturing in the office furniture sector

4.3.13.4 Possible mitigations

Benefits of localised operations

Develop local contact points for the sale of remanufactured furniture. Having local capability to meet demand for remanufactured office furniture creates local jobs, minimises transportation costs and also provides rapid turnaround for clients. This could include storage facilities and localised sales operations to meet with clients.

Centralised remanufacturing facilities to realise economies of scale

Developing centralised remanufacturing facilities. This would allow remanufacturing equipment to be better used justifying investment in expensive machinery. It would also benefit from economies of scale, reducing cost and making remanufactured furniture more cost-competitive.

Disseminate best practice to the industry

Disseminate best practice for remanufacturing to new market entrants. The lack of specialist skills is limiting remanufacturing of office furniture. Technical understanding, knowledge and creativity is critical for planning how to take the furniture core and remanufacture it into high value, high margin items that are in demand, for example, converting modesty panels into bookcases, or designing a remanufacturing process for 200 oak doors.

4.3.14 Vending machines

4.3.14.1 Introduction

The UK operates about 1.2 million vending machines (one for every 55 people)¹⁴² with an estimated replacement rate of between 20 % and 25 % annually.¹⁴³ This represents a significant remanufacturing opportunity and an effective means minimise the overall cost of vending machine operators (whose primary income is from selling of the goods from the machine).

Vending machines lend themselves to remanufacture as they are modular products containing valuable electro-mechanical components. Added to this, vending machines are usually owned and operated by a servicing company making easy collection and maintenance. Remanufacturing makes up 10 % of the overall vending machine market.¹⁴³ However, while there are several vending machine manufacturers operating in Scotland, the Automatic Vending Association confirmed the findings of our desk-based research: that there are no vending machine remanufacturers in Scotland.¹⁴⁴

4.3.14.2 Market size

| Employment | GVA | % of sector | Environmental benefits | Growth potential to 2020 |
|------------|-----|-------------|------------------------|--------------------------|
| N/A | N/A | N/A | N/A | Low |

Table 39 Market size of vending machine remanufacturing activities

Assumptions:

- There is no remanufacturing activity taking place in Scotland in the vending machine sector.
- There is limited scope for growth because of competition from England.

¹⁴² UK Vending Machines website, Vending machines in the UK, [Link](#) Accessed 1 October, 2014

¹⁴³ Centre for Remanufacturing and Re-use, Product group report: vending machines, 2009

¹⁴⁴ Personal communication, 11th September, 2014

4.3.14.3 Trends and barriers

Sales through vending machines are expected to grow by 3 % year-on-year; the market is expected to be buoyant with new product ranges and formats becoming available as people accept more and more the convenience of this form of retail.¹⁴⁵

| Barrier | Description |
|------------------------------------|---|
| Disassembly | Products and components are often difficult to disassemble, particularly where components are glued, riveted, or welded. Where the remanufacturer is not the OEM then lack of availability of technical details about design logic can obstruct efficient disassembly. Machines produced by overseas manufacturers will represent a particular barrier (unless the remanufacturer has an agreement with the OEM to transfer knowledge). |
| Component inspection | Determining the state of components that are recovered may be difficult. Deeply embedded components may be found to be excessively worn but only after effort to access them. In some cases where the remanufacturer is not the OEM, then the state and performance of returned components cannot be properly assessed (to match the required performance in remanufacture). Reverse engineering becomes a significant effort. |
| Customer demand | Customers see remanufacture as second-hand, and therefore inferior. This perception is particularly problematic for branded manufacturers. Where a product both in function and appearance varies regularly, then remanufactured product may be seen as outdated. |
| Cheaper equivalents | Cheaper products, often produced by overseas OEMs, are cost competitive with remanufactured product. |
| Re-used components not permissible | In the case of food-related machinery some components need to be food-grade, which may be difficult to obtain. |

Table 40 Barriers to increased remanufacturing in the vending machine sector

4.3.14.4 Possible mitigations

Demonstration of cost-effective remanufacturing

A demonstration that vending machines (and their components) can be remanufactured in a cost effective manner could help the industry to recognise that remanufacturing is a valuable and viable business model for vending machines. This demonstration could take the form of case studies or best practice guidelines, supported by evidence of the environmental benefits of remanufacture.

Standards

The adoption of common standards of vending machine design by the industry would help to increase the remanufacturing potential of components. Currently the market is diverse with a wide range of parts and components. Standards may also have a role in defining remanufacturing processes, particularly when equipment is required to meet food-grade specifications.

Investigate design for disassembly

Vending machines are an ideal test bed for designing for efficient disassembly. In particular, developing ways to upgrade units so that they remain aesthetically modern is of vital importance. This could be conducted in conjunction with Scottish manufacturers, Universities and operators such as Barr.

¹⁴⁵ Barriers and their descriptions have been taken from Centre for Remanufacturing and Re-use, Product group report: vending machines, 2009

5 Summary of the Scottish remanufacturing industry

5.1 Market size

An analysis of 14 key remanufacturing sectors, Table 41, estimates that remanufacturing contributes £1.1 billion to the Scottish economy. Remanufacturing in Scotland is dominated by the aerospace MRO sector. In addition to this sector, key areas include energy, rail and automotive. Remanufacturing makes a larger (and therefore more important) part of the Scottish economy than it is in rest of UK.

| Product group | Turnover UK ¹ (£ m) | Turnover Scotland (£ m) | Scotland as % of UK | Employment (no of persons) | Environmental impacts (tCO ₂ e) | Growth potential |
|----------------------------------|--------------------------------|-------------------------|---------------------|----------------------------|--|------------------|
| Aerospace | 2,000 | 670 | 33 | 3,400 | 17,000 | Medium |
| Energy | N/A | 300 | N/A | 10,000 | 6,600 | High |
| Automotive | 410 | 35 | 9 | 900 | 4,100 | High |
| Rail industry | 80 ² | 35 | 3 ³ | 160 | 4,100 | Medium |
| Marine industry | N/A | 34 | N/A | 650 | - | Low |
| ICT and mobile electronics | 75 | 19 | 25 | 700 | 630 | High |
| Pumps, fans and compressors | 200 | 30 | 15 | 360 | 3,500 | Low |
| Ink and toner cartridges | 440 | 6.6 | 3 | 30 | 88 | Low |
| Medical equipment | 14 | 0 | 0 | N/A | N/A | High |
| Tyre re-treading | 110 | 3.5 | 3 | 50 | - | Medium |
| White goods | 26 | 1.1 | 4 | 70 | 1400 | Medium |
| Catering and food industry | 11 | 1.0 | 9 | 350 | 210 | Low |
| Furniture/office furniture | 21 | 0.25 | 1 | 20 | 100 | Medium |
| Vending machines | N/A | 0 | 0 | 0 | 0 | Low |
| Total | 4,400 | 1,100 | 25 | 16,700 | 37,700 | |
| Total excluding aerospace | 2,400 | 470 | 20 | 13,300 | 20,700 | |

Table 41 A summary of the impact of key remanufacturing sectors on the Scottish economy, ranked in terms of potential impact.

1 From Remanufacturing in the UK: A snapshot of the remanufacturing industry, 2009.

2 We believe the estimate of the size of the remanufacturing industry in the rail sector was underestimated in the 2009 survey.

3 Calculated as a percentage of the national expenditure on infrastructure maintenance

NOTE: includes both remanufacturing and refurbishment

ICT and mobile electronics, and medical equipment are currently smaller but have high growth potential to 2020. There are also clear interventions within office furniture, tyre retreads and white goods that could lead to some benefit to the sector.

There is significant variation between the size of the product groups and sectors. As a result, it is difficult to compare sectors and further grouping could to provide additional rationalisation of the structure, Table 42. However, it is clear that this analysis, although making 'themes' more comparable, masks insight and therefore potential intervention at an appropriate level.

| Theme | Product group |
|----------------------|--|
| Aerospace | Aerospace |
| Engineering | Automotive; Marine industry; Rail industry Energy, Pumps, fans and compressors, Catering and food industry; Vending machines |
| Electronic equipment | Electronics, ICT and business machines; Ink and toner cartridges; Medical equipment |
| Other | Tyre re-treading White goods; Office furniture; |

Table 42 Product groups combined into themes.

5.2 Barriers and market failures

The identified barriers and market failures from the sector studies in section 4.3 can be broadly categorised into four areas:

- 1 **Supply:** These relate to issues preventing access to the end of life product that enables remanufacturing.
- 2 **Technical:** These relate to problems faced by remanufacturers that prevent them effectively remanufacturing products.
- 3 **Demand:** These are market barriers preventing increased demand for remanufactured products.
- 4 **Informational:** This is a lack of data and categorisation of remanufacturing that prevents effective government or sector intervention.

5.2.1 Supply

Access to end-of-life product is a major barrier for remanufacturers.

5.2.1.1 Lack of control of collection

There is a need for efficient and cost-effective methods for returning end-of-life products back to remanufacturers. Not only is the cost of such activity a potential barrier, but also the return routes must generate sufficient quantities required for remanufacturing complete products. In addition to the cost of

transport, there are also costs associated with product and component storage, and identification and handling of returned product.

There is little incentive for installers of new equipment to remove product in a way that is suitable for remanufacturing. Many sectors reported that during removal, irreparable damage limited remanufacturing opportunities and that product was usually sent directly for recycling or landfill. This was seen as particularly problematic where remanufacturing was largely a third-party activity. Suppliers of new product had no incentive to carefully remove old product for remanufacture because of the potential effect on competition for their product.

In other areas, where direct competition was not perceived as a problem, key drivers at end-of-life for many operators are swift, cost-efficient and safe removal of products. De-construction and disassembly in situ is slower and therefore costlier at the client's site. Potential savings of re-using or remanufacturing equipment are made further downstream.

With consumer goods where a remanufacturer is not directly involved in collection of the products methods for collection need to be developed that incentivise the end user. These usually require financial incentives. Although they are known to work, their efficacy is relatively limited; this particularly relates to electronic goods such as mobile phones and printer cartridges.

Transport and logistic costs can be a significant barrier to collection. This is a particular problem for Scotland's more sparsely populated regions.

5.2.1.2 Residual liability

For a wide array of electronic devices, the removal of information and data during the refurbishment process is important. Without reliable and perhaps even certified data wiping processes, consumers may not be willing for their end-of-life products to be used as core for refurbishment and remanufacturing. This requirement can be a burden for equipment refurbishers/remanufacturers, and can limit refurbishment of certain high-risk items such as electronics from the banking sector and security services.

Particularly with corporate clients, there are concerns over traceability of products which have been sent for remanufacturing. This is a particular issue within the medical devices sector. There is strong concern in the UK that refurbished medical equipment would be traceable to the original hospital, and some responsibility would be retained should the device malfunction. This forces the sale of re-usable equipment as scrap.

5.2.1.3 Availability of spare parts

Parts are not always readily available or are too expensive for use in remanufacturing and refurbishment activities. This usually results in remanufacturers salvaging parts from other pieces of equipment.

A slightly different issue is that the spare parts can come as part of larger assemblies which can add additional costs.

5.2.2 Technical

These barriers are associated with the physical act of remanufacturing by a remanufacturer. They largely revolve around the engineering and logistical challenges associated with remanufacturing.

5.2.2.1 Increasing technological complexity

Across a wide variety of sectors, incorporating mechanical, electromechanical and electronic products, there was a perception that there was a need to develop new techniques to enable remanufacturing. This presents problems for both OEM-affiliated remanufacturers and independents in that new techniques and technologies need to be developed.

Independent remanufacturers also face the additional barriers associated with determining tolerances and developing tools and systems for integrated electronics in traditionally mechanical equipment. This trend is particularly significant within the automotive and rail industries.

With fast moving technologies, there is a danger that older equipment is significantly less efficient and possibly obsolete. This limits the market of certain products.

5.2.2.2 Intellectual property issues

Without access to competitively priced spare parts from OEMs, third-party remanufacturers seek the use of compatible components from other outlets. These components may infringe the design rights or intellectual property of the OEM. OEMs have been known to take legal action against remanufacturers, which can be a significant disincentive even if the remanufacturer is cleared of any infringement.

5.2.2.3 Skills/infrastructural

Remanufacturing requires a technically-minded multi-skilled and flexible work force to deal with the challenges of remanufacture. These are different from normal manufacturing production processes. A limited skills-base is a drag on how fast a sector can grow. The skills needed to undertake remanufacturing are closely associated with manufacturing skills. It is difficult to grow or develop a remanufacturing based without a healthy community of manufacturers in a particular area.

Initiating new remanufacturing activities in a sector usually requires significantly large capital costs. This may be a barrier to extending remanufacturing into new areas or technologies, and for smaller companies that want to enter the remanufacturing sector. Also, because it is a less well-understood business model, investment is more difficult to secure.

5.2.2.4 Design for remanufacturing

Products and components are often difficult to disassemble, particularly where components are glued, riveted, or welded. Where the remanufacturer is not the OEM then lack of availability of technical details about design logic can obstruct efficient disassembly. Products produced by overseas manufacturers will represent a particular barrier (unless the remanufacturer has an agreement with the OEM to transfer knowledge).

Determining the state of components that are recovered may be difficult. Deeply embedded components may be found to be excessively worn but only after effort to access them. In some cases where the remanufacturer is not the OEM, then the state and performance of returned components cannot be properly assessed (to match the required performance in remanufacture). Reverse engineering becomes a significant effort.

5.2.3 Demand

These barriers are associated with the market pull. They are usually associated with customers and their perceptions.

5.2.3.1 Consumer/procurer perception

The level of awareness and reputation of remanufacturing varies between sector and even between procurer groups. Overall there is an issue with remanufacturing being poorly understood and purchasers being unwilling to consider remanufactured items even when competitively priced. Reasons for this include concerns over quality, lack of awareness and difficulty in identifying a reputable remanufacturing brand.

Although education is an obvious route to begin to break down these barriers, there are few methods available to convey this information cost effectively.

5.2.3.2 Institutional barriers

Current public procurement funding patterns do not consider remanufactured products as part of their purchasing criteria. Due to informational barriers on remanufacturing, there is little driver to change procurement specifications to include remanufacturing. In addition, the perceived risks associated with procuring remanufacturing also act as an incentive for procurers.

In certain sectors, the lack of infrastructure makes buying remanufactured more difficult or a poorer “experience” than when buying new. Without high-quality sales channels, remanufacturers are relying on “ethical-decisions” as drivers which will limit their appeal to niche sectors and markets.

5.2.3.3 Uncertainty over liability

Where there is strong health, safety and quality assurance requirements for products, there may be a natural favouring of new items over re-used and remanufactured alternatives. This applies equally to both consumer products such as brake callipers for cars as well as industrial products such as food manufacturing equipment.

5.2.3.4 Low cost competition

Although not unique to the remanufacturing industry, low cost competition can affect sales. What is unique is how it is affecting the remanufacturing market. There is a clear perceived difference between the quality of a low-cost import and a ‘named’ brand. However, this differentiation is lost when comparing a remanufactured ‘named’ brand product with a low-cost import. In fact the new low cost import is perceived to be of higher quality than the remanufactured product even if the tolerances and technical specifications are lower.

Lower cost competition also limits remanufacturing to high cost products. It is uneconomic to remanufacture low-cost products meaning these products are usually recycled.

5.2.4 Informational

Information barriers are largely associated with the ability of policy makers to effectively target remanufacturers. This can include issues of providing external support or even identifying where the activity is being undertaken.

5.2.4.1 Definition

In certain industries the term ‘remanufacturing’ is infrequently used or mixed with other phrases that could be classed as remanufacturing. Also, the lack of a standard definition means that companies that claim they are remanufacturing are engaging in other re-use activities. This makes it difficult to report and understand remanufacturing activity.

5.2.4.2 Data skew

As with the manufacturing sector, remanufacturing activity involves a large number of SMEs. Data are more readily available from larger remanufacturers and most of the case studies focus on the activities of larger companies and OEMs. A lack of baseline information for SMEs could skew the recognised potential of remanufacturing by under- or over-estimating the impact of a particular barrier based on large company issues.

5.3 Recommendations

5.3.1 Supply

5.3.1.1 Improve and incentivise ‘core’ return rates

Improving the core return rate of suitable products for remanufacturing will help grow the remanufacturing industry, either for sale in Scotland and the UK, or overseas. Collection techniques

tend to be product-specific; however, there is potential for sharing best practice between remanufacturing practitioners. Currently there is no forum for this, and one could be established in Scotland. Research into new collection techniques (which could be either product-specific or cut across several products) could improve collection rates and increase remanufacturing activity in supply constrained markets, particularly in printer cartridges, compressors, white goods and office furniture.

Development of low-cost methods of reverse logistics will reduce costs and encourage remanufacturing. This is particularly important in remote regions of the country. This could be achieved by exploring links with delivery companies or the postal service. Trials could be developed with remanufacturers and delivery services along these lines. Alternative approaches could also be developed using advanced tracking systems such as RFIDs.

Incentives such as deposit return schemes or additional producer responsibility schemes could be developed in conjunction with industry. Such activities could either be led at a Scottish level or be taken up throughout the UK or EU. Consumer-related products are probably most susceptible to these schemes, in particular, cartridges, furniture, ICT and tyres.

5.3.1.2 Increase access to spares

Investigate the development of brokerage services for core or spare items. Remanufacturers usually encounter a wide variety of devices and models on the market, an increased access to core and spares will help enable refurbishers to meet the demand for particular products. Part of this would include engagement with OEMs to ensure that access to new spares is guaranteed and that products are appropriately designed to enable repair and refurbishment.

5.3.1.3 Promote products suitable for remanufacture

Engage with designers and remanufacturers to develop products suitable for remanufacturing. This could be achieved through workshops, direct engagement or active procurement. Also develop a rating system for products so that purchasers can compare products' suitability for remanufacture and upgrade. This gives the choice of opting for equipment with a view to remanufacture as a planned maintenance operation. This could enable predictable costs over a longer period than the normal expected lifetime.

This activity will require engagement both nationally (in developing the tools and guidance for design for remanufacturing) and internationally (to engage with OEMs and also set policy agenda at a European level, for example through the Ecodesign Directive).

5.3.2 *Technical support*

5.3.2.1 Share best practice to new market entrants

Disseminate knowledge and skills from successful remanufacturers to grow the number of remanufacturers in the marketplace. The use of case studies, exchanges/forums and seminars to highlight best practice in a particular industry should help encourage the uptake of remanufacturing.

Scottish links with the Circular Economy 100 (CE100) should be exploited to share best practice. This could act as a way to both learn and disseminate best practice to Scotland and also showcase Scottish remanufacturing to multinationals.

5.3.2.2 Identify technical issues through current delivery bodies

Use current front-line delivery bodies such as Zero Waste Scotland and Scottish Enterprise (possibly through SMAS) to highlight key issues within the industry. Industry bodies could also be used to facilitate this, for example, Scottish Engineering, the Institute of Mechanical Engineers and the Institute of Directors. Many technical issues associated with remanufacturing will only come to light through direct engagement with a company. Engagement and education of current front line delivery bodies will help identify and overcome these issues. This can include promoting remanufacturing to

delivery body practitioners, highlighting the benefits and linking with universities (in particular the Scottish Institute of Remanufacture).

5.3.2.3 Research into advanced repair technology

Research into advanced material repair technology (particularly for aerospace, energy and rail industries). Collaborative projects with universities could provide opportunities to research ways to detect and repair faults in the advanced composites and metals increasingly used in aircraft and other high-value products.

Also, research is needed into methods for repairing electrical and electro-mechanical systems which are of particular importance for the automotive industry.

There is also a lack of low-cost non-destructive testing technologies for both metal and plastic parts. Engage with industry and academia to begin developing new technologies for non-destructive testing. This could be facilitated through vehicles such as Innovate UK, EPSRC and the Scottish Innovation Centres (in particular, CENSIS) - working with the Scottish Funding Council and SIR regarding engagement with the Innovation Centres.

5.3.2.4 Develop cross disciplinary teaching support for remanufacturing

Remanufacturing cuts across all areas of a business requiring the development of different skills sets and ways of thinking. As such the development of a unified teaching approach at all levels including undergraduate, post graduate and professional development will help train remanufacturing practitioners. There are three areas where skills are needed:

- Business leadership: understanding how alternative business models could be used to maximise the value for remanufacturing
- Technical engineering skills: developing the techniques and technologies to effectively remediate and remanufacture products
- Design tools: providing designers with the tools and techniques to develop products that are easier to disassemble and remanufacture.

These three areas involve different disciplines, requiring input from different faculties within a university. To help coordinate this activity, a Remanufacturing Chair could be established. The role will be to develop cross-disciplinary courses and teaching aids, bringing together specialisms from different subject areas. This position could be linked with the education activities that are undertaken within the CE100 group of which Scotland is a member.

On a company level, Continual Professional Development courses could be developed that would provide on-the job training. By targeting both academic studies and also current practitioners, this approach will increase the awareness and understanding of remanufacturing at all levels of industry.

5.3.3 Demand

5.3.3.1 Encourage procurement

Use public procurement to increase demand for remanufactured products in identifiable markets where remanufactured products are present. Procurement policy is one of the most powerful tools for promoting the remanufacturing market. For example, in the USA, a bill was introduced to Congress in February 2014 which would require all vehicles in the Federal fleet (about 588,000 vehicles) to be repaired and maintained using remanufactured parts, unless it can be demonstrated that to do so would be more expensive, take longer or be of lower quality.

Part of this work should be to ensure that the liability over procurement of remanufactured products is resolved to remove the risk of purchase from the procurers.

The barriers and opportunities for the use of refurbished medical equipment by NHS Scotland should be investigated. As the largest user of medical devices in Scotland, developing purchasing policies in

NHS Scotland that promote refurbished medical equipment could help grow the market, and encourage OEM and third-party refurbishers to develop operations in Scotland.

5.3.3.2 Certify remanufacturers

Develop a scheme to provide certification for remanufacturers. This could build on BS 8887-220 which defines remanufacturing procedures. It could be implemented either nationally or at a UK level. Linked to procurement, a scheme that identifies remanufacturers and remanufactured product would enable procurers to purchase with confidence. This would tie in with public procurement activities.

As a market 'pull' Scotland could use its position in the CE100 to lobby for the group's members to specify products or operate to this standard.

5.3.3.3 Promote remanufacturing

Produce promotional material aimed at potential purchasers clearly describing the benefits of using remanufactured products. In addition to the price differential, other advantages include:

- Product availability and security of supply: For products where the lead time for purchasing new can be quite long, remanufactured products - particularly products that have been remanufactured to stock - can have a significant advantage over new.
- Delays upgrade time: Where a replacement product is required which is part of a larger facility, remanufactured products can extend the life of the overall fleet by postponing the need for a comprehensive upgrade.
- Limit liability and down-time through the use of product service systems.

This promotion should not only look at actively encouraging the life extension of old equipment, but should also embed the idea of remanufacturing potential when investing in new equipment.

Promotion could take the form of case studies or best practice guidelines, supported by evidence of the financial, customer and environmental benefits of remanufacture. Also, the use of widely disseminated, projects highlighting key benefits could break down some of the misconceptions. Events showcasing remanufacturing organised for specific sectors, directed at procurement teams and other buyers could be developed. Alternatively, remanufacturing could be promoted to procurers as part of the Circular Economy support programmes.

5.3.3.4 Develop procurement protocols

Develop a comprehensive procurement support programme for remanufactured products under the remit of the Procurement Reform Act, the guidance for which is currently being developed.

Developing a set of protocols that will maximise the procurement of remanufactured products will require several different interventions. In particular:

- Use good practice from existing or develop new procurement standards. Standards help procurers identify high quality remanufactured products. These standards can either be set at an industry level, or specified within procurement specifications.
 - Provide training to procurers. Procurers will need training to brief them on the benefits of remanufacturing and how procurement of remanufactured products should be undertaken. The procurers should also be included in this process to ensure that any decisions on the procurement process align with the current procurement requirements.
 - Provide support to manufacturers who wish to develop remanufacturing capacity. There will be a need to help with manufacturers with the transition between producing new and remanufacturing. This is particularly important where there is a need to significantly increase the capacity of Scottish industry to remanufacture particular product mandated in new purchasing specifications.
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5.3.4 *Overarching recommendations*

5.3.4.1 **Develop links with other nations**

Develop closer ties with other nations to facilitate collaboration and promotion of remanufacturing activity and research. For example, collaboration with Nordic countries - particularly within the oil and gas and renewables sectors - could further remanufacturing across the North Sea. Sweden has recently launched a competition, through the Mistra initiative, to research remanufacturing. Scotland could play a role in facilitating interaction between its universities (in particular the Scottish Institute of Remanufacture) and those in Sweden. Other potential links could be sought with Korea, Malaysia (particularly oil and gas) and the USA where remanufacturing is widely promoted.

5.3.4.2 **Develop new funding routes**

Expanding remanufacturing activities within companies will require access to finance. A risk-averse finance sector may perceive the alternative business models and unusual methods of doing business as a remanufacturer as too risky for investment. There are alternative funding routes available; in particular, the Green Investment Bank (GIB) which could provide support for these companies through supporting investment in remanufacturing infrastructure.

At present, the GIB has shown little activity for financing remanufacturing activities. This is partly due to no clear brokerage service to encourage remanufacturers to apply for additional funds. The GIB could provide guidance for remanufacturers who wish to apply for funding. Alternatively, business support services such as those provided through Scottish Enterprise could be briefed on how to help remanufacturers apply for funding.

5.3.4.3 **Examine options for decommissioning of North Sea energy**

The oil and gas industry is starting to decommission offshore platforms. This process will last for at least 20 years. There is an opportunity to maximise the value of that process by remanufacturing useable equipment (either for use in the oil and gas industry or for other uses).

The monetary benefit is likely to be a relatively minor incentive for the sector (compared to the sector turnover, the value to the oil and gas sector will be relatively small). Therefore, to gain full engagement, additional benefits need to be highlighted including social responsibility and closer ties with other industries.

Engage with industry bodies such as Decom North Sea (DNS) in the development of pilot project or research projects. Also, investigate new markets for products to open up new opportunities for reuse and refurbishment. Some work is currently underway by Zero Waste Scotland and DNS but this could be expanded to include remanufacturing. In particular, inventory analysis is a key step in understanding the value of remanufacturing.

Clarification over liability should be sought to ensure that remanufacturing will not expose off-shore operators to additional liability risks for remanufactured equipment.

The expertise, particularly around Aberdeen, could place Scotland as a cluster in North Sea energy. Activity could centre on coordinating current stakeholders in the area rather than developing new facilities. Due to the location of deep-sea ports, links with Highlands and Islands could bring additional income to deprived areas of the community. There is also the opportunity to link with the European Marine Energy Centre (EMEC) on Orkney which is at the forefront of developing new tidal and wave technologies.

Investigate the potential for future infrastructure investment in renewable energy to enable remanufacturing at the end of its life.

5.3.5 *Informational*

5.3.5.1 **Collect data on remanufacturing annually**

Engage with the Office of National Statistics to begin collecting annual data on remanufacturing, both from a Scottish perspective and UK-wide. This will enable a clearer picture of the business trends and help identify emerging remanufacturing areas. A prerequisite to this recommendation would be the agreement of a definition of remanufacturing.



6 Global best practice

6.1 Select country analysis

6.1.1 USA

Remanufacturing is well established in the USA. It is the world's largest producer, consumer, and exporter of remanufactured products.¹⁴⁶ U.S. production of remanufactured aerospace products, Heavy Duty Off-Road equipment, and motor vehicle parts together accounted for 63 percent of total U.S. production of remanufactured goods.

From a policy level, one of their main drivers has been to encourage remanufacturing exports both to Europe and the Far East. As a consequence, the United States International Trade Commission have published reports to aid the industry. They have provided an international survey of remanufacturing (predominately focusing on the USA but also encompassing activity throughout Europe, South America and the Far East). This was largely to inform further policy in this area. Additional market intelligence has been provided through an Automotive Resource Guide for US exporters. It examines import markets for over 40 countries including barriers for US remanufacturers. The USITC have also been at the forefront of talks amongst APEC economies (Asia-Pacific Economic Cooperation). They have led on the development of agreements that remove barriers to imports and exports of remanufactured products, in particular focusing on issues of quality and concerns of waste imports and exports. Again, this activity has been funded to encourage and open markets for US remanufacturers into emerging economies.

On the domestic front, federal legislation is encouraging federal automotive fleet operators to purchase remanufactured parts over new. The bill is designed to increase awareness of remanufacturing cost benefits. New parts can only be purchased where they are less expensive, there are safety concerns, or they have a shorter lead time or remanufactured parts lower performance. The bill requires each agency's head to encourage the use of remanufactured parts where possible.

Outside of legislature, there are many organisations devoted to promoting remanufacturing. These include several for the automotive industry, such as APRA and MERA. Interestingly there is also and the Remanufacturing Industries Council, trade body that represents a wide variety of remanufacturing industries automotive, aerospace and medical imaging industries. The Council was developed from the Rochester Institute of Technology, who are seen as one of the centres of excellence in remanufacturing.

6.1.2 China

Formal remanufacturing is just emerging in China, having first been established in 2008. Since then, Government-led remanufacturing pilots have driven a rapid increase in remanufacturing interest and activity in the world's second largest economy. Two remanufacturing pilots currently exist dedicated to different industry sectors: the automotive parts pilot, which began in 2008, and the mechanical and electrical products pilot, which began in 2009. In the automotive sector, the pilot allows permits to be issued for remanufacturing a range of components including engines, transmissions and starter motors.

China's interest in remanufacturing was originally motivated by the strategic importance of key industries and products, such as the automotive sector. More recently, policies within China have raised the profile of remanufacturing as a way to reduce industrial environmental harm. Following on from this increased attention, eleven key government departments, including the National Development and Reform Commission, jointly issued the guidance document 'Opinions on Promoting

¹⁴⁶ United States International Trade Commission Investigation No. 332-525 USITC Publication 4356 October 2012 Remanufactured Goods: An Overview of the U.S. and Global Industries, Markets, and Trade

the Development of the Remanufacturing Industry' in 2010. This led to the release of further permits for remanufacturing activities. In addition, local and regional authorities are being encouraged to develop and promote policies that support remanufacturing, including technical projects, such as innovation in remanufacturing techniques, and business projects, such as strengthened coordination between remanufacturing companies.

Complementing the development of industrial infrastructure in remanufacturing, the establishment of academic research into the benefits of remanufacturing in China is also gaining traction. The National Key Laboratory for Remanufacturing, based in Beijing, is a centre of excellence and is run by Professors Xu Binshi and Sheng Zhu. The research provides guidance for the government's thinking on remanufacturing, addressing economic and technological benefits and barriers as well as the environmental case for remanufacturing.

As well as joint ventures with established foreign companies, the demand for remanufactured products is leading to new, local entrants into this market. While these new entrants may provide additional competition both within China, and possibly internationally, greater remanufacturing "know-how" is needed in the near-term. For example, Mingjie Resources are developing a new remanufacturing plant in China. While the group's main business originated in recycling and dismantling waste electrical and electronic equipment and end-of-life vehicles, they have taken a strategic decision to increase the value of their products by moving from recycling to remanufacturing. To help with this transition, they have commissioned a project with Bayreuth University and Fraunhofer engineers to help develop cutting edge remanufacturing systems.

6.1.3 Europe

There is little available national policy on remanufacturing in Europe and nothing set through EU directives. At the national level, various highlights include:

- **Germany:** The University of Bayreuth hosts a Fraunhofer institute for remanufacturing. Their focus is on automotive remanufacturing and have strong links with both the Rochester Institute and companies in China. VDI represent automotive remanufacturers and have 75 members including Bosch, BU Drive and CamPro.
 - **France:** France hosts a number of high profile remanufacturing companies, including ZF, Caterpillar, Bitzer, IBM and Neopost. Academic remanufacturing research includes the GSCOP laboratory at the University of Grenoble and the University of Strasbourg, where there is a focus on design for remanufacturing.
 - **Netherlands:** There is a growing hub of remanufacturing promotion activity in the Netherlands based around the annual ReMaTec remanufacturing trade exhibition, which alternates between Amsterdam and the US. In 2015, the event will be part of the first International Remanufacturing Week, along with the World Remanufacturing Summit and the International Conference on Remanufacturing.
 - **Italy:** The PREMANUS project (Product Remanufacturing Service System) is an FP7 funded project co-ordinated by the Politecnico di Milano with partners in seven European countries. The project aims to take product information and make recommendations on the viability of remanufacturing this product. Italy's importance in the remanufacturing sector is reflected by the decision to host a number of high profile remanufacturing events in the region this year, including: APRA's European Remanufacturing Symposium and Exhibition and the Static Control and Automation Hold Seminar for the printer cartridge industry.
 - **Sweden:** Academic research into remanufacturing is spearheaded by the University of Linköping, which has a strong focus on developing business models for remanufacturing. The Swedish Foundation for Strategic Environmental Research (Mistra) is also supporting remanufacturing research activities in its call for "Product design for resource efficiency: Towards a circular economy", which specifically refers to remanufacturing.
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There are several remanufacturing trade associations operating in Europe, notably the European branch of APRA, the European Toner & Inkjet Remanufacturers Association (ETIRA) and the International Federation of Engine Remanufacturers and Rebuilders (FIRM).

Horizon2020 funding has provided a number of opportunities for remanufacturing research. Funding has recently been announced for the formation of a European Remanufacturing Network with eight European partners: Oakdene Hollins, TU Delft, Fraunhofer, Linköping University, INP-Grenoble, VTT, University of Strathclyde and Circle Economy. The Horizon2020 Factories of the Future call on “Re-use and remanufacturing technologies and equipment for sustainable product lifecycle management” is a €143 million call, which aims to help remanufacturers develop technologies and equipment for improving remanufacturing operations.

6.1.4 Korea

The Korean government is actively engaged in promoting remanufacturing of both auto parts and printer cartridges. There are approximately 20 staff directly involved in promotion and certification activities as part of the Korean Institute of Technology (KITECH). Their certification activities include the development of a suite of product specific standards along with provided certification services to certify companies. There are currently 35 certified products. Unusually, promotion to the end user is also being trialled through supermarkets.

The Koreans are also planning to open a new industrial complex that will showcase remanufacturing technology and expertise. This is due to open with public and private funding by the start of 2015.

6.1.5 Japan

The Japanese government has long promoted the reduction of pollution and waste generation, for example through the 3Rs initiative to reduce waste generation, re-use parts and recycle used products.¹⁴⁷ Remanufacturing is such a waste reduction strategy and has been adopted by a number of industry sectors. Japan is home to several large photocopy manufacturers that have expanded their activities to include remanufacturing: Fuji Xerox, Ricoh and Canon. A notable distinction between Fuji Xerox and the other manufacturers is that Fuji Xerox reportedly uses remanufactured components in their new products.¹⁴⁸ The companies collaborate to collect returned units and have invested in design for remanufacturing principles. Single-use cameras is another well-developed remanufacturing sector in Japan. Fuji Film developed a fully automated remanufacturing line for processing returned cameras in 1998. Again, key elements of success in the sector include collaboration between OEMs to get a high core return rate and design for remanufacturing.¹⁴⁸

In contrast to these two sectors, remanufacturing in the automotive sector and printer cartridge sector is predominantly led by independent remanufacturers rather than OEMs. Remanufacturing in the automotive sector is highlighted as a potential growth area (from a relatively low baseline) as the average age of passenger vehicles in Japan increases and the repair industry is deregulated.¹⁴⁹ Remanufacturing of Japanese heavy duty and construction equipment is another active sector, e.g. by Hitachi Construction Machinery and Komatsu.¹⁵⁰

Academic research into remanufacturing is spearheaded by Dr Mitsutaka Matsumoto, Centre for Service Research, in the National Institute of Advanced Industrial Science and Technology, and Professor Shozo Takata at Waseda University.

¹⁴⁷ Ramstetter, E. Remanufacturing and the 3Rs in Japan: Lessons for Thailand, *Thammasat Economic Journal*, Vol. 30, No. 4, December 2012

¹⁴⁸ Matsumoto, M. & Umeda, Y., An analysis of remanufacturing practices in Japan, *Journal of Remanufacturing*, 2011 1:2

¹⁴⁹ U.S. Department of Commerce, U.S. Commercial Service Automotive Resource Guide, A reference for U.S. Exporters, Third Edition, 2014

¹⁵⁰ APEC, US AID, Remanufacturing Resource Guide, 2013

6.2 Academic review: The future of remanufacturing

This section reviews a variety of publicly available UK and international academic studies of the future of manufacturing. It assesses how the predicted changes might enable the adoption of remanufacturing practices. 28 different reports were reviewed and are summarized in Annex 2.

6.2.1 Overall role of remanufacturing

All except one future orientated manufacturing study places a very significant emphasis on the future critical role of remanufacturing. Such consistency is unusual and does not apply in many other topics. The reports are consistent on the rising role of remanufacturing, repeatedly explaining the smaller number of existing examples and extrapolating those across the relevant economy.

There is increasing consistency on the claimed benefits of remanufacturing. Importantly they use different methods which offer some reliability in the claims for 34 % and up to 60 % cost reduction for a remanufactured component. All reports offered up a set of co-benefits such as job creation, national resource resilience, trade balance, avoidance of landfill, reduction in greenhouse gases and transport.

There are some words of caution that remanufacturing is not the answer to all problems, and that other approaches (re-use networks, recycling of base materials) can be better in some contexts.

The one diverging report, the German Industrie 4.0, was not intended as a future prediction of all trends but focused on smart technologies. Hence the absence of commentary on remanufacturing - for example resource availability challenges - is no surprise, and the lack of commentary on remanufacturing is consistent with its focus.

6.2.2 Material security and resource efficiency

All sectors and nations reported concerns with future material security (and in particular availability of materials in politically charged times and locations) as a key driver for exploring remanufacturing. Some (UK and USA) reports show concern for national resilience and mention “a future of scarce resources”. The reports expect this to act as a catalyst for remanufacturing, and suggest critical roles for governments in using their own procurement to encourage remanufacturing.

Remanufacturing is viewed as a strong influence on company strategies, especially where those companies have concerns over resource resilience. Company strategies then influence remanufacturing by building in the design, materials and organisational competence to implement remanufacturing, which must be a long-term strategy that works over multiple product life-cycles.

6.2.3 Technological and product design

New technologies are emerging that enable greater remanufacturing. For example in the USA, turbine blade remanufacturing or ship remanufacturing is becoming more prominent. As the role of technology changes (through new materials, ICT, or sensors in everything with big data processing) reports are consistent that remanufacturing will increase. There is no evidence for technologies that will reduce demand for remanufacturing.

Solutions that operate at scale are expected to be cross-sectoral, as there is felt to be a high demand for inter-organisational coordination. This will be enabled by future IT, such as increasing use of sensors allowing for greater tracking of materials and components through their life, and use of big data to identify pre-failing equipment in the field.

Product design is emphasized as critical to remanufacturing, as performance and costs are often fixed by the design itself. Modular design, ease of disassembly, repairability and information availability are seen as key to good product design for remanufacturing.

6.2.4 *Business practices*

Much is written about the likely emergence of new business models, with leasing, repair services and sale-of-service offered as the three most prominent innovations. These are growing in use and are argued to offer a platform for remanufacturing as these new business models remove the concern of product users for ownership and transfer that ownership to technically and financially competent organisations (companies) that seek to maximize their profitability by keeping materials and products in the value system for as long as possible.

Remanufacturing will place demands on product manufacturers, specifically in terms of workforce skills, managing resource flows over long periods, and coordinating with other organisations.

6.2.5 *Overview*

These reports show remarkable consistency. They agree that, from planetary, national interest and economic perspectives, remanufacturing is increasingly needed. The need for long term co-ordination is agreed. The benefits and co-benefits are agreed remarkably closely given the paucity of high quality historical data.

Government support may also be needed to help catalyse action from manufacturers. There is significant evidence of many research projects across the world that is setting out to develop national innovation systems that are resource efficient and include remanufacturing as an element of that strategy.

Remanufacturing, therefore, is felt to be inevitable; but the ability to co-ordinate disparate actors in the industrial system and to co-ordinate action between government and industry and citizen-consumers is seen as non-trivial, with limited insight offered. Individual actions, whether by industry alone or governments alone, are felt to be unlikely to deliver an efficient remanufacturing system.

6.3 Exemplar companies

6.3.1 *Bond group*

The Bond Group (TBG) is the UK's largest remanufacturer of Refrigerated Display Cabinets (RDCs). Based in Sheerness on the Isle of Sheppey, Kent, they employ nearly 200 staff.

TBG operate a service-type business model where they remanufacture on the supermarkets' behalf. In general, the old, remanufacturable cabinets are stored in TBG's warehouse. When TBG receives an order to refit a supermarket, they survey the site in order to determine the number and type of RDC required. The old cabinets stored at TBG are then remanufactured to the desired standard, and, once the entire order is ready, TBG removes the old stock from the supermarket store. The stock removed from the supermarket is then inspected, potentially remanufacturable cabinets are placed in storage, and other irreparable stock is sent for disposal. TBG then installs the remanufactured cabinets in the supermarket store.

To allow rapid turnaround, TBG carries 80,000 spare parts for a wide range of RDCs. In fact, OEMs use TBG as a spare parts supplier for older models of their units. To service and repair such a wide selection, TBG has had to develop an extensive knowledge base, encompassing detailed technical drawings of hundreds of RDC models. In addition to the selection of spare parts, it also has the ability to manufacture new and custom parts.

R&D also features highly: TBG has onsite test and R&D facilities, making them unique amongst UK remanufacturers. This research has allowed the remanufacture of old RDCs to modern efficiency standards.

6.3.2 *Edwards Vacuum*

Edwards is one of the leading organisations in the world specialising in the design and manufacture of vacuum and exhaust management products for both general vacuum and semiconductor applications. Edwards employs around 3,500 people globally, in the design, manufacture and support of high technology vacuum equipment. Its turnover in 2013 was €9.7 bn. It is also a world leader in vacuum technology for industrial, scientific, process, and R&D applications.

Edwards locates its own remanufacturing and support facilities near to its larger customers. The scale of the semiconductor industry in particular, where a large fabrication plant may contain over 600 vacuum pumps, clearly justifies this approach. In the largest of plants, where even a small downtime due to loss of pumping capacity can far outweigh the cost of repairing or replacing a pump, the fabricator may opt for an on-site service team.

Over the last decade the concept of selling remanufactured pumps alongside the new alternatives has become established. These pumps offer cost advantages for the purchaser and are additionally supported by the sale of fitting kits which simplify installation. Thus the customer is fully “bought in” to the remanufacturing programme.

6.3.3 *Amaryllis*

Amaryllis remanufactures office furniture. They have the capability to change the size, colours and overall aesthetic of the furniture. Many of Amaryllis’ contracts involve ‘repair or replace’ clauses that require them to either repair the original item or replace it with another of a similar quality and design as well as short, medium and long term furniture and equipment hire contracts.

Central to reusing furniture has been the development of a stock control system that enables the effective redeployment of used products. All items that are ready for reuse are logged onto the system. Details of the furniture type and location are held. When an order for furniture is placed, the used stock list is interrogated to determine whether the order can be made from furniture already available. Where the order cannot be filled from reused products, it is supplemented with new stock.

Amaryllis has depots located throughout the UK. Depending on the size, distance and timescales, furniture can be transported across the UK. An overriding criterion is the cost associated with the transport of the furniture; these can be significant, limit stock movement and sometimes force the procurement of new.

Good contracts place responsibility on Amaryllis to save money. Any reductions in procurement costs result in an increase in margin afforded by the Amaryllis. This has led to the development of systems that enable reuse of a large portion of the stock of furniture. Crucial to this, is avoiding using the term ‘new’ within any contract.

6.3.4 *MCT*

Over the past 40 years MCT ReMan Ltd has been involved in the Remanufacturing of Automotive drive line products. Based in Weston Super Mare, the SME has built a strong reputation in the remanufacturing industry, offering high quality product with a warranty that usually exceeds the OEM’s.

Since 2010 MCT ReMan has developed a service offering beyond transmissions (for which it is best known) with significant investment in capability to support their OEM partners with both new and remanufactured engines. This capability has now been fully endorsed as MCT Reman currently produces new & remanufactured engines for customers Ford, Jaguar Land Rover, London Taxi Company (black cabs) & VW Heritage.

6.3.5 *ZF*

ZF are a tier 1 automotive supplier who also remanufactures most of their products. They offer remanufacturing services on transmissions, clutches, steering components and torque converters for

sale either into the aftermarket or as part of warranty returns. Their remanufacturing lines operate using the same procedures and standards as their new products.

During remanufacture, they combine new technologies and techniques to upgrade their products making them technically superior to when they were originally fabricated. To obtain core, ZF offers cash incentives to vehicle owners for giving core to an authorized parts dealer.

Remanufacturing at ZF is connected to the global network of ZF Services that comprises 77 locations in 36 countries, including Nottingham in the UK.



7 Future benefits on the Scottish economy

This section estimates the benefit to the Scottish economy from implementing the recommendations from the report. The growth in the Scottish remanufacturing economy is modelled using the estimated growth potential until 2020 highlighted within sector report.

7.1 The model overview

The model estimates turnover and employment in remanufacturing in Scotland under three future scenarios. This is conducted by projecting forward the analysis of the survey data. Where appropriate, the Green Book discount rates¹⁵¹ are used to take into account the timing of projected benefits.

The first part of the analysis is to construct a baseline scenario for remanufacturing in Scotland. The baseline turnover is assumed to grow at around 2 % per year (similar to the expected trend GDP growth). Two types of scenario are possible: policy incentives to increase this trend rate of growth or significant one-off capital investment to boost the size of the remanufacturing sector. The effect of these interventions is shown in Figure 6.

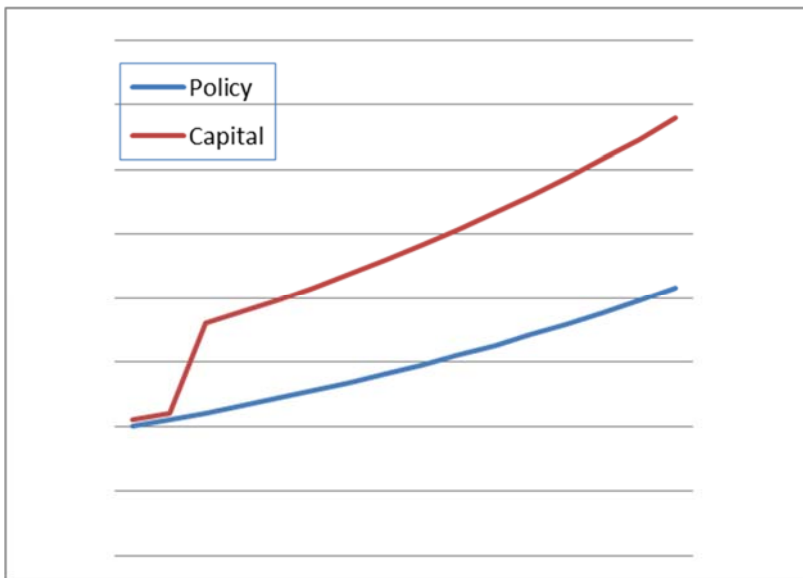


Figure 6 Types of scenarios and possible impacts on turnover

The majority of interventions suggested throughout this document are policy/action-oriented rather than capital investments. Therefore the analysis has been built to reflect this assumption.

The major focus of the scenario modelling will be upon projected turnover benefits, as this is much simpler to forecast with any degree of accuracy. GVA was not estimated because of the gross assumptions used. As for estimating future employment, evidence shows that it does not map one-for-one with increases in (discounted) subsector turnover. This is because companies tend to achieve economies of scale, as turnover grows, such as spreading overhead costs over a large output or by increasing the capital intensity of the operation, such as through greater automation. This effect has been shown in previous editions of the BIS Low Carbon Environmental Good and Services reports.¹⁵² It therefore seems reasonable to assume that only employment will only increase by 60 % of the increases projected for turnover, even though remanufacturing can often be quite labour intensive in comparison to the initial remanufacture.

¹⁵¹ UK Gov't HM Treasury (July 2011), The Green Book – Appraisal and Evaluation in Central Government

¹⁵² UK Gov't BIS (July 2013), Low Carbon Environmental Good and Services (LCEGS) – Report for 2011/12

It is worth briefly discussing whether increases in Scottish remanufacturing might cannibalise turnover and jobs from other parts of the economy. The majority of the goods used in Scotland are produced overseas. Therefore turnover/employment that might be otherwise cannibalised will actually take place outside of Scotland, meaning that increased remanufacturing in Scotland will unambiguously bring growth and employment benefits.

The second order growth and employment benefits for greater remanufacturing in Scotland are likely to be positive. This is because remanufacturing leads to cost savings for the companies buying remanufactured over new, and therefore offers companies greater possibilities to invest and grow their business. These types of cost savings can contribute an additional 15-25 % to trend growth rates¹⁵³ for the sector buying the remanufactured products. However, because of the position in the global supply chain, these benefits may also be obtained (through exports) by organisations outside of Scotland and so have been omitted from the scenario.

The scenarios modelled aggregate subsector specific data and growth potentials, summarised in Table 41. The growth potential was applied separately to the estimated employment and turnover figures identified for each sector. Each sector was modelled annually. The increase in employment was modified (reduced to 60%) to account for a reduced growth rate associated with increased capital intensity. Three scenarios were modelled (plus a baseline increase) based on the amount of Scottish Government intervention:

- **Low:** this is the baseline where there is little or no additional intervention beyond the normal business support offered through Scottish delivery bodies such as SMAS, Scottish Enterprise and Zero Waste Scotland. The assumed growth potential rate (over baseline – set at 2% annual growth rate) will be as follows: low = 0.5 %, medium = 1 %, high = 2 % pa.
- **Moderate, action-oriented interventions:** Elevated and targeted action-oriented intervention to increase remanufacturing at a sector level. Dedicated funds to helping businesses. Assumed growth potential rate (over baseline – set at 2% annual growth rate) will be as follows: Low= 1 %, medium = 3 %, high = 5 % pa.
- **High action-oriented, policy changes and international dialogue:** Wider ranging action-oriented interventions, dedicated sector-specific programmes to raise profile and create critical mass and government-level intervention to overcome institutional barriers and engaged internationally to encourage growth. Additional dedicated funds. Assumed growth potential rate (over baseline – set at 2% annual growth rate) will be as follows: low =2 %, medium = 5 % high = 7 % pa.

For the medical equipment sector, which is considered to have a high growth potential, but starts from a zero baseline, the low, medium and high scenarios consider linear growth to a market size in 2020 of £1 million, £3 million and £5 million respectively. Employment in the medical equipment sector is assumed to scale with turnover in the same proportion as in the ICT and mobile electronics sector.

It is important to state that these scenarios are based on broad assumptions and should therefore be used as illustrative. A full impact assessment would be necessary to fully explore the impact of intervention.

7.2 Scenario outputs

Using the model described above, an estimate on the potential growth of the Scottish remanufacturing industry for turnover is provided in Figure 7 and for employment in Figure 8.

¹⁵³ UK Gov't Defra (October 2010), The Effect of Business Resource Efficiency on Employment and Competition

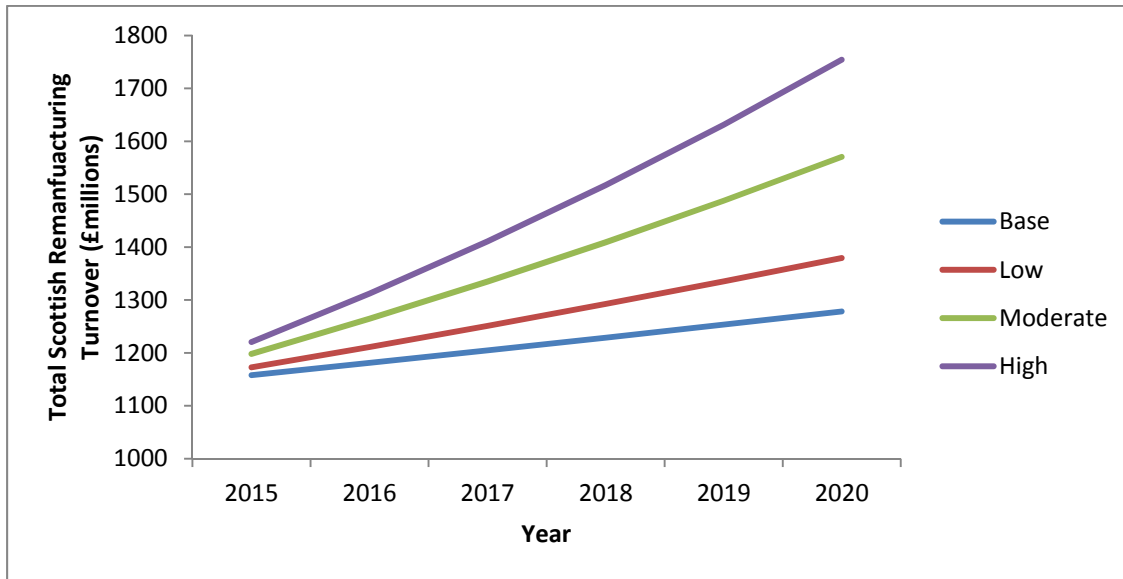


Figure 7 Projected turnover growth in remanufacturing in Scotland based on different levels of policy intervention.

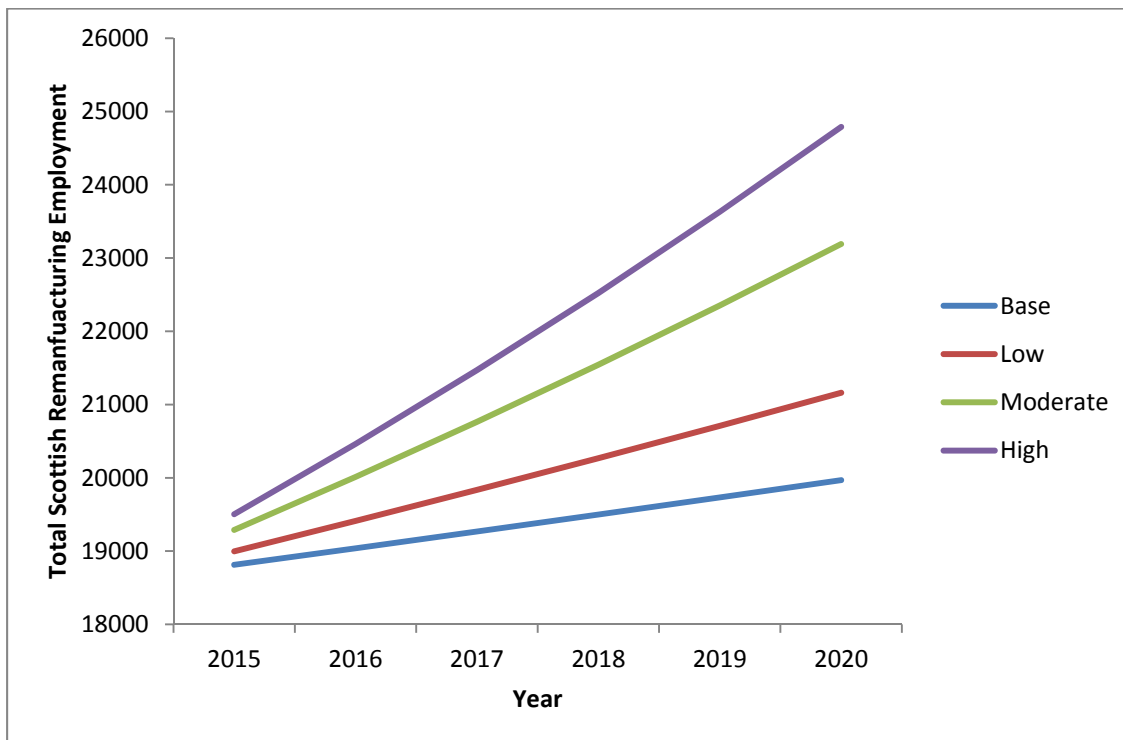


Figure 8 Projected employment growth in remanufacturing in Scotland based on different levels of policy intervention.

Based on our illustrative analysis, with significant investment and action by the Scottish government, remanufacturing could add up to £620 million to the Scottish economy; an additional 5,700 jobs could also be created. A full cost benefit analysis would be necessary to fully validate these findings.

8 Conclusions

Worldwide, remanufacturing is a significant economic activity. It accounts for about \$110 billion in sales. It is similarly important in Scotland, accounting for £1.1 billion and employing some 17,000 people. Major areas of activity in Scotland are in the aerospace, automotive: parts, energy, and rail. Nascent areas, which with some support could be significant, include ICT and medical equipment.

Identified barriers and recommendations are wide ranging but can be categorised into three key areas of the remanufacturing value chain, namely: supply of core, technical issues preventing remanufacturing and market development issues supressing demand.

If these challenges can be overcome, remanufacturing activity in Scotland could grow by an additional £620 million by 2020. However, there is no single intervention that will address all the barriers and a mixed approach that will require effort and collaboration by a range of delivery bodies along with Scottish Government and foreign national governments.

If these challenges can be overcome, the goal of developing a more 'Circular' economy will become one step closer. This will benefit both the Scottish economy, in terms of jobs and sales, and the wider environment, through a reduction in resource use.

Annex 1: Literature survey

identifying barriers and opportunities

This section presents a review of publically available literature on remanufacturing. The key aspects drawn from the literature are:

- Drivers and opportunities (both policy and other measures).
- Barriers and mitigations.
- Action-oriented approaches to encourage remanufacturing.

Remanufacturing in the UK: a significant contributor to sustainable development? (Oakdene Hollins, 2004)

This study was the first to document and quantify the impact of remanufacturing on the UK economy. The study concluded the drivers for existing remanufacturing activities are economic, rather than environmental, with remanufacturers benefiting from the greater profit margins associated with service-based, rather than 'make and sell' businesses. The sector was estimated to contribute around £5 billion to GNP and employ around 50,000 people. Legal barriers identified included: denial of access to manufacturer design information; banning of remanufactured components in new goods; and, redefinition of what constitutes waste. Other barriers identified included: competition from cheap imports; poor public perception of consumer goods; lack of technically skilled and motivated personnel; and, poor design for remanufacturing.

Product group report: automotive components (CRR, 2005 reissued 2009)

This sector study focused on remanufacturing of automotive components primarily for in-warranty and out-of-warranty replacement parts. The study notes that the logistics of core return usually necessitates local or regional remanufacture, except for large, high-value components e.g. engines and heavy end gearbox assemblies. The report highlights remanufacturing opportunities for air-conditioning units and notes the increasing complexity of electronic components, making remanufacturing more challenging.

Case study: rail sector (CRR, 2006 reissued 2009)

The sector study focused on remanufacturing of traction and rolling stock. The study notes the rail industry has a culture of maximising cost efficiency, e.g. through remanufacture of rolling stock and offerings of product service systems by some vehicle manufacturers promotes repair and re-use rather than replacement. The study suggests that remanufacturing is driven purely by cost and will be pursued wherever economical; therefore, there is limited policy intervention that could increase remanufacturing during scheduled overhaul. Changes to the rail network infrastructure such as construction of electrification or high speed sections could necessitate rolling stock replacement and temporarily reduce demand for remanufacturing.

Product group report: aerospace (CRR, 2006 reissued 2009)

This sector study focused on remanufacturing of aerospace components and aircraft, commonly referred to as "maintenance, repair and overhaul" in the sector. These activities are mostly carried out by OEMs, rather than independent service providers. Suppliers and service agents must meet strict certification and test regulations, therefore their products are of an extremely high standard. Challenges for the sector include methods for repairing new materials (e.g. composites) and remanufacturing a greater range of parts.

Product group report: ATMs (CRR, 2006 reissued 2009)

This sector study focused on remanufacturing of automated telling machinery. The study notes that there is an active remanufacturing market for complete ATM and spare part/module remanufacture. The control of bank ATM spare parts, for commercial and security reasons, acts as a barrier for entry

into the market for complete ATM remanufacturing by other remanufacturing organisations; however, there is a large global market for remanufactured spare parts and modules and non-bank machines.

Product group report: compressors (CRR, 2006 reissued 2009)

This sector study focused on remanufacturing of industrial compressors. The study notes that as an energy-consuming product, any decision to remanufacture should consider improvements in operating energy – it may be more efficient to replace a compressor rather than remanufacture, unless it can be upgraded. Notably, the shift to variable speed drives (VSD) has limited the opportunity to remanufacture older compressor units; however the higher price of VSD could incentivise remanufacturing of newer units. Remanufacturing is predominantly carried out by independent companies and OEM distributors and is commonly termed ‘refurbishment’. Suggested policy options include: extending government grants for energy efficiency to include remanufactured equipment; and, a rating system to allow purchasers of new equipment to compare suitability for remanufacture and upgrade.

Product group report: fans (CRR, 2006 reissued 2009)

This sector study focused on remanufacturing of fans for ventilation duties. The study found that remanufacturing of fans is extremely rare in the UK with no dedicated fan remanufacturers operating. Any remanufacturing activities are undertaken by service organisations involved in industrial equipment maintenance.

Product group report: TFT screens (CRR, 2006 reissued 2009)

This sector study focused on remanufacturing of thin film technology (TFT) (i.e. LCD) displays. The falling price of LCDs per m² is identified as a barrier to remanufacturing as well as emergent technology development, e.g. LED displays.

Product group report: laptops (CRR, 2006 reissued 2009)

This sector study focused on refurbishment and re-use of laptops. The study notes that remanufacturing of laptops must be lean and efficient to make it competitive against low, cost imports of new goods. Remanufacturing may involve the repair of the whole unit, or of individual components for spares.

Product group report: office equipment (document printers) (CRR, 2007 reissued 2009)

This sector study focused on remanufacture of photocopier equipment. The high capital costs and service-based model of photocopier use has led to remanufacturing becoming an established activity in the sector; however, the report notes the value of new, and therefore second-hand, photocopiers is falling rapidly, making remanufacturing less attractive. The transition from analogue to digital technology can be a barrier to the remanufacture of older devices. Most remanufacturing is done in-house by OEMs. Remanufacturing could be incentivised through public purchasing.

Product group report: office equipment (CRR, 2007 reissued 2009)

This sector study focused on remanufacture of ink-jet printer cartridges. Unified inkjet cartridges are more attractive for remanufacturing than separate print-head and ink reservoir cartridges as their greater complexity gives them a higher inherent value. Barriers include: the public perception that remanufactured cartridges are inferior to branded OEM cartridges; the inclusion of smart chips and product design features that prevent re-use, e.g. irreversible welds. There is significant opportunity to increase the collection of inkjet cores, most of which currently end up in landfill.

Product group report: cutting tools (CRR, 2006 reissued 2009)

This sector study focused on remanufacturing of cutting tools. The report notes that remanufacturing of standard cutting tools can commonly be remanufactured by independent organisations, while remanufacturing of bespoke cutting tools is more likely to be entrusted to the OEM. One barrier to remanufacturing is the sourcing of low cost imported tooling, which negates the economic benefit of regrinding and reduces the cost and inconvenience of sending tooling away for remanufacture.

Product group report: machine tools (CRR, 2006 reissued 2009)

This sector study focused on remanufacturing of manual and CNC tooling machinery. The report notes that few large OEMs offer full remanufacturing services, with smaller OEMs and independent organisations more likely to offer these services. Remanufactured machine tools are attractive because of lower capital costs, use for lower volume or backup production, or possibly for reduced lead times. The report suggests that for remanufacturers to compete in the global market, they must also offer up-grade services, e.g. the addition or upgrade of CNC controls.

Product group report: tyres (CRR, 2006 reissued 2009)

This sector study focused on remanufacturing, or re-treading, of tyres. By volume or mass, remanufacturing of car tyres makes up the majority of remanufacturing activity, followed by truck tyres, with a small amount of aerospace tyres. However, the fraction of remanufacture in these categories is reversed: nearly all aerospace tyres are remanufactured, while only a very small percentage of car tyres are remanufactured. This suggests an opportunity – remanufacturing of aerospace tyres produces high quality and high performance tyres; therefore, there is little technical reason why there could not be greater remanufacturing in the truck and car tyre sectors. However, new budget vehicle tyres are very competitive compared to the cost of re-treading.

Product group report: vending machines (CRR, 2006 reissued 2009)

This sector study focused on remanufacture of vending machines for beverages and other products. The report notes that with an increasing number of imported vending machines, it is likely that the remanufacturer will not be the OEM. Barriers identified include: the availability of cheaper equivalents; increasingly complex and variable products making disassembly more challenging; and, a lack of technically skilled workers. An opportunity identified by the report is for remanufactured parts suppliers with specialist technical knowledge for remanufacturing vending machine components.

Product group report: floor tiles (CRR, 2007 reissued 2009)

This sector study focused on the remanufacture and refurbishment of textile-based floor coverings. The report notes that both Milliken and InterfaceFLOR, the leaders of European floor tile remanufacturing, have both enlisted the help of social enterprises to refurbish and/or distribute floor tiles. Public purchasing policies and Green Procurement Codes could increase the uptake of remanufactured floor tiles.

Product group report: industrial food processing equipment (CRR, 2007 reissued 2009)

This sector study focused on the remanufacturing and re-use of industrial food processing equipment (IFPE). One barrier noted in the report is the high embodied labour in IFPE; the value of the components is relatively small compared to the cost of assembly, which inhibits remanufacturing. Remanufacturing is limited in this sector, with about 15 % of the IFPE market made up by second hand equipment sales. An additional barrier is the need for remanufactured equipment to gain CE marks.

Product group report: office furniture (CRR, 2007 reissued 2009)

This sector study focused on the remanufacture of office furniture. The report notes that it is unclear how many OEMs remanufacture their own furniture products, but it is estimated that there are very few that do. Remanufacturing is attractive in this sector as the majority of production costs are from purchasing raw materials, which can be retained during remanufacture. Drivers for increasing remanufacturing recommended by the report include: encouraging full lifetime services including maintenance and end-of-life take back; raising awareness of furniture remanufacturing; public purchasing policies; social enterprise funding to develop remanufacturing skills; promote design for disassembly; establish a central waste management organisation to reclaim and distribute office furniture for remanufacture; and, continue the development of take-back schemes.

Product group report: industrial boilers (CRR, 2009)

This sector study focused on the remanufacturing of industrial boilers. The report notes an increasing trend in the UK for OEMs to offer service-based models as a means to compete against lower cost, and quality, imported boilers. Remanufacturing in the sector is limited due to: bespoke specifications, re-certification costs and incentives to purchase new, efficient equipment. Upgrading boilers as part of their regular servicing is much more common than remanufacture at end-of-life.

Product group report: tower cranes (CRR, 2009)

This sector study focused on the remanufacturing of static lifting equipment. The report notes that there is no remanufacturing of cranes in the UK and it is considered unlikely to become commonplace in the future due to concerns for safety and being uneconomic. There is a limited amount of crane refurbishment that takes place during the life of the crane, e.g. to repair major damage.

The carbon footprint of remanufactured versus new mono-toner printer cartridges (CRR, 2008)

This study compared the carbon footprint of a new and remanufactured mono-toner printer cartridge. The study found that the remanufactured cartridge, which can be remanufactured on average 3.5 times, has a carbon footprint 46 % lower than that of a new cartridge.

Product group report: printing presses (CRR, 2009)

This sector study focused on the remanufacturing of offset and digital printing equipment. The report notes there is little opportunity for remanufacturing of traditional printing presses, while there may be greater opportunities for digital press technologies. There is an active second hand market for used traditional offset presses; however, refurbishment is more common than full remanufacture. Remanufacture of digital presses does occur, generally by OEMs due to the availability of skills and specialist components. Some OEMs are also designing digital presses with re-use and remanufacturing in mind.

Product group report: photovoltaics (CRR, 2008)

This sector study focused on the remanufacturing of photovoltaic solar cells. The report notes that remanufacturing of solar cells would be influenced by the long financial payback time than the energy payback time, which is typically less than 20 % of life. Current remanufacturing issues identified include: low core availability, recovery logistics, complexity of disassembly, and remediation techniques. A key technical issue is that the joining technologies used to create impregnable and long-life panels may make remanufacturing more difficult.

Product group study: the potential for remanufacturing of wind turbines (CRR, 2008)

This sector study focused on the remanufacturing of wind turbines. The report notes that the opportunity for remanufacturing turbines is currently low in the UK due to the low wind turbine base. The opportunity noted is for remanufacturing of turbines for community and company projects. One driver for remanufacturing is the motivation to repower existing wind turbine sites and upgrade equipment located at the most favourable generation spots. This creates a supply of core that could potentially be remanufactured and commissioned elsewhere. One barrier for remanufacture would be the ability to transport increasingly large turbines.

Market failures in remanufacturing (CRR, 2010)

This report identifies and describes four market failures in remanufacturing and suggests a range of mitigations supported either by intervention or led by government policy. (1) Transaction costs: incentivise return of products, web exchanges, subsidies for remanufacturers, capital grants, VAT rebates. (2) Information failures: warranties, long-term contracts, standards, certification schemes, provision/subsidies of testing facilities, penalising miss-sellers, provision of information. (3) Externalities (climate change, technological and consumption externalities): strengthen underlying

signals of externalities pricing, modular design and open standards, supply chain initiatives to encourage whole life management. (4) Market power: national competition policy.

Policy report: a review of policy options for promoting remanufacturing in the UK (CRR, 2008 updated 2009)

This report identifies three transaction points where barriers to remanufacturing can exist: Firstly, during reverse logistics, or core collection, barriers include: cost and availability of storage space, and limited product returns. Secondly, during sorting and disassembly barriers include the cost of gathering the information necessary to facilitate remanufacturing, e.g. identifying components, confirming suitability for remanufacturing and the remanufacturing process. Thirdly, at the purchasing decision barriers include: the perception of remanufactured products as inferior to new, user 'lock-in' to specific technology and the increase of product functionality in new products. Potential areas for policy intervention identified include: incentivisation of product return; correction of information deficits or asymmetry; diffusion of technical knowledge and design for remanufacture; and, removal of policy failures.

Re-use of office furniture – incorporation into the 'quick wins' criteria (CRR, 2009)

This report is a study of the market potential for re-used and remanufactured office furniture in the UK and particularly looks at the role of public procurement policy, for example, the 'Buy Sustainable – Quick Wins' list. Good practice business models identified include: buy-back scheme, in-house refurbishment and third party collection. Barriers identified include: a lack of demand for re-used furniture; logistics for re-use and remanufacture, e.g. storage and transportation; quality and technical issues, such as damage prior to or during transit, identifying items suitable for remanufacture, changing trends in office design, and low quality items designed for low cost, not durability; heavy discounting on new furniture products; and, new legislation prohibiting the sale of particular chemicals, which may be present in furniture coatings etc.

Calculating the environmental benefits of remanufacturing (King and Gu, Proceedings of the Institution of Civil Engineers, Waste and Resource Management Special Issue 2010)

This paper highlights environmental legislation that has been a driving force for remanufacturing. In Europe, the end-of-life vehicle directive and the waste electronic and electrical equipment (WEEE) directive both aim to increase recovery and reduce disposal of waste. However, neither contains any specific provision for remanufacturing, unlike regulation in the USA. The New York remanufacturing bill passed in 1998 (and now in force in Texas, Connecticut and California) requires that invitations to tender for durable equipment firstly consider remade goods. Since 2000, New York also gives a tax credit to remanufacturing firms.

An introduction to remanufacturing (CRR, 2007)

This report introduces the concept and practice of remanufacturing. The report notes that remanufacturing typically occurs for products with significant embedded material, energy and labour resources, and where most of this value can be retained through remediation.

Remanufacturing in the UK – a snapshot of the UK remanufacturing industry (CRR, 2009)

This study was an update to the 2004 CRR report. The total value of remanufacturing and re-use activities estimated following the 2009 survey was £2.4 billion (excluding aerospace) with remanufacturing making up about half of this value. In addition to the economic and environmental benefits of remanufacturing, other benefits identified include: more flexible businesses and business models, better relationships with customers, a more skilled and adaptable workforce, and benefits over materials reclamation alternatives. Issues identified in the survey that can act as a barrier to remanufacturing include: a declining UK manufacturing base, competition from low cost new products, high cost of labour, low purchaser awareness and understanding of remanufacturing, lower quality and quantity of core available, a shift from remanufacturing to lower value refurbishment activities, longer product lifetimes, increasing complex business operations and economic recession.

Product group study – drivers and barriers for remanufacturing of small- and medium-scale wind turbines (CRR, 2010)

This study focused on the remanufacturing of wind turbines. The report noted that at the time of writing the UK wind turbine remanufacturing industry was in decline with many remanufacturers attributing this to the introduction of feed-in-tariffs, which, while promoting small-scale, low-carbon electricity generation, does not include refurbished or remanufactured wind turbines.

The LEIF brief: remanufacturing and recommerce (Carbon International, 2012)

This edition of the LEIF brief looks at the potential for remanufacturing and recommerce to be environmental growth strategies. Barriers to remanufacturing identified by research partner, Oakdene Hollins, include: fast reductions in cost and/or product evolution, fashionable goods or goods where status is associated with newness, and poor design for disassembly. The report notes that standards can have a role in reducing the risk of consumers being exposed to inferior 'second-hand' products and that the methods used for core recovery will depend on the perceived value of the used product by the customer, e.g. high value products may involve full service contracts while low value products may rely on customers disposing of items responsibly, for example, donating or sending inkjet cartridges for remanufacturing.

Resource resilient UK – a report from the Circular Economy Task Force (Green Alliance, 2013)

This report discusses how re-use, remanufacturing and recycling can help reduce resource insecurity. One intervention recommended by the report is in product design, through existing legislation, to make products easier to remanufacture. The report notes that the tight resource loop of remanufacturing not only provides the greatest risk mitigation (e.g. against scarcity, impact, political, carbon risk), but also tends to recover the most product value. Two barriers for the greater uptake of circular opportunities, such as remanufacturing, are: market barriers and material barriers. Market barriers create uncertainty over the supply and demand and include: the current low perception and therefore low cost of material security risk favouring established linear systems; split incentives, e.g. design for disassembly may not end up being beneficial to the OEM but a third party; and, inadequate recovery infrastructure. Material barriers are issues where the properties of materials and products may either inhibit or encourage remanufacturing and include: value; ease of remanufacture; pace of evolution for material or product function; concentration of material for recovery; level of material or product contamination. Along with addressing market and material barriers, the report recommends clarifying exposure to risk, e.g. from material scarcity, and facilitating co-operation between businesses to promote circular resource approaches. For increasing the ease of remanufacturing, as part of the draft action plan for a resource resilient UK, the report recommends the business-led action of using remanufacturing standards; government-brokered actions of: developing collection standards for re-usability, initiating dialogue to limit material use and setting green public procurement rules; and, government-mandated actions of: requiring ability to repair, recycle and disassemble via Ecodesign or incentives and setting minimum re-use targets.

'Sweating our assets' - productivity and efficiency across the UK economy (2020 Productivity & Efficiency Commission, 2014)

This report proposes policies to improve productivity, efficiency and resilience in the UK economy over the coming years. One of the key findings of the report is that to become highly resource productive, the UK should focus on the remanufacturing/reprocessing/reengineering sector with the potential to create 300,000 jobs and £5bn per annum additional profits for remanufacturers. As part of this focus, the redefinition of 'waste' to 'resource' could facilitate the creation of new remanufacturing ventures, including the movement of waste policy from Defra to BIS. Landfill bans for particular products or materials would be another driver towards remanufacturing.

Examining remanufacturing in supply chain and operations management (APICS Foundation, 2014)

This report summarises the findings from an industry survey on remanufacturing attitudes and practices. Key organisational challenges to remanufacturing include the additional complexity of reverse supply chain logistics, which may necessitate specialist training, and forecasting the condition and volume of core arising.

Remanufacturing – towards a resource efficient economy (All-Party Parliamentary Sustainable Resource Group, 2014)

This briefing paper discusses the opportunities and challenges remanufacturing faces and makes recommendations to Government for how to address them. The lack of a globally accepted legal definition for remanufacturing is identified as a barrier and the report recommends Government adoption of an appropriate definition. Opportunities for remanufacturing could be identified by considering criteria for successful remanufacturing and observing areas where remanufacturing has not yet been explored. The report recommends the Government develops a fund to optimise remanufacturing development in these areas. Barrier to the uptake of remanufacturing include: a lack of design for remanufacturing, poor information sharing along the supply chain, elements of the regulatory framework, return of core, international trade conditions, and the need for a trained workforce. Specific examples of regulation that may inhibit or are unclear on remanufacturing include: the WEEE Directive, the Waste Framework Directive, the End of Life Vehicles Directive, the Sales of Goods Act, the REACH Regulation, the RoHS Directive and the Energy using Products Directive. Recommendations related to regulation include: amending guidance on the Legal Definition of Waste to exclude remanufacturing core; amending the Freedom of Information Act to require designers to impart on request information to facilitate remanufacturing; and, addressing the other examples of regulatory barriers to remanufacturing. The report also recommends: considering a certified mark for remanufacturing, adopting whole life costing, setting up a Centre of Excellence for UK Remanufacturing, considering a tax break for remanufacturers and setting up a cross-departmental committee to ensure collaboration when considering the policy areas around remanufacturing.

An economy that works (Aldersgate Group, 2014)

This report explores opportunities to create a smart, low carbon and resource efficient UK economy. One of the six core characteristics for such an economy identified in the report is 'zero waste', and remanufacturing is an important circular production model to help achieve this, and increase profitability. The two main drivers for a 'zero waste' economy identified in the report are resource depletion and accumulation of waste to landfill. The three policy interventions identified to facilitate the transition to a zero waste economy are echoed from the Circular Economy Task Force report: clarify exposure to risk from material insecurity, broker supply chain co-operation, and enable system design.

Materials for manufacturing – safeguarding supply (EEF, 2014)

This report highlights the importance of materials and resources in manufacturing: materials and resources account for about 40 % of manufacturers' costs and volatile costs and supply risks are important concerns. The report states that remanufacturing is poorly understood by EU policy makers and contrasts policy in the USA to promote remanufacturing, with the existing policy framework in the UK, which creates barriers to remanufacturer's competitiveness. The legal barriers to remanufacturing are taken from the All-Party Parliamentary Sustainability Resource Group report. The report highlights public procurement as a potential driver for increased remanufacturing as well as support for a Network of Excellence in Remanufacturing, of which the University of Strathclyde is a proposed partner.

The next manufacturing revolution: non-labour resource productivity and its potential for UK manufacturing (Lavery/Pennell, 2degrees and IfM, 2013)

This report explores opportunities for improving non-labour resource productivity in the manufacturing sector. One opportunity identified is circular resource use, of which remanufacturing is cited as an important component. The report highlights three manufacturing sectors with the greatest opportunities for circular resource use. These are: electrical, electronic and optical products, machinery and equipment, and transport equipment. The report estimates that remanufacturing in

these three sectors could create £5.6-8 billion value per annum and over 310,000 new jobs. Barriers identified include: senior executive leadership – remanufacturing may involve a change of culture and/or business model; information – including awareness of the benefits of remanufacturing and a standardised definition of remanufacturing; skills; design – including modular design and design for disassembly; recovery infrastructure; legal constraints – including regulatory barriers access to product information; and, collaboration to change the throw-away culture and improve customer perceptions of remanufactured products.

Towards the circular economy Vol. 3 (Ellen MacArthur Foundation, 2014)

This report explores how the move towards the circular economy can be accelerated across global supply chains. Two of the challenges for circularity identified that apply to remanufacturing are: separation of products and materials and sufficient scale and reliability of supply.

Growing a circular economy: ending the throwaway society, third report of session 2014-2015 (House of Commons Environmental Audit Committee, 2014)

This report summarises the evidence received by the Environmental Audit Committee on the experiences, benefits, barriers and opportunities of circular economy practices. One opportunity for policy intervention to support greater circularity is through landfill bans. By banning particular products from landfill, return mechanisms for products and materials will have to be established. Other policy areas for growing a circular economy include: taxes to support resource efficiency, e.g. taxation of the lowest levels of the waste hierarchy, differential VAT rates and tax allowances for businesses involved in repair/re-use; producer responsibility and 'take-back' schemes; standards to promote circular products, e.g. in design and warranties; trade and definition barriers for remanufactured goods and components; and government procurement.

Remanufactured goods: an overview of the U.S. and global industries, markets, and trade (United States International Trade Commission, 2012)

This report summarises the current state of the US remanufacturing industry, including markets, trade and major factors affecting the sector. The US has the largest remanufacturing industry in the world, valued at \$43 billion in 2011 and supporting 180,000 full-time workers. The report identifies three barriers to trade in remanufactured goods and core in foreign markets: regulatory barriers, import bans and the lack of a common legal definition of remanufactured goods.

Resource futures (Chatham House, 2012)

This report outlines the findings of the Resource Futures project, which explored constraints and uncertainties in future resource markets and the implications for policy makers and the political agenda. The report identifies demand reduction as an important strategy for protecting companies from high and volatile resource prices. Remanufacturing is a demand reduction strategy as it reduces the demand for virgin materials. The World Economic Forum is cited in the report as calling to promote new circular business models (such as remanufacturing) with the drivers of: reducing cost, creating new revenue streams and building resilience to tougher regulation and public scrutiny. Information transfer along the supply chain is identified as a potential barrier to remanufacturing. The report identifies two main opportunities: firstly, cross-border piloting of circular business models, particularly with China, Japan and South Korea, e.g. work on standards innovation and global supply chain management; secondly, development of appropriate metrics, resource accounting tools and guidance to promote the uptake of circular practices by SMEs.

Manufacturing the future: the next era of global growth and innovation (McKinsey, 2012)

This report explores the manufacturing landscape and identifies trends and influences that will shape the future manufacturing industry. Innovation in manufacturing business models is identified as an important influence, which includes remanufacturing practices as part of the circular economy.

Resource security action plan: making the most of valuable materials (BIS and Defra, 2012)

This report sets out the risks of resource insecurity and summaries current and future actions to mitigate these risks. The report identifies circular business models such as remanufacturing as a potential source of supply constrained materials and represents “the simplest way for businesses to manage the risk” of material shortages by being more efficient with their existing critical resources.

Circular economy evidence building programme renewable energy sector report, working draft (AMEC, 2014)

This report examines the uptake of circular economy practices in the renewable energy sector. The report identifies design for re-use as an enabler for remanufacturing; however, it not widely used in the renewables industry due to a lack of demand from customers, with the most development in the wind sector. Influence in design for re-use is also limited in Scotland to locally produce small-scale turbines and the marine sector. The report identifies remanufacturing of wind turbines as a significant opportunity for Scotland – a key barrier to remanufacturing devices has been overcome as remanufactured turbines meeting specific conditions can be certified by OFGEM and therefore be eligible for Feed-in-Tariffs.

Circular economy evidence building programme sector study on aerospace-defence-marine (AMEC, 2014)

This report examines the uptake of six circular measures in the Scottish ADM sectors and estimates the potential benefits arising from projected uptake rates. One of the circular measures examined is maintenance, repair and overhaul or remanufacturing activities. The study estimates the existing percentage uptake of this measure (in value terms) is 75 % for aerospace and defence, and 60 % for marine. The report suggests that remanufacturing in the ADM sectors has the greatest potential for creating jobs and growth in Scotland; however, the capital and infrastructure investment necessary to develop remanufacturing may be a barrier. The report suggests the presence of large OEMs in Scotland will be important for developing the remanufacturing industry. Motivators for uptake of remanufacturing include: a focus on the high intrinsic value components, a moderate pace of technology evolution, robust reverse logistics and design for remanufacturing. The report highlights the success of the aerospace MRO model as an example for other sectors wanting to develop remanufacturing activities. Particular drivers emphasised are traceability of components and design for re-use.

Remanufacturing, refurbishment and recycling of automotive components: trends and opportunities (Optimat, 2013)

This report looks at the remanufacturing, refurbishment and recycling aspects of the Scottish automotive sector and the trends and opportunities that may arise. The report suggests that the anticipated shift from mechanical to mechatronic parts, with their higher residual value, will further encourage remanufacturing and refurbishment over recycling. The report identifies numerous opportunities for a more circular automotive supply chain (page v). The update to the End-of-Life Vehicle Directive, requiring 95 % re-use and recovery by 1 January 2015 presents an opportunity for increased re-use and remanufacturing of components; however there are barriers to the use of re-used automotive components, including: safety, consistency and quality concerns, availability, uncertainty over return policies and opaque pricing structures. Some of these concerns could be addressed by using standards e.g. PAS. Potential policy actions recommended in the report include numerous suggestions to promote remanufacturing. The report notes that the insurance industry is a driver of remanufactured automotive components due to lower costs than new OEM or aftermarket parts. Vertical integration of dismantlers and service/repair facilities might represent an opportunity to mitigate the issues of short lead-time availability. Maintenance of Scottish public sector vehicle fleets might represent an opportunity for remanufactured components; the report estimates that between £14-20 million is spent annually on fleet vehicle parts.

Circular economy evidence building programme oil and gas sector report, working draft (AMEC, 2014)

This report examines the uptake of circular economy practices in the oil and gas sector. While significant volumes of material are expected to be decommissioned in the coming years, only 39 installations have been decommissioned to date; therefore, the process of decommissioning is not yet mature or optimised for circular economy approaches. The report identified that there are a number of firms in the UK oil and gas sector offering remanufacturing services for small to medium sized equipment, e.g. for pumps and valves. Remanufacturing benefits identified for the sector include: “greater product lifetime, retention of resources and values within the economy, increased re-use potential, lower costs, employment potential, reduced lead-in time for equipment and increased security of supply”. Drivers for increasing remanufacturing in this sector include accreditation of remanufacturers, Green Passport initiatives (to provide product traceability), and waste regulation review to prevent remanufactured products and core being classified as waste. Barriers to increased remanufacturing include: a lack of design for remanufacturing, installation-specific equipment, increased time/cost/risk to decommissioning, product obsolescence, liability issues and concerns, obtaining warranties and assurance, and document maintenance.

Fiscal instruments to stimulate a more circular economy, draft final report (Triple E Consulting, 2014)

The report notes that remanufacture is typically much more profitable than material recycling. This is especially true for large, complex, mechanical and electromechanical. In European legislation, there has been a trend towards viewing waste as a resource; the most recent example is the adoption of the EC communication: towards a circular economy: a zero waste programme for Europe. The Scottish Government’s Zero Waste Plan has key targets to achieve a 70 % recycling rate and reduce landfill to 5 % by 2025. Scottish waste policy seeks to both move material up the waste hierarchy and maximise the resulting economic benefit. The report notes that variable VAT is an interesting fiscal instrument and reports that there is a 5 % VAT rate on the use of remanufactured material in aircraft (not verified). The Scottish Recycling Fund is reported to have been extended to include remanufacturing as an eligible activity. Barriers to design for disassembly (DfD) include: actual/perceived additional cost of producing a DfD product; lost revenue of replacement products; conflict with functional design requirements; lack of DfD knowledge. Modular design is identified an enabler for remanufacturing but relies on a well-developed market for spares. Mechanisms for sharing design information throughout the supply chain could allow feedback into the design process, enabling design for remanufacture, for example the International Material Data System in the automotive sector. Barriers to this include intellectual property issues and the loss of revenue from new product sales. Innovative business models that can enable remanufacture include: performance based service models, retention of asset ownership by the producer and the use of warranties with remanufactured products. In addition to fiscal instruments, public procurement and standards development could be important remanufacturing enablers.

A regulation and circular economy review, draft final report (Ricardo-AEA, 2014)

This report reviews legislation and regulations that may influence circular economy practices, such as remanufacturing. The key issues relating the remanufacturing include: producer responsibility regulations focusing on recovery and recycling with no specific remanufacturing targets; waste regulations focusing on recycling with no specific remanufacturing targets; health and safety regulations potentially limiting remanufacturing applications; and, eco-design regulations lacking focus on remanufacturing and therefore not incentivising design for remanufacturing.

Annex 2: A review of the future direction of remanufacturing

Foresight Future of Manufacturing: Evidence papers

EP 1 (evidence paper 1 of the 37 papers used to inform the analysis and final Foresight report). EP1 was concerned with 'The future of manufacturing: international perspectives – workshop report'

Section, Drivers of Change: Economic (out of Social Technological, Economic, Environmental, and Political)

Circular economy listed as one of 5 drivers including Human Capital, Manu Services, Collaboration and Competition, New Markets and Competitors.

"Circular Economy (medium/low certainty, high impact) Advances in resource efficiency promise to cut use of materials and energy. Advances in resource efficiency promise to cut use of materials and energy. An emerging "Circular Economy" will help stretch resources further, where waste outputs can be used as resource inputs elsewhere. New technologies and processes are increasing our ability to recycle more material goods, while design for reuse will help ⁹⁹realized waste."

EP24 What role does Government procurement plays in manufacturing in the UK and internationally and how might this change in the future?

Context

The report highlights the context of emerging technological sectors in the UK:

"A discussion of emerging technologies up to 2050 requires the examination of the future global context within which manufacturing will take place, the present emerging technologies and sectors in the UK, the impact of resource scarcity, the importance of the circular economy and the increasing move from products to services."

Manufacturing sector innovation in the long term

"Stakeholders participating in this review felt that, in the longer term UK manufacturing will based not only on [names technologies] but also from R&D and commercial application of a combination of technologies and others yet to emerge. Seeing the future of manufacturing developing only from particular sectors was seen by the stakeholders as being limited by a 'silo' based way of thinking which would limit future potential up to 2050. This cross-sectoral approach is particularly apt for a future of scarce resources and a need for a circular economy. Stakeholders believed that the issues of resource scarcity and resilience will be amongst the mix of influences likely to determine the future form of manufacturing in the UK"

Circular economy

"Stakeholders consulted during this review were firmly of the view that technologies will not develop in silos (or specific sectors) and their application will be cross cutting. So we can expect cross-sectoral research and development to offer great advantages to UK manufacturing in the future. One reason given for this view is the emergence of the global circular economy (Royal Society of Arts, 2013) (Ellen MacArthur Foundation (2013, 2013). Many of our stakeholders anticipate that approaches based on the circular economy [can] help the UK economy build resilience in the face of resource shocks and threats to security of supply of key raw materials. In this respect trends in the UK follow those of other nations, since the European Commission called for a 'circular resource efficient and resilient economy in December 2012, while a 'large scale circular economy' is one of China's environmental goals for 2020 (ENDS Report, 2013)

WRAP (Waste Resources and Action Programme) states that the “circular economy is an alternative to a traditional linear economy (make use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life (WRAP, 2013).”

WRAP’s vision for the UK circular economy to 2020 is highlighted by the report and states that ‘considerable economic benefits’ are associated with the adoption of a circular economy, citing Defra figures which suggest that UK businesses could benefit by up to ‘£23 billion per year through low cost or no cost improvements in the efficient use of resources. The report also cites McKinsey whose estimates suggest that the global value of resource efficiency could eventually reach \$3.7 Trillion per year.

The report highlights that the remanufacturing sector is already reported to be worth \$2.4 bn and employs 50,000 people, “so there is potential for UK public procurement to stimulate the merging remanufacturing sector through its specification of goods and services (ENDS report 2013)”.

“Having considered the global context for UK manufacturing, the likely emerging technologies that the UK has strengths in, the need for a wide view of cross sectoral technologies of the future, the impetus of future resource security issues and the potential of the circular economy, this review will now look at particular existing and emerging technologies and sectors to determine the potential of public procurement to stimulate the UK manufacturing sector up to 2050.”

“Stakeholders at the strategic supply chain group’s discussion of this review quoted examples of how UK public sector procurement is already supporting infrastructure development in line with the circular economy and ‘resilience’”

“In Scotland, the Ready for Business initiative is aimed at building capacity amongst third sector organisations, including SMEs and social enterprises, enabling them to compete for public sector contracts...Significantly this programme provides training to public procurers to develop their understanding of how to procure innovative solutions from a relatively young market including firms involved in the remanufacturing sector.”

“ Extending producer responsibility requirements to encourage take-back and recovery of products for remanufacturing, reuse and recovery of component materials – this would reduce product footprints by improving lifetime optimization (Pers. Comm. Mervyn Jones, 2013)”

Concluding remarks

“Looking into the future, the stakeholders we consulted felt that a number of trends are likely to affect availability of non-renewable natural resources, raising concerns from a government and industry regarding resource security. These trends can help promote a move towards a circular economy and increase the servitisation of products, which will affect UK manufacturing through increased demand for design maintenance repair and overhaul (MRO) and remanufacturing operations, as well as services such as reverse logistics.”

Summary/ Conclusions

The report highlights 5 key approaches that the authors believe can catalyse the impact of public procurement on the manufacturing sector in the UK. These include Procurement mentality / culture, procurement methods, inter-departmental strategies, innovative procurement models and new business models.

The ‘New business models’ approach was described as follows:

“A move towards a circular economy that reflects increasing pressures around material scarcity would help create a more sustainable and resilient economy. This will also support manufacturing sectors that can design closed-loop supply chains and that are able to re-use and recycle disposed materials on a regional or national basis.”

“Some of the most significant conclusions concern the prospects for building capacity in the UK manufacturing base to respond to the threats and opportunities associated with climate change and the need for resilience in supply chains more widely. Looking out to 2020 and 2050, this is necessarily subject to uncertainties but a majority of those participating reported it as an area in which there is likely to be opportunities to stimulate closed loop business models based on the concept of the circular economy, for example.”

“ Stakeholders also saw great opportunities in the future for UK public procurement to gain advantages from reuse and remanufacturing , particularly of scarce materials, linking this to the possible development of a skills base as part of a future UK economy. The development of skill sin reuse, refurbishment and remanufacture is seen as critical to attracting employment opportunities back to the UK. Where manufacturing has been outsourced to low cost economies, stakeholders commented on the scope for some parts of the UK manufacturing base to gear themselves up for a future trend towards ‘on-shoring’. Similar trends are apparent in the energy supply sector. Evidence from Ellen MacArthur Foundation(2012) suggest that there will be a role for intermediary organisations or matchmakers in this process, promoting and facilitating ‘closed loops’ and the circular economy”

Key factors in the public sector stimulating UK manufacturing with respect to the circular economy and remanufacturing included

- *“Sustained buy-in to the concept of circular economy at senior level by public sector organisations (in particular by HM Treasury)”*
- *“Investment in skills, training, apprenticeships and employment opportunities to support the growth of firms focused on reuse, refurbishment, remanufacturing of materials (closed loop systems).”*

EP 27 The future impact of materials security on the UK manufacturing industry

The report examines the impact of critical raw material supply risks on UK manufacturing supply, highlighting the following linkage between manufacturing and the circular economy and remanufacturing.

“The functional performance of carbide tools will ensure buoyant demand for tungsten in the foreseeable future, despite some loss of market share in some applications to advanced ceramics. Net raw material demand could be reduced by expansion of closed- loop tool-bit use, where products are returned from the field for remanufacture and re-use. If fusion technologies prove feasible and are implemented, a significant demand for tungsten hard-metals in reactor liners may arise.”

Mitigating strategies for issues of materiality criticality are identified and include

- Primary supply structure
- Substitution
- Re-use or recycling

In the substitution section the following is highlighted:

In order to develop a circular economy in which waste becomes a resource and is fed back into the economy as a raw material, a range of policies which encompass the whole product lifecycle is required. Material resource efficiency is radically improved when increased recycling is combined with greater product longevity, achieved through product design, or repair/reuse/remanufacturing. Recycling and collection targets are already in place in the UK for a wide range of products which coincidentally contain critical raw materials. However, additional targets and measures are required to ensure that critical raw materials are both recovered effectively when products become waste and used in a more efficient way.

Relevant report recommendations:

“Encourage remanufacturing and re-use as a means of avoiding dissipation of small concentration materials. This may be assisted by a move to more serviced business models.”

“For low-carbon technologies such as photovoltaic and LED lighting it is critical that policy measures are put in place before products reach their end-of-life to ensure that materials are recovered

effectively. Recycling is a cornerstone in ensuring resource efficiency and moving towards a circular economy by recovering valuable resources. However, from many products critical raw materials are not currently recovered and are instead lost during processing. Collection and processing of low-carbon technology products should be established in the UK.”

EP 33 Which business models might ensure UK value from emerging sectors

Summary findings

“Offerings based on a more circular flow of products, including repair, remanufacturing and collaborative consumption will become more prevalent, driven by an increased separation between ownership of products and their use, and by various environmental pressures. This could result in a manufacturing system where remanufacturing and re-use is the norm, and origination of products from virgin raw materials, to be sold once and for all to the end user, is the exception.”

Business models which “Connect the forward and reverse flows of products in a circular economy” will be key.

Section: Business models to 2050: Themes and Drivers

“The market offering of manufacturing firms is where value is co-created with the firm’s customers, and is the basis for value capture. The market offering will become increasingly interactive, comprise various forms of what we currently term ‘services’, will be valued in new ways, many of which are associated with environmental and social sustainability; it will also be part of a circular, repair-based economy, rather than a linear, production-and-consumption-based economy. New market offerings will be the way to capture value from new technologies, and will be the basis for creation of new needs-based sectors.”

Section: Repair, the circular economy and collaborative consumption

“Models based on temporary or shared ownership achieve many similar ends, adding up to a shift from a linear economy to a circular economy, i.e. from an economy based on the conversion of raw materials into products that end their lives as waste, to an economy where products are re-used, ‘re-purposed’, repaired, re-manufactured and recycled, rather than being used and discarded (Mulgan, 2013).”

“The circular economy can generate extra value for manufacturers, customers and other intermediaries ...as well as making a significant environmental impact. Indeed, that impact is monetized by the avoidance of material costs, landfill taxes and other charges that will surely be increased as pressure on sustainability mounts. Value of other kinds can also be derived.”

“Remanufacturing, whereby high-value or high-use parts of (typically) capital equipment are returned, repaired and re-sold, is carried out in aerospace, commercial vehicles, passenger cars, tyres, medical equipment to name but a few. Material scarcity, oil prices, extreme weather events and wider sustainability pressures may lead to a desire for greater self-sufficiency within the national borders, or at least within Europe. As such, one might envisage a manufacturing system where remanufacturing and re-use is the norm, and origination of products from virgin raw materials is the exception. Remanufacturing is also currently being used as a market-entry mechanism in developing markets e.g. by Volvo truck in India, where remanufactured engines are sold at 65% of the price for a new engine. Remanufacturing is becoming realisation through standards, and more products are being designed from the outset with remanufacturing in mind. More generally, repair suggests different forms of offering, based on access and activity rather than sale of artefacts; it also requires different forms of connection between organisations, new technologies of product and process, and new ways of valuing. As such, it is both full of potential in its own right, and as a breeding-ground for broader capabilities in the longer-term.”

Case study

“ENVIE, a social enterprise in France, refurbishes and re-sells conventional white goods in order to provide a way back into work for long-term unemployed people. The refurbished machines are sold on

to low-income households who would not otherwise be able to buy a machine. ENVIE partners with a wide range of organisations, including: machine makers and retailers, who provide used machines for refurbishment; social services, who can provide additional support to employees; energy suppliers; and a variety of local and regional administrative and environmental bodies. In this way, the washing machine or other white good's passage through the circular economy becomes a platform for value-creation of a more multi-faceted nature, developing skills and work routines among its employees, and making new connections between them and various social institutions."

Summary of themes

The report suggests that business models will be influenced by new kinds of value, information technology, rely on strategic control of assets and involve many more small organisations rather than few large organization and this analysis leads to the following comment on the circular economy and remanufacturing:

"ownership will become more and more decoupled from use of products, and various forms of the circular economy will require the development of products, institutions and systems appropriate to recycling, remanufacture and to more fluid attachments of products to owners and users"

Key emerging opportunities and constraints

Connect the forward and reverse flows of products in a circular economy

"Opportunity: Repair, remanufacture and other aspects of the circular economy will become normal, and yet require technological, realisation and institutional change of a profound nature to reconcile the traditional linear, forward flow with the growing circular flow. This requires systemic change.

Barrier: Many technological, organisational, accounting and other institutional contexts in which manufacturing takes place are predicated on a linear, forward-flowing supply chain. "

Policy Implications

"Domains could be based on locales, such as particular cities or towns (it has recently been observed by the Secretary of State that there remains huge regional disparity in the economic impact of the financial crisis). One possible focus for such a domain is the development of circular economy and collaborative consumption infrastructures in relation to selected business-to-business and business-to-consumer products."

EP 35 Sustainability and manufacturing

Decoupling from environmental impact

"In China the 3Rs are articulated through the "circular economy" concept and this is supported by a number of incentives, including integration into the national 5-year plans, regulation, environmental management, taxation, government procurement and a dedicated investment fund. As a result primary energy consumption, industrial wastewater discharge and SO₂ emissions have been relatively decoupled from economic growth since the 1990s, while industrial solid waste discharges and freshwater consumption have been absolutely decoupled."

Closed Loop Business models

"Contemporary business models are based predominantly on a linear conception of a value chain, where, at one end, resources are extracted, converted into something of perceived value and then disposed of at the other end. By associating a cost with the end and the waste products a linear value chain can be joined up either with other value chains, as in the networks of industrial symbiosis, or with itself, as conceived in "closed-loop", "cradle-to-cradle" or "circular economy" (CE) strategies. In effect these are all articulations of the "3R", reduce-reuse-recycle waste hierarchy, applied at different scales, from product to industrial.

In a circular value chain various 3R strategies can be implemented that act to reduce reliance on virgin raw materials and energy usage, insulated manufacturers from price volatility to an extent. These include reuse, remanufacturing and recycling and can act to reduce exposure to supply chain volatility

risks, particularly of note in the automotive and electronic sectors (HM Government, 2012b). At the industrial scale effective markets for secondary materials need to be developed so that what would otherwise be “waste” is perceived as “resource”.

The closed-loop model at a product level requires that products are designed for durability, standardisation of components, modularity and easy of disassembly (Allwood and Cullen, 2012) so as to facilitate upgrading and remanufacture and have low toxicity to allow for biodegradation where appropriate.”

“If this approach were to be adopted by the EU it is estimated that savings of between \$340bn - \$630bn, depending on degree of penetration, could be realised by 2035 (Ellen MacArthur Foundation, 2012). Annually the benefits could be worth between \$170-200bn for the automotive sector, \$110-130bn in the machinery and equipment sector and \$75-90bn for electrical machinery. The value that the UK could capture from this approach has not yet been calculated.”

“Whether a circular economy would lead to real emissions and resource reductions is questionable: reductions from UK production only affect a small proportion of emissions associated with UK consumption (WRAP, 2009, HM Government, 2011b) and increasing the efficiency of production systems does not address fundamental patterns of consumption (Preston, 2012). These business models have not been extensively tested and there are significant barriers to adoption. It is not clear how these models will work for B2C in a hyper-consumptive economy or rapidly growing markets where ownership can be a sign of affluence.”

Next manufacturing revolution report

Based on factors conducive to remanufacturing the following sub-sectors were identified as having the greatest potential value:

- Electrical, electronic and optical products (including computers and other ICT equipment, medical devices, appliances, and electrical motors)
- Machinery and equipment (including engines, pumps, compressors, lifting equipment, office equipment excluding ICT, agricultural machinery, and industrial tools)
- Transport equipment (including aircraft, rail rolling stock, commercial vehicles, fleet motor vehicles, and private cars¹⁶⁷).

In summary, the cost for remanufacturing involves, at a high level, twice the labour required for new products, and twice the transport, but saves 70% of input goods, materials and services. Given that the average spend across the whole UK manufacturing sector in 2010 for goods, materials and services was 66% of revenue, labour 18% and transport a small proportion, the net reduction in input costs (goods, materials & services plus labour) through remanufacturing is 34%.

This is lower (and therefore more conservative) than the typical range of input cost savings of 40% to 65% identified by Giuntini & Gaudette for the USA.

Given various assumptions, applied to the three key sub-sectors of interest identified earlier suggests full potential benefit for UK manufacturing of £5.6 to 8 billion per annum in EBITDA and an additional 310,000 to 320,000 jobs, based on 2010 figures.

Comparing these results with other research, the Ellen MacArthur Foundation circular economy report estimated the potential of remanufacturing in similar sectors to those examined in this work, for the European Union as a whole. Pro-rating their results to the UK based on GDP, their ‘transition’ case for remanufacturing represents a £30 to 34 billion per annum saving in materials. Their ‘advanced’ case estimated potential materials cost savings of £47 to 57 billion per annum. These ‘transition’ case figures align with the £30 to £34 billion saving in goods, materials and services calculated in this study.

Barriers to remanufacturing identified include, Senior Executive Leadership, Information, Skills, Design, Infrastructure, Legal Constraints, and Collaboration (customers).

Future of Manufacturing Foresight report

Constant adaptability will pervade all aspects of manufacturing, from research and development to innovation, production processes, supplier and customer

interdependencies, and lifetime product maintenance and repair. Products and processes will be sustainable, with built-in reuse, remanufacturing and recycling for products reaching the end of their useful lives. Closed loop systems will be used to eliminate energy and water waste and to recycle physical waste.

- Remanufacturing needs manufacturers to expand their capabilities and this may require government support.
- A number of stakeholders can support the development and roll out of the circular economy including government, the Royal Society for the encouragement of Arts, Manufacturers and Commerce (RSA)
- Lessons should be drawn from overseas initiatives such as the 2009 China 'Circular Economy Promotion Law'.

UK Evidence to Remanufacturing Inquiry

British Tyre Manufacturers' Association (BTMA) response to APPSRG call for evidence on remanufacturing

How does remanufacturing fit into the Government's idea of a circular economy?

- Maximising the useful life of natural resources: presently only 12% by mass of new tyres sold in the UK are remanufactured. Whilst retreading in the truck tyre sector is well established, the car and van tyre sector is almost virgin territory;
- Over 50% of new car and van tyres sold in the UK are manufactured in Asia. The development of retreading (inherently a "home market" activity due to logistics costs) in this market sector would minimise "product miles" associated with bringing the product to market;
- Retreading meets the ambitions of the Waste Hierarchy favouring reuse above recovery or disposal;
- Retreading reduces the quantity of used tyres requiring disposal each year.

How does remanufacturing improve the UK's economic and environmental resilience?

- Product life extension reduces dependency on imported products and natural resources;
- Logistics costs favour remanufacture of tyres in the country of use so contributing to GDP.

UK Cartridge Remanufacturers Association UKCRA RESPONSE TO THE APPSRG CALL FOR EVIDENCE

REMANUFACTURING - RESOURCE SECURITY AND OPPORTUNITIES FOR GROWTH

According to statistics provided by *The Recycler Magazine*, a publication for the cartridge remanufacturing industry, the UK remanufactures 6.06 million cartridges per year comprising approximately 2.61 million laser cartridges and approximately 3.45 million inkjet cartridges. The largest remanufacturer is producing over 0.5 million cartridges per month. The average number of employees directly working in remanufacturing is 5.7 per remanufacturer. The average time for remanufacturing a laser cartridge is about 27 minutes per cartridge. An inkjet cartridge takes on average 3 minutes to produce. The UK collects around 11.5 million cartridges per year which is about 45% of the total cartridges sold. About 40% of cartridges are not suitable for remanufacturing. There is a need to be able to collect and dispose of a potential 18 million cartridges per year of all types and origins.

A circular economy is an industrial system that is restorative by intention and design. In a circular economy, products are designed for ease of reuse, disassembly and refurbishment - or recycling - with the understanding that it is the re-use of vast amounts of material reclaimed from end-of-life products, rather than the extraction of new resources, that is the foundation of economic growth. Moreover, the circular economy shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.

UKCRA recognises that the circular economy is one in which there is a wide variety of processes and systems which support resource productivity and mitigation of environmental (and climate) damage.

UKCRA maintains that the circular economy requires a re-evaluation of the way in which value add is built into and maintained within environmentally-preferable products. The fully-developed circular economy will require a fundamentally new form of service systems to sustain much higher levels of remanufacturing than is currently possible. Legislation would be required to stimulate and encourage such developments.

In the future development of the circular economy, one might expect to see remanufacturing service systems that are designed to track individual cartridges, to identify counterfeit cartridges (which are harming the UK economy), and to optimise the remanufacturing processes to achieve the greatest productivity for each cartridge, to maintain the highest levels of Print Quality (PQ) over numerous cartridge life cycles, and to minimise the carbon footprint of each cartridge over numerous life cycles. Service systems are also required to coordinate a plethora of recursive remanufacturing systems, in which components within a remanufactured product are themselves remanufactured.

Overall, the formation of the circular economy can be understood in terms of two important features: the physical circular economy and the informational (or knowledge-based) circular economy. It is the informational circular economy that is expected to lie at the heart of and underpin the remanufacturing service systems, which could develop.

The UK is already experiencing a significant shortage of landfill and so remanufacturing would be expected to play an increasingly important role in future developments. This has additional benefits in terms of not relying so much on imports of materials.

APSRG/APMG Inquiry into Remanufacturing - Evidence from WRAP (the Waste & Resources Action Programme)

- *Remanufacturing is a very valuable process, but it is not a silver bullet. It needs to be considered in context, as one element in a suite of approaches to promoting product reuse and growing a more circular economy.*

Our 2013 report 'Switched on to Value'¹⁵⁴ shows:

- why extending appliance and consumer electronic product lifetimes and trading used products can benefit consumers, retailers, suppliers and the environment;
- that the average home contains around £1,200 worth of electrical and electronic equipment – but many householders don't realise their used products still have significant value, worth around £3 billion across the UK;
- that when asked, two-thirds of UK consumers expressed a willingness to trade in consumer electronic products – but would prefer to do so with reputable high-street retailers; and
- that changing how we design, make, buy and dispose of electrical and electronic equipment could reduce the UK's carbon footprint by up to 15% and add £800 million to UK GDP.

Also in 2013, our report 'Economic impacts of resource efficient business models'¹⁵⁵ analysed a number of alternative business models, including take-back for re-sale schemes, leasing and refurbishment arrangements, remanufacturing and extended product lifetime models, using four example product types (washing machines, clothing, TVs and business-to-business office furniture). The report concluded that the most significant returns would come from the TV and clothing sectors:

- *for TVs, the take-back for re-sale business model could lead to an additional increase in GDP of over £750m in 2020;*
- *for clothing, the impact is even greater at over £1bn additional GDP in 2020.*

¹⁵⁴ 'Switched on to Value', WRAP, 2013. Available at www.wrap.org.uk/content/switched-value.

¹⁵⁵ 'Economic impacts of resource efficient business models', WRAP, 2013. Available at www.wrap.org.uk/node/18471.

Remanufacturing: Towards a Resource Efficient Economy - Response from the Manufacturing Technology Centre

Currently remanufacturing of engineering components entails a series of operations requiring parts to be transferred around manufacturing facilities and often to subcontractors. Each process is labour intensive and final part quality depends upon the skill of the operator. This makes remanufacturing of engineering parts rather inefficient and difficult to manage.

Key areas of technology which the MTC can bring to remanufacturing include;

- Automated disassembly of parts.
- Automated cleaning of parts using environmentally friendly techniques.
- Use of advanced NDT methods for detection and analysis of part damage.
- Scanning systems to enable the geometry of parts to be quickly captured.
- Testing of adaptive CAM solutions.
- Development of Hybrid Manufacturing systems which enable “one stop” repair of components.
- Advanced NDT & metrology techniques for final inspection of repaired parts.
- Smart part tagging and management of part specific data.

The MTC was a key partner in the Innovation UK supported RECLAIM (Remanufacture of high value products using a combined Laser cladding, Inspection and Machining system) project. In this project the World’s first Hybrid Manufacturing System (HMS) combining laser cladding, high speed milling and inspection in a single integrated remanufacturing cell was successfully developed. This system was developed for automated repair of high value components and was tested on aeroengine blades (ATI Ltd) and automotive turbochargers (Cummins Turbo Technologies Ltd). Hybrid Manufacturing Technology Ltd, a spin-out from the RECLAIM project, is successfully commercialising the new approach.

It is recognised that remanufacturing requires high skilled labour and the MTC Advanced Training centre could play a vital role in training the next generation of remanufacturing engineers and technicians.

CENTRE FOR RESOURCE EFFICIENT MANUFACTURING SYSTEMS (REMS) EVIDENCE FOR THE APSRG AND APMG INQUIRY: REMANUFACTURING

- A key effect of remanufacturing will be that materials and resources embedded in the remanufactured items are not lost to the UK economy, which in turn makes the UK less reliant on imports of materials.
- ..[N]ew jobs will be created in new types of business supporting the remanufacturing system. These new jobs and business will contribute to the UK economy, acting as a balance to the likely reductions in jobs in the existing industries that are focussed on extraction, manufacturing and consumption activities.
- The solution for the UK Government is to continue to investigate what policy interventions could conceivably be used, and to then try to implement those that can be made acceptable. At some point in the future the problem of resource supply will occur – those countries, people and organisations that have been able to implement better systems that insulate themselves from the effects will continue largely unchanged; those that are less well prepared are likely to struggle.

DS Smith - Response to APSRG Inquiry: Remanufacturing – Resource security and opportunities for growth

The circular economy is all about retaining valuable resources within the economy for as long as possible, without detriment to economic, social or environmental costs. Remanufacturing is an ideal model, one of many that businesses and organisations can undertake to aid this process.

As defined in the APSRG’s report this year Remanufacturing: Towards a Resource Efficient Economy, remanufacturing is a series of manufacturing steps acting on an end-of-life part or product in order to return it to like-new or better performance, with warranty to match. This process undertaken in the right conditions maintains the life of materials or component parts, helping to ensure resource security and overcoming the concerns of resource scarcity.

Remanufacturing sits naturally in the top tier of the hierarchy, under reduction and reuse, making a valuable contribution to retaining a product's lifespan and ensuring fewer raw materials are required to make a replacement until absolutely necessary.

Remanufactured products ensure less waste but the logistics and collection infrastructure needs to be undertaken properly to achieve this. This will require collaborating with other partners within the supply cycle, finding businesses and organisations that can provide the necessary logistical and transport network to deliver products in the best condition for remanufacture.

We suggest implementing a certified mark for remanufacturing to demonstrate products have been tested and fully comply with standards of a new product,

Collaboration throughout the supply cycle is key for each to realise the potential

opportunities from the circular economy. Designers have a crucial role to play here, reviewing all stages of the product's life, not just the one that will appeal to the consumer buying it. They need to take a more holistic approach, engaging with other partners in the supply cycle to fully understand what will happen to the product when it is discarded by one consumer and / or comes to the end of its life.

HIGH VALUE MANUFACTURING CATAPULT (HVMC) EVIDENCE FOR THE INQUIRY INTO RESOURCE SECURITY AND OPPORTUNITIES FOR GROWTH

Prepared By Professor Graham Hillier, CEng, FRSA and Dick Elsy, CEO, High Value Manufacturing Catapult

Potential changes in the next 10 years:

1. Reduced availability of imported raw materials for political or economic reasons;
2. Improved remanufacturing processes will reduce remanufacturing costs;
3. Changes in business models that move to fee for service models and encourage remanufacturing;
4. Reduced disposable income making it more attractive for users to use remanufactured goods rather than purchase new as their preferred investment route.

Leasing and fee for service models are likely to be the most supportive of remanufacturing systems.

A remanufacturing strategy that used a leasing model that ensured procured products were returned and remanufactured should be encouraged and this should be combined with a procurement approach that uses high quality long life assets that reduce costs and can be returned in good condition for remanufacturing.

British Coatings Federation

Leftover paint is a major waste issue in the UK. In an environment when landfilling of paint is likely to be banned and other policy developments lead to the increased segregation of left-over paint from general domestic waste, costs are likely to increase for local authorities. As an industry which takes its social and environmental responsibilities very seriously, we wish to be pro-active in finding a national, long term solution to this problem, which also minimises the costs to local authorities.

We believe that the introduction of a national paint recycling programme could potentially halve the collection / disposal costs to local authorities per tonne, and create a closed loop recycling system, demonstrating at least part of a potential solution and contribute towards a business case for the commercialisation of recycling paint.

If 80% of waste paint were collected under a national paint management programme, we estimate it would cost £12.3m to local authorities, if there is no increase in paint recycling. If landfilling of paint is banned, this bill will go up to £23.4m. However, with the introduction of paint remanufacturing, the cost would reduce by almost 50% to £12.5m, as it is cheaper to sort the waste paint and ship it to a paint recycler than pay for it to be taken away as hazardous waste, thus saving over £10m. Also important is having a solution for what to do with the recycled paint, which will need further analysis. Whilst the various options are known, the size of the market for recycled paint from the UK will need to be established.

International reports:**USA reports****TESTIMONY OF ALBERT J. SIMONE PRESIDENT, ROCHESTER INSTITUTE OF TECHNOLOGY TO THE SUBCOMMITTEE ON DEFENSE COMMITTEE ON APPROPRIATIONS UNITED STATES HOUSE OF REPRESENTATIVES APRIL, 2000**

The testimony placed remanufacturing in the context of defence industry activities highlighting amongst other benefits value for money, jobs, lead times reduction and resource efficiency.

“RIT’s National Centre for Remanufacturing and Resource Recovery (NCR3) has developed processes and technologies that will convert a Surface Effect Ship (SES) to a ship with a SLICE hullform. The cost of that remanufacture will be \$7.5 million. A comparable new SLICE ship would cost the Navy \$18.5 million. If NCR3’s process is used to convert the 19 laid-up SES 100 ships, savings will total \$209 million.”

“Remanufacturing is certainly not a foreign term to the Department of Defense, which has undertaken several programs with similar types of methodologies and goals in recent history. The power of remanufacturing has been recognized by DoD branches as a solution to the issues facing them in terms of equipment life and procurement.”

“Remanufacturing is a highly effective strategy of restoring used, durable products to a “like-new” condition while enabling technology upgrades at substantial savings to the end user.”

“Remanufacturing retains approximately 85% of the labor, energy and manufacturing operations that comprise the value added in the original production process. The result is a product that is as good as the original and can be sold to consumers at 50% to 70% of the price of a comparable new product.”

“Remanufacturing is a powerful approach to sustaining and advancing technological systems. It is often conducted through a series of steps including disassembly, cleaning, inspection, refurbishment, technology upgrade, assembly and testing to original or enhanced specifications. Often, remanufactured systems are upgraded with the advanced features of today’s equipment.

Remanufacturing serves a strategic goal of satisfying technology needs at critical moments while reducing lead times for procuring new systems.”

“Over the last several years, the DoD has been making a concerted effort to establish more cost-effective methods for the production of military platforms. Included in these efforts are two DoD objectives that identify remanufacturing as a key element to the critical area of military readiness. The first initiative, the Sustainment/Readiness Working Group (SRWG), was established by the Joint Defense ManTech Panel (JDMTP) to identify the necessity for guidelines and business policy practices designed specifically for manufacturing issues related to DoD weapon systems. The SRWG has identified repair and remanufacturing technologies as a primary focus for the DoD as a means to minimize costs for modernization, upgrades, and retrofits of existing weapon systems.

A second initiative, the Affordable Sustainment of Aging Aircraft Systems, was identified in 1997 as a Defense Technology Objective (DTO MP.07.06) and was specifically targeted to develop affordable repair and remanufacturing technologies as a solution to the increasing age of military aircraft and the increasing costs of purchasing new aircraft. This objective identifies remanufacturing as a key method for supporting life extension of aging aircraft systems, reducing life-cycle costs, enhancing operational readiness, and advancing lean concept deployment in repair.”

“Typically, remanufacturing is only considered once a system is approaching the end of its useful life. Remanufacturing can yield significant economic and performance returns, however, if it is integrated into the design process.”

Life Cycle Assessment in the Print Industry: A Critical Review (Bousquin et al 2012)

“This version of the study updated data related to the production/remanufacturing practices, end-of-life trends, and product quality and reliability. This study examined differences in print quality page acceptance between original and remanufactured toner cartridges.”

“Remanufacturing, recycling, and reuse of equipment and consumables are other areas of debate for the printing industry because the benefits of these practices can be greatly influenced by the underlying assumptions of the analyses”

CHALLENGES IN INCORPORATING SUSTAINABILITY INTO PRODUCT DEVELOPMENT: AN EXPLORATORY STUDY (Athalye et al. 2009)

“The firm had the foresight, mostly driven by economics, to develop strategies for remanufacturing and converting these assets in order to extract the maximum financial benefits from their investment. A secondary benefit, aligned with corporate values to be responsible corporate citizens, would reduce the environmental impact of placing used equipment in landfills.”

“There is a discrepancy between the academic and philosophical views of sustainability and current practice. The triple bottom line concept, even though it is stated in terms that should appeal to the corporation, was not intuitive to the managers interviewed. In the firms studied, the dominant design paradigm was firmly centered on cost and performance. The individual activities that these firms have been pursuing for decades are strictly in the domain of eco-efficiency – more of a be “less bad” approach (e.g. reuse, recycling, remanufacturing). In many cases, it was felt that managers were missing the connections between the economic and environmental aspects of their eco-efficiency based programs and projects.”

Japanese reports

The 23rd Asia Pacific Economic Organisation MINISTERS MEETING, Honolulu, Hawaii November 11, 2011

“We agreed to facilitate trade in remanufactured goods by making existing and future tariff and non-tariff measures applied to goods that are not newly-manufactured publicly available, electronically, in their domestic languages, and, where possible, in English. When laws and regulations related to such measures are under development, we agreed to provide a meaningful process for stakeholders to comment and to take those comments into consideration in producing final rules.”

Annex D: Pathfinder on facilitating trade in remanufactured goods

- *Frequently, exports of remanufactured goods face trade-restrictive non-tariff measures due to a lack of understanding about trade in these goods or concerns over public safety.*
- *Barriers can arise when economies apply measures concerning the importation of used goods to remanufactured goods or classify remanufactured goods as used goods for customs purposes.*
- *remanufactured goods meet the same technical and safety specifications as newly manufactured goods is what truly distinguishes them from used goods.*

In 2011, the listed economies (Japan, US, Chile Canada, New Zealand, Chinese Tapei, Papua New Guinea, Australia, Mexico, Singapore and Korea) agreed to reflect the following in implementing their current tariff and non-tariff measures or developing future tariff and non-tariff measures:

- *Apply import-related measures specifically concerning used goods only to used goods and refrain from applying them to remanufactured goods. Remanufactured goods are not used goods. Therefore economies should not be prohibiting or limiting their importation based on reasoning that they use to restrict trade of used goods.*
 - *If economies do not prohibit the importation of new goods, they should not be prohibiting the importation of remanufactured goods.*
 - *Treat remanufactured goods like corresponding new goods when applying tariffs or other border charges. Treatment of remanufactured goods as new goods for customs purposes can further facilitate trade in these products by avoiding the application of higher duties or other charges to remanufactured goods that economies sometimes apply to imports of used goods*
-

- Generally apply technical regulations, conformity assessment procedures, and documentation and import licensing requirements concerning new goods to remanufactured goods.
- Remanufactured goods should only be subject to import licensing requirements that an economy applies to the importation of new goods.

German reports

INDUSTRIE 4.0: SMART MANUFACTURING FOR THE FUTURE

Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group

No references to remanufacturing or circular economy are made in this set of reports. There is a strong equipment focus.

Finnish reports

SMART 2020: Enabling the low carbon economy in the information age

“This rigorous assessment underlines that the world can realize a green economy and make the transition to a low carbon economy... Achim Steiner, UN Undersecretary General and Executive Director, UN Environment Programme.”

“Policy support is needed for innovation to occur at scale.”

“China’s circular economy approach, which recognises the strategic role of resource productivity, is being developed into law, chiefly because environmental pollution is recognised as constraining economic growth. China is also investing in low carbon innovation zones – like the free economic zones that drove economic development – to ensure China’s global competitiveness in low carbon solutions.”

“Better information in real time on the optimal places to introduce caps or targets would help ease the transition for all sectors as they seek to cut their emissions dramatically.”

DemaNET – Dematerialisation through new models for industrial networking

“Remanufacturing means radical rethinking of physical products, their lifecycle and the production and service system. Strategic eco-industrial networks advance de-materialization through symbiotic forms of inter-industry collaboration.”

“Product concepts will undergo a radical change from “planned-to-age” to “eternal”, long-life, renewable products with reuse in the form which is most eco-efficient. To support the vision, new ultimate reuse concepts, such as remanufacturing, are needed.”

Metal Recycling: Make technology, service & business model design match / match design, Dr. Christian Hagelüken

- Still far away from closing the loop for most technology metals
- Consensus exists on the benefits of the circular economy - One man’s trash is another ones treasure
- Minimise metal losses at all stages of life cycle
 - Reduce creation of residue streams
 - Collect & recycle residues where ever possible
 - Use high quality recycling process to obtain high metal yields
- Recycling, mining, substitution, product design & use need to be developed as interdependent tools in a holistic system approach.
- Recycling needs a chain, not a single process – a system approach is crucial

Matching and partnering companies for win-win industrial symbiosis concepts (Jyri Arponen)

- Industrial Symbiosis Advances Sustainability
 - Industrial symbiosis will be recognised across the world for its contribution to the circular economy through green growth, eco-innovation, job creation and resource efficiency.
-

TSB

The UK national innovation system funds a number of remanufacturing related projects, primarily through the TSB (now InnovateUK) which are listed here to evidence the industrial efforts already in place and the likely emergence of multiple new technologies (both product and process technologies) that will change the landscape and encourage take up of remanufacturing.

TSB projects and calls related to remanufacturing and/or the circular economy include:

- 1. Electric Vehicle Battery Remanufacturing (EV BATT-RE)(#131159)
- 2. Remanufacture of high value products using a combined Laser cladding, Inspection and Machining system (RECLAIM)(#100538)
- 3. Lifetime Extension of Rail Brake Discs by Laser Cladding(#131300)
- 4. Diamond re-tooling (#131404)
- 5. Nano Particle Polymer Enhancement for Recycling Sustainability (PPERS) (#131381)
- 6. Polyester recycling (#750399)
- 7. Return to Sender (#131391)
- 8. Feasibility of Implementing a Circular Economic Business Model for Phineas Products (#131386)
- 9. Design requirements in product, process, organisation for End-of-Life Vehicle (ELV) to achieve Circular Economy State(#131396)
- 10. Developing a working prototype for sustainable high welfare intensive pig houses integrated with renewable energy generation to inform innovative commercial products and services (#101829)
- 11. Sustainable Capillary Iron Project (#101753)
- 12. Smart green railway sleepers (#101686)
- 13. ERICE- Electronics Recycling In A Circular Economy(#101755)
- 14. Feasibility Studies to implement the Circular Economy model in large retail food cabinets. (#131399)
- 15. Office Chair for Life (#101756)
- 16. Design of new tools for closed loop manufacturing (#131397)
- 17. Ultra Low Impact Chalk Tile Construction System (#710525)

Calls:

- 1. Call for SPIRE 2014 - sustainable process industries SPIRE-02-2014: Adaptable industrial processes allowing the use of renewables as flexible feedstock for chemical and energy applications
- 2. Waste - A resource to recycle, reuse and recover raw materials (call for proposals)

TSB Case studies: Carbon8

"A discovery by geologist and hazardous waste expert, Dr Colin Hills, led to an innovative green business opportunity. In 2006, Colin founded the company [Carbon8](#) with three colleagues. He wanted to find a way to produce concrete blocks from recycled industrial waste.

The company's patented Accelerated Carbonation Technology (ACT) makes waste materials less hazardous. This means they can be removed without having to pay to place them in landfill."

TSB Resource Efficiency

£6 million committed in 2014-15

- Up to £500k to support sharing of resources between companies
- Up to £4m to support new supply chains that extract value from waste
- Up to £250k to support UK SMEs on a 'clean tech' mission overseas
- Up to £1m to explore business and supply models for a circular economy

Online / News Articles

REALCAR (Recycled Aluminium Car) "Continuing its support of cutting edge technology, Innovate UK (the new name for the Technology Strategy Board), has played a key role in enabling Jaguar Land Rover to develop a new aluminium alloy, which means that up to 50% of the body of the new Jaguar XE is made from recycled aluminium.

This new lightweight aluminium alloy, which is made from processed scrap, is not only better for the environment - the lighter car will also produce less CO₂ emissions - but it also has the potential to be used by other producers in the transport sector."

"A second project, REALCAR 2, is now working on further increasing the percentage of recycled aluminium."

<http://www.wired-gov.net/wg/news.nsf/articles/Recycled+aluminium+innovation+23102014071013?open>

The above technology enables manufacturers to repair and recycle a variety of worn, high value components such as turbine blades to a consistently high quality. The innovations are expected to make a major contribution to the efficiency of the aerospace, defence and power industries in particular.

MTC operations director Leigh Carnes said every industrial sector had a requirement for remanufacturing and it contributed around £5 billion to the UK economy, not to mention its impact on environmental sustainability and the avoidance of waste. However, conventional remanufacturing processes were slow and labour intensive.

"The new process (that MTC are pioneering) enables cost-effective, rapid and reliable remanufacturing of high value engineering parts. It can be fitted onto existing machine tools, and allows seamless transition between cladding, machining and inspection operations. There is no doubt that this technology – a world first for the MTC and its partners – will transform the whole process of remanufacturing."

Between 2008 and 2012, the £1m Reclaim project (which received £537k of grant funding from Innovate UK) brought together eight partners from business and academia to reinvent remanufacturing.

The Manufacturing Technology Centre (MTC), part of the High Value Manufacturing Catapult, joined the consortium in its later stages to help test and refine the new process.

The project developed a hybrid manufacturing technology based on a multi-purpose machine. It brings together the separate elements of remanufacturing high value metal parts - additive manufacturing, machining and inspection - into one seamless, fully automated process.

The project developed a hybrid manufacturing technology based on a multi-purpose machine. It brings together the separate elements of remanufacturing high value metal parts - additive manufacturing, machining and inspection - into one seamless, fully automated process.

This new technology combines the flexibility of additive manufacturing (better known as 3D printing) with the precision of high speed computer controlled machining and the quality assurance of in-process inspection. The machine switches smoothly from one part of the process to the next, so laser cladding (where a laser melts metal wire or powder to deposit metal onto a component) can be immediately followed by precision machining and inspection. Hybrid manufacturing offers significant benefits over additive manufacturing, machining or inspection on their own. The process can be scaled up or down to produce parts in a wide range of sizes, productivity can be up to 100 times higher, and accuracy and surface finish are on a par with existing precision manufacturing methods.

It also has lower capital investment costs than other metal additive manufacturing processes, and can be retrofitted to existing machine tools - bringing it within the reach of a much wider range of companies.

Delcam, MTC and HMT have teamed up with German specialist machine tool company [Hamuel Maschinenbau](#), to develop a machine to manufacture or repair industrial gas turbine parts. It was launched in September 2013 to much acclaim at EMO, Europe's largest machine tool show, and was awarded the prestigious prize for 'Best Multifunction machine' at the show.

<http://www.wired-gov.net/wg/news.nsf/articles/Sucess+Story+Leading+a+remanufacturing+revolution+27082014161500?open>

https://hvm.catapult.org.uk/case-studies-details/-/asset_publisher/YFXiSex5cXid/content/leading-a-remanufacturing-revolution/contact





Oakdene Hollins is registered to ISO 9001:2008 and ISO 14001:2004

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| 1 | 14/11/14 | Final Draft | RW/BW | BW |
| 2 | 08/12/14 | Revision based on steering group comments | RW/BW | BW |
| 3 | 04/03/15 | Revision based on steering group comments | RW/BW | RW |
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