*A report by*

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A study of the Potential of VRPs for Resource Efficiency

*Prepared for Innovate UK by Oakdene Hollins on 18th February 2022*

# A study of the Potential of VRPs for Resource Efficiency



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| Reference: | UKRI_565_VRP_Processes_for_RE_Final_Report |



*Value-driven consulting*

*Science-led research*

# Contents

# Glossary

| | |
|---|---|
| ATI | Aerospace Technology Institute |
| B2B | business-to-business (marketing model) |
| B2C | business-to-consumer |
| BEIS | Department for Business, Energy & Industrial Strategy, UK |
| BOM | bill of materials |
| BOP | balance of payments |
| BSI | British Standards Institute |
| C2C | consumer-to-consumer (also known as peer-to-peer) |
| CAD | Canadian dollar |
| CCME | Canadian Council of Ministers of the Environment |
| CE | circular economy |
| CMM | component maintenance manual |
| CNC | computer numerical control (machining) |
| CNY | Chinese Yuan |
| $CO_2e$ | tonnes of $CO_2$ expressed as their equivalent mass of $CO_2$ to achieve the same greenhouse gas impact |
| CP | current prices |
| CR&D | collaborative research & development |
| CVM | chained volume measure |
| Defra | Department for Environment, Food & Rural Affairs, UK |
| DfT | Department for Transport |
| EASA | European Air Safety Authority |
| EDM | electrical discharge machining |
| EEE | electrical and electronic equipment |
| ELV | end-of-life vehicle |
| EoL | end-of-life |
| EoU | end-of-use |
| EPA | Environmental Protection Agency |
| EPR | extended producer responsibility |
| ERN | European Remanufacturing Network |
| EU | European Union |
| EV | electric vehicle |
| FTA | free-trade agreement |
| FTC | Federal Trade Commission |
| FTE | full-time equivalent (employees) |
| GB | Great Britain |
| GDP | gross domestic product |
| GHG | greenhouse gas |
| GWP | global warming potential (quantified as tonnes $CO_2$ equivalent) |
| HDOR | heavy duty and off-road |
| HVM | high value manufacturing (Catapult centres) |
| ICE | internal combustion engine |
| ICT | information and communication technology |
| IRP | International Resources Panel |
| ISO | International Standards Organisation |
| IT | information technology |
| JNY | Japanese Yen |
| KATS | Korean Agency for Technology and Standards |
| KRW | Korean Won |
| KTN | Knowledge Transfer Network |
| LCA | lifecycle analysis/assessment |
| MHRA | Medicines and Healthcare Products Regulatory Agency |
| MIIT | Ministry of Industry and Information Technology |
| MRO | maintenance, repair and overhaul |
| NDT | non-destructive testing |
| NHS | National Health Service |
| NICER | National Interdisciplinary Circular Economy Research |
| NMCL | National Manufacturing Competitiveness Levels |
| NSA | not seasonally adjusted |

| | |
|---|---|
| OEM | original equipment manufacturer |
| OES | original equipment supplier |
| ONS | Office for National Statistics |
| PAS | Publicly Available Specifications |
| QR | quick response |
| R&D | research and development |
| REACH | Registration, Evaluation, Authorisation and Restriction of Chemicals (Act) |
| REMADE | Reducing EMbodied energy And Decreasing Emissions (Initiative) |
| RFID | radio-frequency identification |
| RoHS | Restriction of the Use of Certain Hazardous Substances (Act) |
| ROSCO | rolling stock companies |
| RRRDR | remanufacturing, refurbishment, repair and direct reuse |
| SIC | standard industrial classification |
| SME | small and medium-sized enterprise |
| SWOT | strengths-weaknesses-opportunities-threats analysis |
| TES | through-life engineering services |
| TRL | technology readiness level |
| UAE | United Arab Emirates |
| UK | United Kingdom |
| UoB | University of Brighton |
| UN | United Nations |
| UNEP | United Nations Environment Programme |
| USA | United States of America (also US when prefixing entities e.g. US markets) |
| VAT | value added tax |
| VRPs | value retention processes |
| WEEE | waste electrical and electronic equipment |

# Units

Conventional SI units and prefixes used throughout.

kt, Mt Thousands, millions of metric tonnes mass (1 tonne = 2205 lb)

g, kg Grammes, kilogrammes mass (1 kg = 2.205 lb)

# Definitions related to end-of-life treatment

**Arranging direct reuse** The collection, inspection and testing, cleaning and redistribution of a product back into the market under controlled conditions (e.g. a formal business undertaking). (1)

**Comprehensive refurbishment** Refurbishment that takes place within industrial or factory settings, with a high standard and level of refurbishment. (1)

**Core** A product assembled from durable components suitable for recovery and remanufacture. Paraphrased from (2).

**Prevention** Measures taken before a substance, material or product has become waste, that reduce the quantity of waste, including through the reuse of products or the extension of the life span of products. (3)

**Recovery** Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. (2)

**Recycling** Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. Includes the reprocessing of organic material but does not include energy recovery nor the reprocessing into materials that are to be used as fuels or for backfilling operations. (2)

**Refurbishment** Modification of an object that is waste or a product to increase or restore its performance and/or functionality or to meet applicable technical standards or regulatory requirements, with the result of making a fully functional product to be used for a purpose that is at least the one that was originally intended. (1)

**Remanufacturing** A standardized industrial process that takes place within industrial or factory settings, in which cores are restored to original as-new condition and performance or better. The remanufacturing process is in line with specific technical specifications, including engineering, quality and testing standards, and typically yields fully warranted products. Firms that provide remanufacturing services to restore used goods to original working condition are considered producers of remanufactured goods. (3)

**Repair** Fixing a specified fault in an object that is a waste or a product and/or replacing defective components, in order to make the waste or product a fully functional product to be used for its originally intended purpose. (1)

**Reuse** Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived. (2)

**Value Retention Processes** Activities, typically production-type activities, that enable the completion of and/or potentially extend a product's service life beyond traditional expected service life. These processes include arranging direct reuse, repair, refurbishment, comprehensive refurbishment, and remanufacturing. (3)

**Waste** Any substance or object which the holder discards or intends or is required to discard. (2)

# Key

| | | | | | |
|---|---|---|---|---|---|
| | **Transferable learning point** | | **Future research topic** | | **Context information fragment** |

# Contents amendment record

This report has been amended and issued as follows:

| Version | Date | Description | Author | Editor |
|---|---|---|---|---|
| 1 | 18th February 2022 | Final report issued to Innovate UK | DP et al. | KB |

# 1 Executive summary

This study relates to assisting the economy to reach Net-Zero through better resource efficiency, specifically via the accelerated adoption of **Value Retention Processes** (VRPs). VRPs are ways of increasing the useful life of manufactured products and include the following:

*Figure 1: The spectrum of reuse*


## 1.1 Aims and scope

As the UK looks forward to a post-Covid recovery and towards targets for a Net-Zero economy, now is an opportune time to look at what economic activities we want to develop and support. This study aims to provide the evidence base to inform technology and innovation needs, and to develop policy options and a set of recommendations to develop a national Value Retention Strategy in the UK. This study looks at the full spectrum of value retention activities (remanufacturing, refurbishment, repair, and reuse) across ten key sectors. These sectors are aerospace, automotive, heavy-duty and off-road, domestic appliances, furniture, ICT, industrial equipment, marine, medical devices and rail.

## 1.2 Defining VRPs

VRPs can be assigned to one of two broad categories: full service-life and partial service-life. Full-service life VRPs (remanufacturing or comprehensive refurbishment) are executed at the end of a product's full service life, are comprehensive and take place within factory operations, **extending the life of the product** by a period at least equal to that of the original service life. In contrast, partial-service life VRPs are executed usually due to a failure before the end of the product's expected life, are limited in scope, take place outside of factory operations, and may only extend the life of the product by a fraction of its original service life.

VRP-related products offer a variety of **environmental benefits** over newly manufactured products including reduced new material input requirements (including critical raw materials), reduced embodied energy, reduced production emissions and lower production waste. In addition, VRPs are also associated with economic benefits such as job creation, reduced production costs, increased export opportunities and access to new market segments.

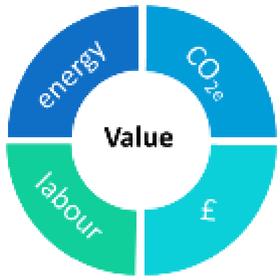
*Figure 2: Value propositions of VRPs*


To what extent these benefits are realised depends upon the VRP approach, with full-service life VRPs being associated with greater production costs, energy requirements and emissions when compared to partial-service life VRPs. Partial-service life VRPs are associated with low-range product value retention and employment opportunities.

## 1.3 The role of VRPs in the economy

VRPs are important for the UK in reaching **Net-Zero** goals and to "build back better" after the EU Exit and the Covid pandemic. Current supply chains are heavily dependent on certain foreign nations for critical materials and are vulnerable to macroeconomic risks. For UK businesses to advance and to gain global competitive advantage requires innovative approaches to the way we deal with current unsustainable consumption of resources, inefficient production and disposal of manufactured products and materials.

*Figure 3: 4 key outcomes*




While switching to renewable energy sources can help address 55% of global greenhouse gas (GHG) emissions, to fully achieve UN climate goals and UK carbon budget targets it is imperative to tackle the remaining **45% carbon emissions** that are **embodied in manufactured products and materials consumed**. A key potential enabler for the ongoing prosperity of UK manufacturing is a focus on high value products, associated services and materials through concerted efforts to maximise the "**Value**" that can be retained. In this study, the "Value" available to be retained includes the **embodied energy, greenhouse gas emissions, economic value**, and **labour**.

## 1.4 The state of VRPs

Although remanufacturing, the highest value VRP, is well developed in a few well-defined sectors (for example, the UK automotive and aerospace sectors had an estimated remanufacturing market of £16 billion in 2020) there is good potential in other areas as well, and this is not yet exploited. Other forms of less formal VRP activity – reuse, repair, refurbishment – are less well organised and there is evidence from stakeholders that they could grow quickly if there were clearer coherence between the market and government policy and incentives.

The barriers to wider use of VRPs are summarised in the table below:

*Table 1: Barriers to VRP uptake and expansion*

| | Technical | Economic | Social | Legislative |
|---|---|---|---|---|
| **Aerospace** | MRO only for mechanical components. | | | Limitations on the recycled content allowed in aircraft components. |
| **Automotive** | Lack of access to software, original specifications, and tolerances (non-OEM). | Economics and logistics of core recovery. Low-cost 'copy' parts. | Increased labour costs. Lack of skills in dealing with electrical components. | Obtaining core from other European countries. |
| **Domestic appliances** | Non-authorised repairs. | Often cheaper to replace than repair/refurbish | Predicted skills shortage in the end of the decade. | |
| **ICT** | Lack of access to software, original specifications, and tolerances. | Economics and logistics of core recovery. | Consumer perception on purchasing new. | |
| **Heavy-Duty/Off-Road (HDOR)** | Limited component availability. | Sale of single-life tyres. | | |
| **Industrial equipment** | Limited information / original component drawings. | | Skills shortage in dealing with electrical components. | |

| | Technical | Economic | Social | Legislative |
|---|---|---|---|---|
| **Furniture** | Lack of understanding of material composition (independent actors). | Procurement processes favour new products. | Consumer perception on what is in style and on trend. | |
| **Marine** | Older ports do not have the right technology to retrofit shipping vessels. | High cost for recertification of refurbished boats. | Skills shortage for retrofitting large ships. | |
| **Medical devices** | Accessing software and core (independent actors). | NHS procurement process favours new products. | | |
| **Rail** | Electrifying existing infrastructure. | Low-cost financing options favour the purchasing of new stock. | | |
| **Barriers across different sectors** | Understanding software and material composition of components. | Making value retention products economically competitive to low-cost imports. | Training and upskilling programs. | Import of cores. |

## 1.5 Recommendations

The key recommendations from this study include:

**Raise the profile of VRP activities**

The image of VRP activities must be transformed from 'dirty' and unappealing to a cutting-edge sector associated with advanced technology and playing a crucial role in sustainability:

- A high-profile centre for VRP technologies, akin to the REMADE Institute in the USA, would act as a focal point for VRP innovation, business engagement and - potentially - training.
- The profile of VRPs should continue to be promoted in the work of the NICER CE-Centres and CE-Hub, to ensure Circular Economy is not limited to recycling.
- The role of VRP activities in achieving the UK's Net-Zero targets and for businesses seeking to set Science Based Targets should be formalised through the development of carbon accounting methodologies specifically for VRPs.
- Targets need to be set for VRP activity in line with plans to reduce UK resource use.
- VRP skills development should be supported through reskilling the workforce in declining sectors (e.g. some traditional manufacturing and fossil fuel sectors) and by supporting university and college-level education. This could also be aligned with existing initiatives, such as Made Smarter, by connecting innovation and upskilling in topics like Industry 4.0 and the digital revolution, to VRPs.

**Seek out opportunities to collaborate**

Collaboration will enable faster progress from shared learning and ensure the direction of travel is aligned:

- International collaboration could support technology and innovation transfer, develop consensus on standards, and align trade policy.
- Intra-UK collaboration could achieve similar objectives as well as consensus on data needs, terminology, and priority sectors.
- Developing the most coherent strategy for UK VRP activities will require collaboration across government departments, particularly BEIS, Defra, the Treasury, and Innovate UK.

**Encouraging behaviour change**

Make VRP activities and purchasing VRP products more attractive and easier than the alternatives, to help accelerate the market transition:

- More widespread requirements to report Scope 3 emissions would help demonstrate the sustainability credentials of VRPs and make using VRP products a more attractive option for entities looking to reduce their emissions footprint.
- Policy levers to make VRPs more attractive include integration into public procurement, expansion of right-to-repair initiatives, extended warranties, and modulated Extended Producer Responsibility (EPR). These options should be considered for consultation.
- Fiscal measures could improve the competitiveness of VRP products compared to alternatives, e.g. through VAT reductions and taxes on carbon emissions.
- Development of centralised data hubs and data requirements could make it easier for actors to undertake and report VRP activities and for consumers to access VRP products. This could align with planned ONS activity on material flows and include industry codes for VRP activities.

**Support VRP experimentation**

The development of new VRP business models and technologies can be risky for businesses and organisations. Support for pilots, trials and experimentation can help encourage innovation:

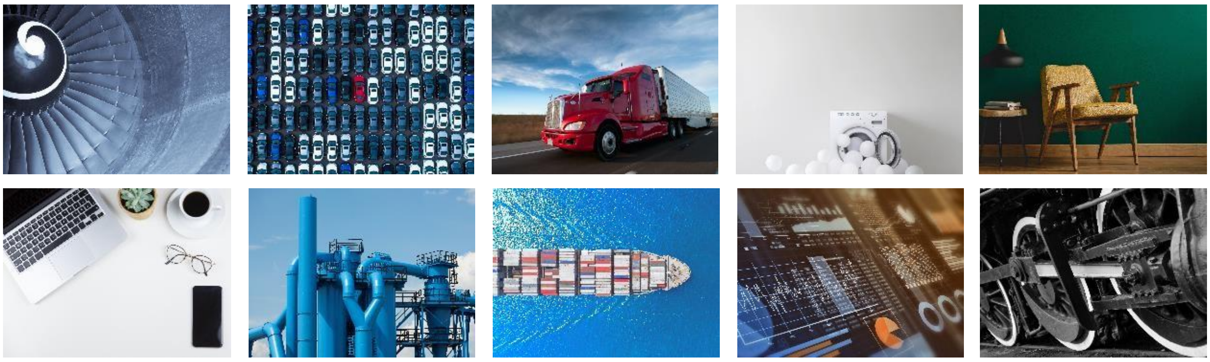
- New VRP business models, particularly related to shared ownership, everything-as-a-service, and community-led initiatives, may need financial, skills and innovation support to develop viable value propositions. Existing organisations like KTN and Innovate EDGE could deliver targeted VRP support in these areas.
- VRP actors, particularly non-OEM, can face limitations in knowledge, equipment, capacity and finance to develop and test new VRP technologies. Support for feasibility studies, industrial research and experimental development in VRP applications would help accelerate the uptake of technical innovations by VRP practitioners.
- Industry and academia can operate 'in silos' when it comes to fundamental research in VRP technologies. Support to foster closer links between industry and academia (for example, through the VPR technologies centre mentioned above) could better target innovation needs for key topics like design for VRPs, automated disassembly and computer vision core identification.
- Existing funding mechanisms are a robust foundation for support in VRP innovation. The continuation (and potential expansion) of funding rounds like the recently closed 'Circular Economy for Small to Medium-Sized enterprises(SMEs)' call would provide further opportunities for VRP projects. It may be valuable for funding rounds to focus on VRP activities if the proportion of funded projects with a Circular Economy scope, are predominantly focused on recycling.
- For innovation funding on topics that have cross-over between manufacturing and VRPs (e.g. blockchain, digital twins, Industry 4.0 etc.) it may be beneficial to encourage or require this research to include VRP applications and considerations as part of the scope.

**Target VRP interventions**

While some interventions will support the acceleration of VRP activities across the board, there are some key sectors and VRP activities that should be targeted:

- There is an opportunity for the UK to leverage its strengths in product design to develop expertise in design for VRP activities. This could be of particular relevance to automotive components, many of which are being re-designed for electric vehicle (EV) applications.
- The medical devices sector is actively looking at VRP options and, as yet, no remanufacturing activities occur in the UK. Government could work with the sector to encourage the choice of the UK to set up VRP operations.

- Higher-value VRP activities (in terms of economic value) are of most relevance in the aerospace, automotive, HDOR and industrial equipment sectors. The priority for realising environmental benefits lies in the lower-value VRP activities in the domestic appliances, ICT and furniture sectors.



The recommendations from this report aim to speed up the adoption of VRPs, and to create a better environment for VRP development. This will be through support to business, including research and development, promotion and demonstration of benefits, advice and making connections, and the establishment of a voice for VRPs across sectors. The recommendations relate directly to support for businesses and do not focus on support for primary research in academic institutions. The study has identified regulatory and legislative blockages and has made recommendations for change. The establishment of a leadership group may engender a lobby group in this respect.

At a high level, increased VRP activity is expected to increase resource efficiency, and through this reduce GHG emissions as part of the more general campaign to reach Net-Zero.

The interventions explored in this study aim to remove or diminish the barriers outlined above through:

- Support for collaborative R&D to develop new innovation solutions and to mitigate the financial risk of adopting new approaches (technical barriers).
- Demonstration projects, both of technology and of business models (technical and economic barriers).
- Support to innovation adoption through making connections with technology providers and research, de-risking experimentation, and providing support in industrial design (technical barriers).
- Establishing a leadership group for VRP which can support its members and identify key areas of skills and regulatory development (technical, economic, social and regulatory barriers)

As a result of the interventions, as well as support to individual companies, the project will leave a centre of excellence in design for VRP, several demonstration projects and a self-sustaining leadership group able to support the further development of VRP.

## 1.6 What is the global market opportunity?

This study estimates that the value of VRP activities in the UK was over **£75 billion** in 2020 and supported over **500,000 jobs**. Outside of this study, the only other nation to have assessed the value of its VRP activity is Canada, with an estimated value of **£33.6 billion** in 2019[1].

Previous analysis reported the European remanufacturing industry was estimated to be worth **£24.4 billion** in **2015**, supporting **190,000 jobs**, which could potentially grow to a value of £73.8 billion by 2030, supporting an additional 410,000 jobs. The UK makes up a considerable portion of this market,

[1] Note the population of Canada is around 37 million compared to the UK, 65 million, so the estimate is not unrealistic.

being the second largest remanufacturer after Germany; however, this activity is not captured within existing trade reporting and, until this study, no previous work had sought to quantify the value of the full spectrum of VRP activity in the UK.

From the 2015 study, Germany, the United Kingdom, Ireland, France and Italy together account for around 70% of the value of remanufacturing within the EU. Of these, **Germany** undertakes the largest proportion of European remanufacturing (30%) with a particularly prominent presence in the aerospace, automotive and HDOR sectors. The remanufacturing industries of **France**, the UK and Ireland have a similar composition to that of Germany, although each is roughly half the size. Notably, the remanufacturing industry in Italy is smaller than would be expected when considering the size of its manufacturing industry. Cultural preferences regarding remanufactured automotive components and the fact that Germany, France and the UK are major global hubs for aerospace maintenance, repair and overhaul activities could account for this difference.

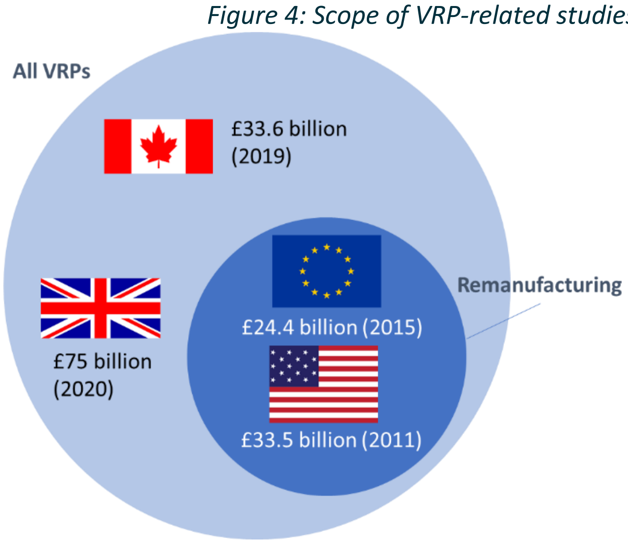
Within the EU, there has also been some support for VRP activity in recent years through the **Circular Economy Action Plan** (2015 – 2019). Under this plan, **Ecodesign standards** have been updated to facilitate greater levels of product repair, and the EU Commission is developing a **product repairability scoring system**. This Action Plan included measures to promote the development of remanufacturing via research and innovation financing from Horizon 2020 and Cohesion Policy funds. More recently, the EU has adopted the 'new' Circular Economy Action Plan. This includes proposals for a sustainable product policy legislative initiative to (amongst other things) enable greater remanufacturing and 'high quality recycling' through widening the existing Ecodesign Directive. At implementation level, France has recently enacted enabling legislation supporting '**right-to-repair**' by consumers. This mandates publication by manufacturers and retailers of a 'repairability' index for five classes of product: washing machines, smartphones, laptops, televisions and electric lawnmowers.

The USA and China are both considered leaders in the field of remanufacturing. A comprehensive assessment of the US market has not been completed since 2011, when it was estimated to be **£33.5 billion.**

In summary, while it is not possible to quantify the size of the global market for VRPs, all developed nations are considering VRPs as part of more general approaches to move to Net-Zero and a circular economy; action needs to take place now if there is to be an impact within a timescale which could materially impact the existing targets. Support in the UK now is likely to produce intellectual property which can be used elsewhere either directly or through licenses; without action there is a danger that other countries will get ahead and that an opportunity is lost. That would be a wasted opportunity given that:

- the UK aspires to high-value added, knowledge-based industries of which VRPs are a key part, and
- VRPs are likely to be an enduring component of a new, global industrial wave presenting many opportunities for enabling innovations on a strong domestic science and engineering platform.

*Figure 4: Scope of VRP-related studies*



## 1.7 What evidence is there of UK strengths and competitive advantage?

The analysis in this study has identified key UK strengths that could be built upon to address the challenges of increasing VRP activity and realise the market opportunities available.

*Table 2: An overview of UK competitive advantage in VRPs*

| Strengths | Explanation/further details |
|---|---|
| Strong engagement in standards development | The UK has been the only European nation to develop a cross-sectoral standard (BS 8887-2:2009) that differentiates remanufacturing from other processes (10). There are many technical committees at BSI working on the topic of remanufacturing standards, and the UK has recently concluded a Joint Working Group activity with China on the same topic. |
| Strong research activity – key universities | A non-exhaustive list of VRP expertise in the UK includes (in alphabetical order): Cranfield University (TES), Nottingham Trent University (product life extension), University of Birmingham (remanufacturing), University of Brighton (remanufacturing), University of Creative Arts (repair), University of Exeter (circular economy), University of Loughborough (remanufacturing), University of Strathclyde (remanufacturing), Warwick Manufacturing Group (remanufacturing), the wider High Value Manufacturing Catapult. |
| Well-established VRP industries in aero, auto, industrial equipment | With remanufacturing originating in the support of military assets from World War I onwards, it is unsurprising that aerospace and automotive show strength. Coupled with the fact that these are global industries under strong competition, highly regulated with safety and liabilities built in, there is an emphasis on maintaining leading-edge practices. However, the nature of modern manufacturing is that many functions are outsourced. As a result, these sectors also display clustering effects where a 'cloud' of suppliers and service providers of specialist sub-systems retains much of the competence in the field. Often the headline brands are simply system assemblers. A consequence of this is that the smaller, specialist suppliers need to be nurtured to provide the genuine innovative backbone, but the aggregators are needed to provide the channel to market, especially when higher risk 'game-changer' developments are being considered. |
| Strong circular economy focus (NICER programme) | After a slow start, the UK has been a strong advocate of circular economy (CE) principles; in the private sector through the globally recognised Ellen MacArthur Foundation, and more recently through public measures to underpin the theoretical and evidence-base roots of the topic through the CE-Hub based in Exeter, and the NICER programme. Materials- and process-based efficiency programmes have been a feature of Innovate UK funding since 2004, with some experimentation in business model innovation and – latterly – designing for circularity. An increased focus throughout on carbon should be a driver for embedding enabling practices such as CE more widely in academic and business thinking. |

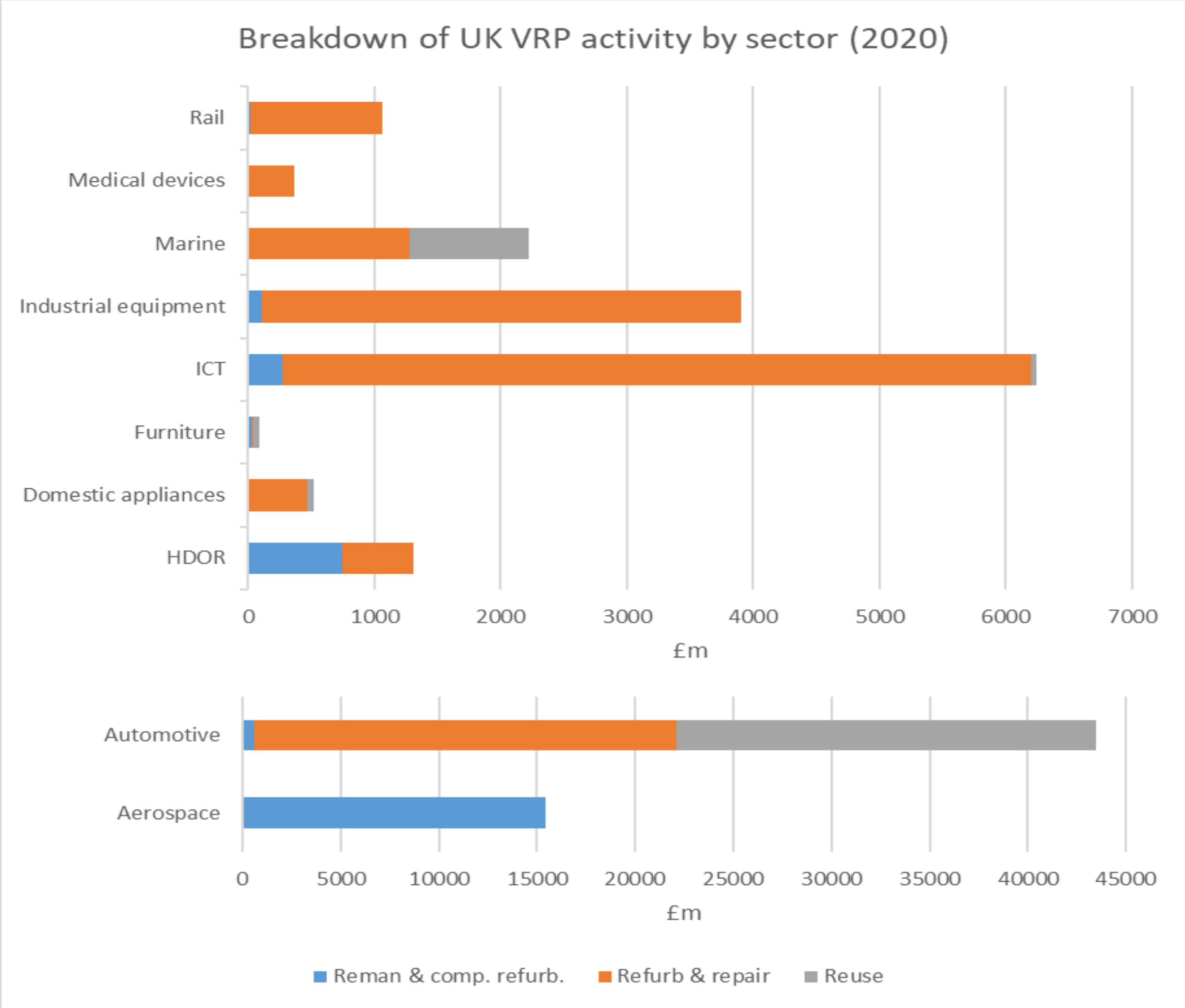
| Strengths | Explanation/further details |
|---|---|
| Advanced manufacturing capabilities (that could be applied to VRPs) | UK has a track record in the development of high-value manufacturing capabilities with a particular relevance to VRPs. These techniques include: additive/subtractive techniques suited to remediation with minimum material and energy inputs; computer recognition and net-shape modelling which can be linked to CNC tooling and additive manufacturing as well as for automated part design recall; an extremely strong materials science and R&T base with effective transfer into industry; and a network of advanced manufacturing centres that can adapt to develop and pilot techniques for single companies or consortia. |

There is an existing market for VRPs: VRP activity in the UK in 2020 is estimated to have generated over £75 billion in revenue and supported over 500 thousand jobs, with significant activity in automotive, aerospace, industrial equipment and ICT. VRP activities in the UK in 2020 are estimated to have prevented at least **620 kt** of waste and avoided at least **4.7 Mt $CO_2$e**.

*Table 3: Summary of VRP economic activity by sector, 2020*

<table>
<tr><th>REVENUE</th><th>Remanufacturing</th><th>Comprehensive refurbishment</th><th>Refurbishment</th><th>Repair</th><th>Reuse</th></tr>
<tr><td>Aerospace</td><td colspan="4">£15,400 m</td><td>N/A</td></tr>
<tr><td>Automotive</td><td colspan="2">£600 m</td><td colspan="2" rowspan="2">£21,500 m<br>(+£560 m HDOR)</td><td>£21,400 m</td></tr>
<tr><td>HDOR</td><td colspan="2">£747 m</td><td>No data available</td></tr>
<tr><td>Domestic appliances</td><td>N/A</td><td colspan="2">No data available</td><td>£470 m</td><td rowspan="3">£143 m</td></tr>
<tr><td>Furniture</td><td colspan="3">£30 m</td><td>£13 m</td></tr>
<tr><td>ICT</td><td colspan="2">£271 m</td><td>No data available</td><td>£5,928 m</td></tr>
<tr><td>Industrial equipment</td><td colspan="2">£112 m</td><td>No data available</td><td>£3,795 m</td><td>No data available</td></tr>
<tr><td>Marine</td><td>£8.1 m</td><td colspan="2">No data available</td><td>£1,269 m</td><td>£945 m</td></tr>
<tr><td>Medical devices</td><td>£ 0 m</td><td colspan="2">No data available</td><td>£370 m</td><td>N/A</td></tr>
<tr><td>Rail</td><td colspan="2">£16.9 m</td><td>N/A</td><td>£1,049 m</td><td>N/A</td></tr>
</table>

*Figure 5: Graphical presentation of sector VRP activity levels, 2020*




The UK is a leader in the field of industrial design[2]. This is a base on which VRPs could be developed through designing products that are optimised for future VRP activities; it would address one of the key challenge areas identified in this study (see Industry Pull section below).

The UK has experience of support institutions for manufacturing which could be used as models for future work. For example, the Scottish Institute for Remanufacturing[3], established with support from Scottish Funding Council and Zero Waste Scotland, has funded over £600,000 in projects supporting Scottish remanufacturing. This is complemented by a series of institutions which support manufacturing in general, notably the HVM Catapult.

Regarding connections with research, and improving networking, KTN has experience of this in other sectors as well as participating in the Manufacturing Made Smarter ISCF challenge. Searching on Gateway to Research suggests that research into relevant fields is widespread in universities, with no single institution leading, showing the need for external coordination and assistance in making links with industry.

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[2] https://www.designcouncil.org.uk/sites/default/files/asset/document/Design_Economy_2018.pdf
[3] https://www.scot-reman.ac.uk/

Activities would build on these strengths, using existing institutions such as the Circular Economy Centres and Circular Economy Hubs, so providing better value for money.

This analysis has identified different sectors and VRP activities where there may be a competitive advantage for the UK (such as might be achieved for remanufacturing of medical devices), along with key economic opportunities and environmental benefits. These are summarised in the diagram below.

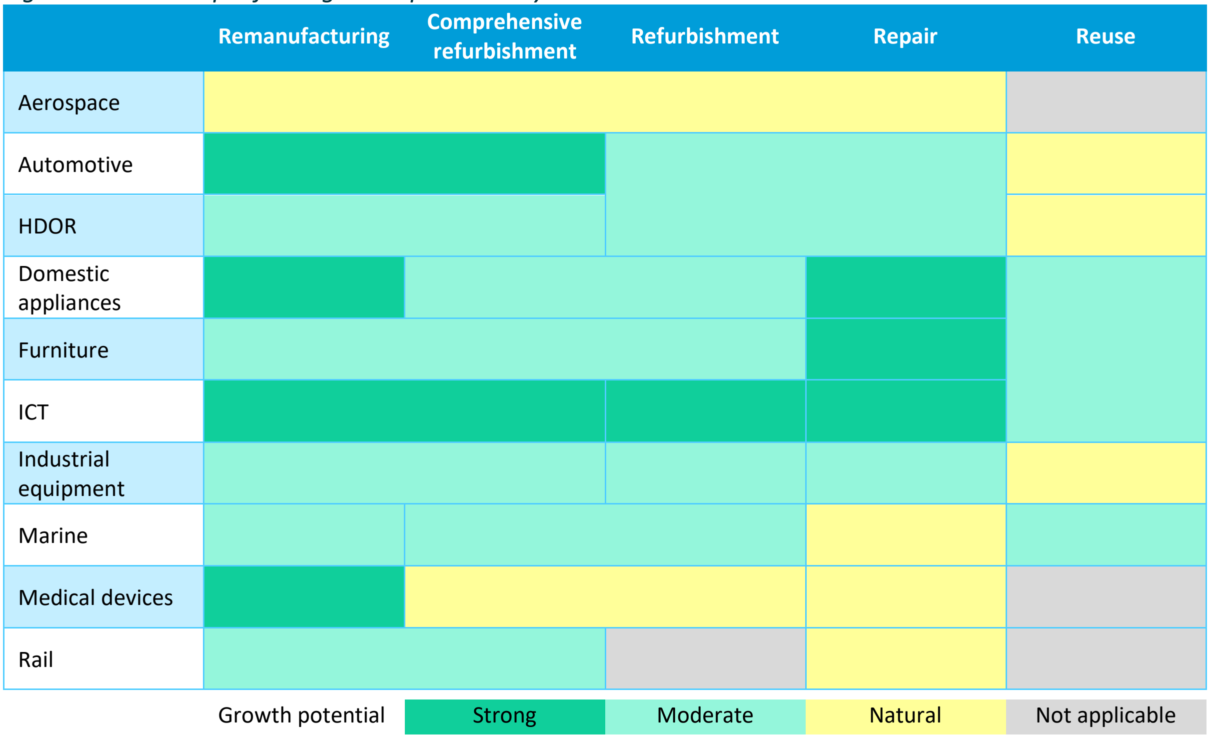
*Figure 6: Segmentation of VRP opportunities by sector*

## 1.8 What is the industry pull?

Research done during this project, together with workshops conducted in 2021, shows that there is considerable appetite for VRPs - as evidenced by the high level of stakeholder engagement during this project. However, at the same time there are barriers to its wider and faster adoption (as listed above) as well as a lack of quantitative data on the current and potential size of the industry, even from stakeholders active in the market.

Our analysis in this project has estimated the growth potential for different VRP activities and sectors, based on qualitative insights from stakeholder engagement and our own analysis and insights. This analysis assumes support above business-as-usual activities in the areas identified through the interventions analysis.

*Figure 7: 'Heat map' of VRP growth potential by sector*




*Source: Oakdene Hollins analysis*

Analysis from the NICER Programme has identified a range of on-going activities related to circular economy, as shown in the diagram below. Of most relevance to this study are the inner loops of the techno-sphere, which include:

- ISCF: Manufacturing Made Smarter (£30m), Next generation services (£3.5m), Driving the electric revolution (£80m)
- EPSRC: Resource recovery from waste (£7m), CLEVER (£1.3m), ExHUME (£1.1m), CE Systems Change (£2.6m).

Figure 8 presents a summary of where major government funders have invested in themes which broadly attach to Circular Economy and energy. In the technosphere, by and large these have focused on the manufacturing phase rather than use phase or whole life considerations. The latter factor should be a focus point for underpinning transformational change in the use of resources.

*Figure 8: Map of major support and research investments in Circular Economy*

**Industrial Strategy Challenge Fund**
1. Industrial decarbonisation - £80m
2. Transforming construction - £170m
3. Future Flight - £125m
4. Driving the electric revolution - £80m
5. Self driving cars - £28m
6. Manufacturing made smarter - £30m
7. Next generation services - £3.5m
8. Smart sustainable packaging - £60m

**EPSRC**
9. Cleaning land for wealth - £3.1m
10. Resource recovery from waste - £7m
11. Clever - £1.3m
12. ExHUME - £1.1m
13. CORE - £0.3m
14. RECODE - £0.5m
15. Ind Sus - £5m
16. CE Systems Change - £2.6m
17. LiME - £10m
18. DARE - £3.2m
19. LATEST 2 - £6m
20. Sus materials CDT - £3.6m
21. Materials substitution - £18m
22. G8 - £2m
23. MDR - £1.7m
24. CE Map - £2.3m
25. Syn bio scale up - £5m
26. Food - £4.5m
27. Sus chem feedstock - £14m
28. Sus chem technologies CDT - £3.5m
29. Industrial biotech catalyst - £58m
30. Bioprocess - CDT £4.4m
31. Next stage digital economy - £20m
32. CENTS - £0.25m
33. Systems Change for CE - £5m
34. Supergen Hubs - £16m
35. Re-distributed manufacture - £3m
36. Henry Royce Institute - £235m

**BBSRC**
37. Synthetic biology for growth - £102m
38. Industrial biotechnology - £5m
39. Networks in industrial biotech & bioenergy - £11m
40. Transforming food production - £90m

**Strategic priorities fund**
41. Clean air - £19.6m
42. UK climate resilience - £18.7m
43. Landscape decisions - £10.4m
44. Constructing a digital environment - £10.4m

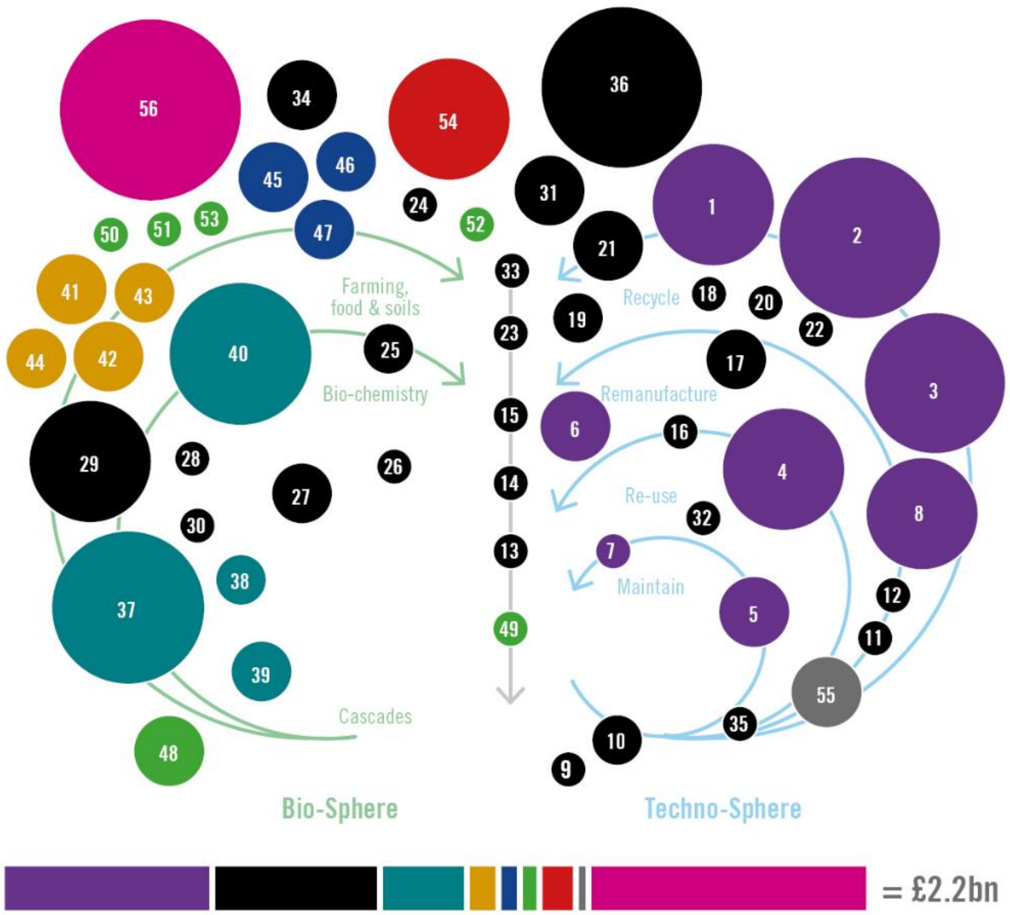
**NERC**
45. UK - SCAPE - £16.7m
46. RISE - £12m
47. ASSIST - £12.3m

ESRC
48. UK energy research centre - £30m
49. CE complexity: nexus network - £3m
50. CAST - £5m
51. CUSP - £6m
52. CECAN - £0.6m
53. P-CAN - £3m

**AHRC**
54. Creative industries cluster - £80m

55. Plastics innovation fund - £20m

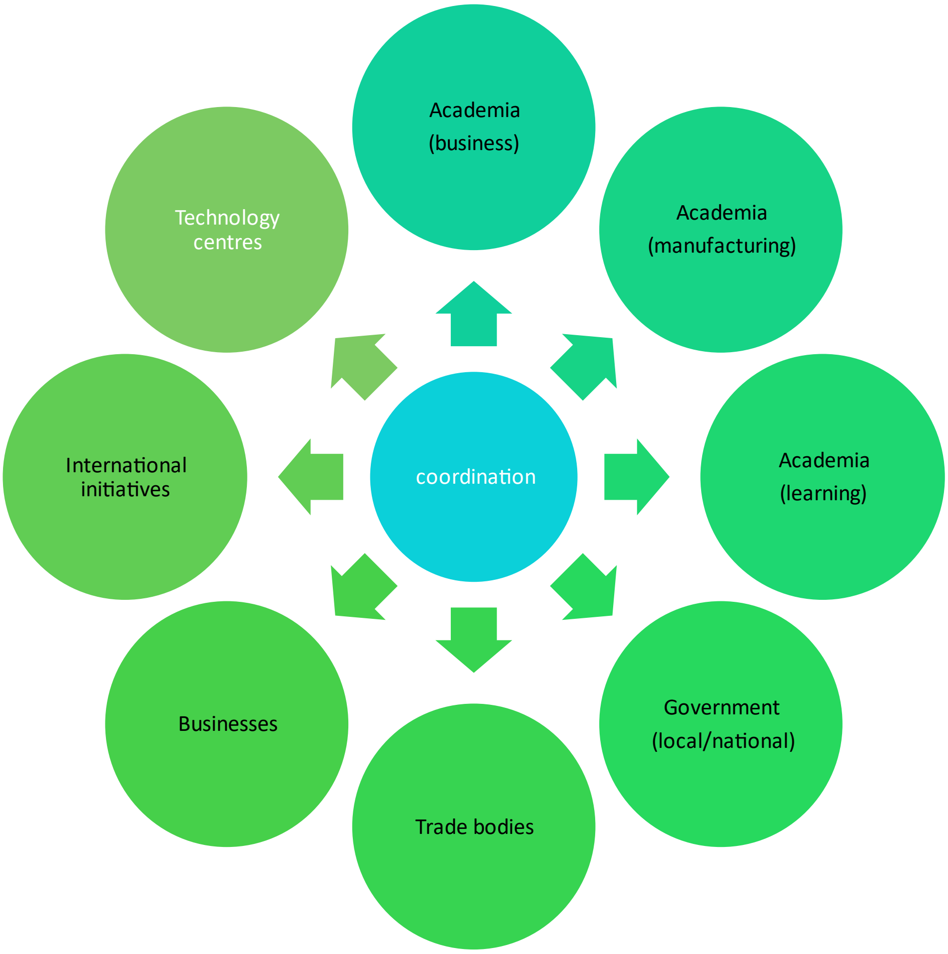
56. Newton fund - £735m




*Source: NICER programme*

More broadly, there is a wider range of stakeholders (Figure 9) that may be relevant to meeting the challenge of ensuring research, development, skills and training resources match industry needs for VRPs. These stakeholders are identified in the following figure. With such a diverse range of stakeholders, it will be important going forwards to consider how these interactions will be coordinated for maximum impact and efficiency.

*Figure 9: Eco-system of potential VRP stakeholders*

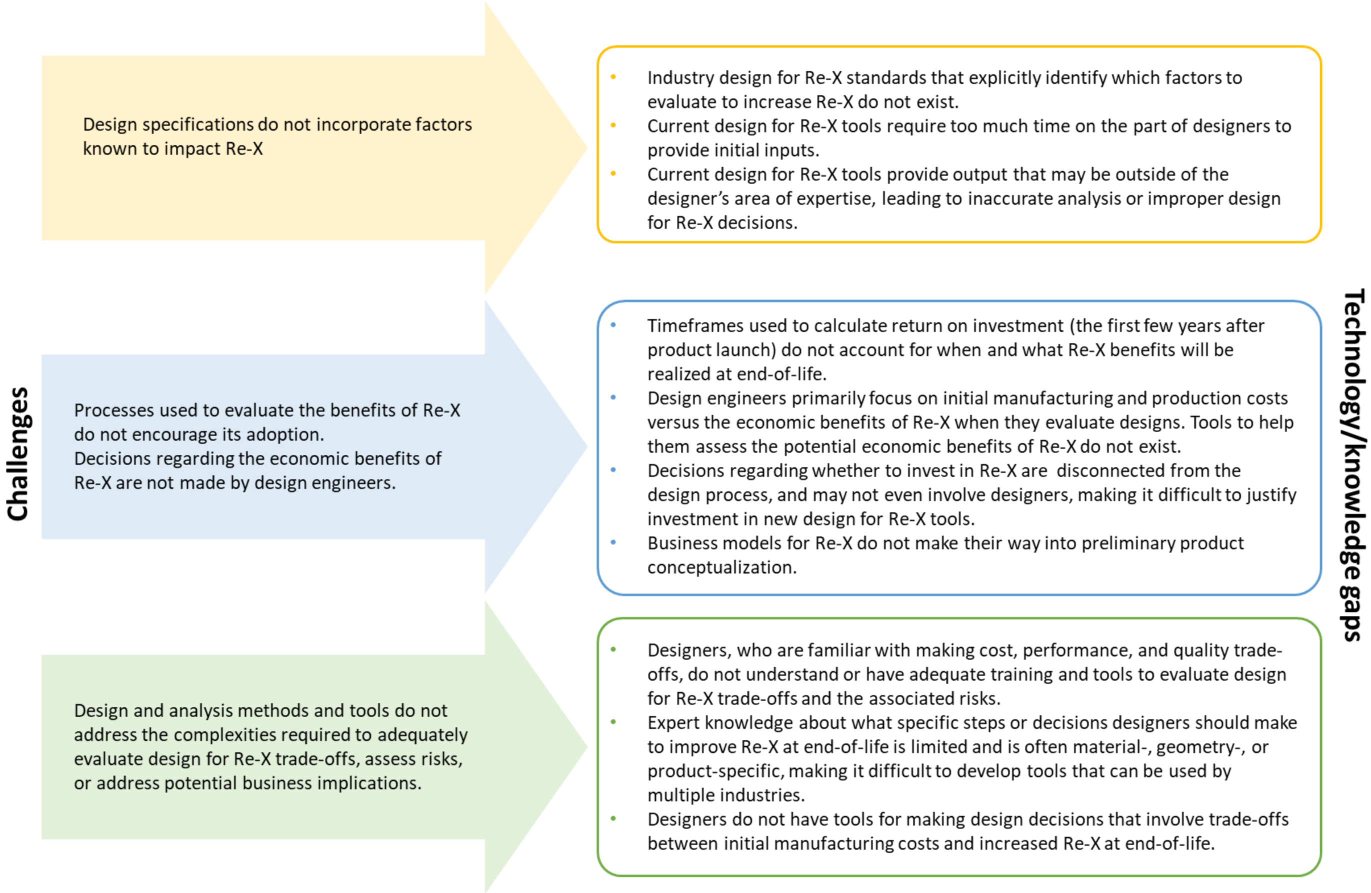


To enable innovation, the main needs that industry has are in two broad categories:

- Those related to design to enable VRP activities in the future.
- Those related to remanufacturing and end-of-life reuse.

A comprehensive analysis of innovation needs has been previously developed by the REMADE [4]Institute in the USA; it is directly transferable to the UK context, and industry innovation needs are summarised in the following diagrams.

*Figure 10: REMADE Institute's broad analysis of VRP innovation challenges*




(continued on next page)

[4] Reducing EMbodied energy And Decreasing Emissions (Initiative)

| Challenges | Technology/knowledge gaps |
|---|---|
| Lack of robust non-destructive inspection/evaluation techniques for assessing damage limit opportunities to remanufacture or reuse components. | • Although condition assessment methods to detect cracks in metal have been developed, methods to measure accumulated mechanical damage (e.g., fatigue) prior to crack development do not exist.<br>• Methods to assess the condition of solid-state components and microprocessors in electronics are not available.<br>• In practice, while used circuit boards undergo functional testing for condition assessment, there are no technologies available to measure or detect latent defects in used printed circuit boards. |
| There are limited techniques for translating inspection/evaluation data into an assessment of residual value and remaining life of products and components. | • Most end-of-life products do not have any associated usage or operational data, making it difficult to assess core value and predict the remaining life of components.<br>• Existing technologies for assessing core condition or value prior to disassembly are based on limited data and limited understanding of condition beyond external appearance.<br>• Remanufacturers do not have access to or awareness of methods for determining the useful life of products or components. |
| The cost of labor and key remanufacturing processes, such as component repair, limits reuse yield and remanufacturing intensity. | • There are currently no methods for in-process monitoring of the bonding strength and properties of thermal spray coating repairs, limiting their cost-effectiveness.<br>• Data to quantify which remanufacturing processes offer the greatest opportunity to improve energy efficiency are frequently not available or have not been consolidated into an accessible and actionable format to inform research priorities.<br>• Quantitative methods for assessing contamination/cleanliness levels for components are not cost-effective or capable of handling production volumes required by remanufacturers, limiting optimization of cleaning processes for used components.<br>• Analysis models and accelerated testing methods for validation of component repairs are extremely limited. |
| Methods for restoring components to "like-new" condition are not available, limiting component reuse in remanufacturing | • There are no cost-effective technologies for removing the conformal coating or potting from circuit boards, limiting repair and reuse of circuit boards.<br>• While light scratches can be polished, there are no cost-effective methods for repairing deeper damage to plastic surfaces. |
| Inefficiencies in the collection of end-of-life products limit cross-industry and cross-product reuse. | • Remanufacturing and reuse-related businesses are not able to find reliable sources of used or end-of-life products because cost-effective approaches for establishing effective reverse logistics networks for new product lines or material reuse opportunities are not available. |

A focus on innovation support that addresses the technology and knowledge gaps identified in the diagrams above would help achieve a range of outcomes as summarised in the table below.

*Table 4: Outcomes expected from targeted programmes of research*

| | Reduced labour costs (disassembly) | Reduced labour costs (inspection) | Reduced replacement parts costs | Reduced process cost | Reduced defect rate | Increased core availability | Increased quality | Increased range of VRP products | Increased product life | Increased market pull |
|---|---|---|---|---|---|---|---|---|---|---|
| **Design for VRPs**<br>Enable products to be designed for VRP activities | ● | | ● | | | | | ● | ● | |
| **Condition monitoring**<br>Technologies to monitor the condition of VRP inputs through use | | ● | | | ● | ● | | | | |
| **Core identification**<br>Technologies to identify core SKUs more efficiently | | ● | | | | | | | | |
| **Non-destructive testing**<br>Technologies to test VRP inputs without damage | | | | | ● | ● | | | | |
| **Remediation**<br>Technologies to improve part remediation | | | ● | | | ● | | ● | ● | |
| **Labour deskilling**<br>Technologies to reduce labour skills requirements | ● | ● | | | | | | | | |
| **Automation**<br>Technologies to automate VRP processes | ● | ● | | ● | | | ● | | | |
| **Product history**<br>Technologies to trace product characteristics, e.g., BOM, drawings | | | | ● | | | | ● | | |
| **Reverse logistics**<br>Technologies to improve the efficiency of reverse logistics | | | | ● | | ● | | ● | | |
| **Low cost and volume spares**<br>Technologies to enable the low cost supply of replacement parts | | | ● | | | | | ● | | |
| **Residual life determination**<br>Technologies to determine the residual life of VRP inputs | | | | | | ● | | ● | | |
| **Consumer platforms**<br>Technologies to connect VRP suppliers and potential customers | | | | | | ● | | | | ● |

These challenges are consistent with previous studies and research in the field.

**Delivery of the challenge**

The following figures summarise the key interventions that could be pursued to accelerate VRP activities in the UK. They show:

- Interventions directly related to company needs and the value proposition (which are more technology focused and directly relevant to Innovate UK).
- Interventions related to the general business environment for VRPs (including policy-related actions).

*Figure 11: Summary of supporting interventions across main levers of influence*

**General business environment for VRPs**

### Direction and control

Formulate policy which incorporates VRPs into CE on an outcome basis

Determine priorities for intervention or assistance based on impact and strategic direction

Set up sector focus groups to better understand strengths, weaknesses, opportunities & threats and for coordination of action

### Statistical, legal and skills framework conditions

Develop and implement CE & VRP ONS metrics to measure impact progress

Enact fiscal frameworks which reward desired environmental outcomes

Enact laws which remove barriers to longevity or embed rights to repair

Develop terminology, accreditation and labelling for remanufactured goods

Ensure research, development, skills & training resources match industry needs

### Market pull and confidence building

Implement public procurement based on the lifecycle impact of goods and services

### Action under local and regional authority control

Adapt infrastructure locally to enable VRP loops especially for home products

Support community-led initiatives to self-help, repair clinics etc.

Target public messaging and knowledge to boost VRP confidence especially in repair

### International co-operative actions

Ensure consistent approach to VRPs, core, imports and exports, and impact tariffs

Agree protocols for recognizing VRP goods and services

Set up international collaborative R&D ventures

**Company needs and the value proposition**

### Technology challenges...

Addressable by existing innovation support
- Design for VRP, automation, predictive techniques, 3D printing, NDT

Addressable by modified VRP-oriented innovation support
- VRP-related EPR

Addressable by international collaboration
- Material and product passports, embedding Scope 1, 2, 3
- 'Global' digital twins

Requiring new or upgraded skills
- Design for VRP

Requiring alternative mechanisms
- Use of CE-centres/CE-Hub to channel funds to address identified sector/general challenge topics, by sector
- Re-conceptualisation of product performance to make it more VRP-ready

### Business related challenges...

- Methods to allow rapid assessment of VRP/Business Model alternatives for businesses
- Establishment of EPD-like standards with clear net-zero (or other) objectives for operations and for funding application that eliminates greenwashing by applicants
- Ability to identify and focus on 'pathfinder' sector/projects

Relating to support for technical innovation, for maximum effect the programme might consist of a portfolio of actions coordinated by Innovate UK as the funding agency. This would likely require a small team to coordinate the programme based within Innovate UK. For the other items, the following approach is suggested:

- Funding for collaborative R&D is disbursed as a normal funding competition.
- Demonstration projects and a centre of excellence in design are identified and established by open tender.
- KTN organises the creation of the network, leadership group, website, promotion of connections between academia and business and events.

Challenges are apparent in finding appropriate companies and institutions based on related experience of industrial strategy challenge fund ISCF targets. Evidence from the current research commissioned by Innovate UK is that there is a sufficiently large market of potential applicants to fund, and this will not be mitigated through issues of technical and commercial feasibility. A key issue will be early promotion of the programme, which could perhaps leverage support from the NICER Programme through the development of the value retention cluster.

The recommended interventions are closely linked to other activities in support of Net-Zero and there may be synergies in tackling them together. Skills for design and manufacturing of VRP-ready products are identified as issues, and there should be coordination with the skills agenda for this reason. Activities will take place where there are concentrations of manufacturing companies and will not be uniformly distributed geographically, meaning that there could be a link to the 'place' agenda.

**Rationale for government intervention**

Innovate UK is the obvious coordinater and funder of innovation support activities. This analysis focuses on types of activities where Innovate UK has experience and expertise, but highlights themes or mechanisms which may need to be developed to augment the current offering.

Early adoption is risky and requires development of new business models: government subsidy is needed to encourage faster, timely uptake through reduction of the commercial risk. If VRPs are to be part of the government roadmap towards Net-Zero, then actions need to be taken now. The programme will assist in this, including identification of blockages related to government (for example need for legislative and regulatory changes). For these items, the Government will be assisted by having a clear voice of business, which the leadership group will help to form.

Additionally, barriers to the uptake and acceleration of VRP activity are not solely technical, and include regulatory and access barriers, market structure barriers, collection infrastructure barriers, and customer market barriers. Developing a co-ordinated framework for intervention including representation from Innovate UK, BEIS, Defra and HM Treasury, would lay the foundation for the systemic changes needed to create a step-change in the business environment for VRPs.

# 2 Study background

- As the UK looks forward to a **post-Covid** recovery and towards targets for a **Net-Zero economy**, now is an opportune time to look at what economic activities we want to develop and support.
- The study aims to provide the **evidence base** to inform **technology** and **innovation needs**, and to develop **policy options** and a set of **recommendations** to develop a national **Value Retention Strategy** in the UK.
- This study looks at the full spectrum of value retention activities (**remanufacturing, refurbishment, repair, and reuse**) across **ten key sectors**.

## 2.1 Wider context/motivation

The market for clean and sustainable technologies has grown in recent years, building on decades of public and private investment in research and development. Discourse about societal factors, notions of "building back better", "levelling up", resilience and job creation is continuing to increase. In addition, the UK's exit from the EU is accelerating a need to develop UK strategy and policy on topics such as resource efficiency and security, resilience, environmental stewardship and manufacturing.

The traditional linear economy (make, use, dispose) results in a single use of materials. In contrast, a circular economy aims to 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 – so-called 'loop' activities. Value Retention Processes (VRP) such as remanufacturing, refurbishment, repair, and direct reuse (i.e. the tighter loops of the circular economy) are central to maximising the value retained in products and materials through the extension of their useful life, and form an essential tactic in meeting the challenges in transitioning to a circular economy.

Extracts from the Climate Change Committee report (3) include a roadmap that states "*Recycling, reusing and sharing products, increasing product longevity and reducing material use through better design, all play a role in reducing Manufacturing and Construction emissions in the Balanced Pathway.*" The report also suggests that, to meet the 2035 carbon budget[5],*"The resource efficiency measures can be split into the following groups: design optimisation to reduce material inputs (3 $MtCO_2e$ per year in 2035), increasing recycling and reuse (3 $MtCO_2e$, of which half is through reuse of construction materials), increasing product longevity (2 $MtCO_2e$, largely from electronics), and increased product utilisation and sharing (1 $MtCO_2e$, including sharing leisure equipment and car clubs)."*

The vision is a system in which the products the UK designs and makes deliver more value across their lifecycle to their customers and to society, but with reduced environmental impact. This is achieved through the deployment of digital technologies, remanufacturing[6], business model innovation, product design and through-life engineering services.

This reflects a future for UK manufacturing that is more resilient, higher value and reflects some of the UK's strengths in product design, the service economy, business model innovation, digital technologies and finance, all of which are key to implementing value retention systems. Specifically, digital technologies and approaches are a considerable enabler, and include:

- Internet of Things and big data (on the shop floor and through product lifetimes).
- Robotics and sensors (e.g. to enable automation of the dirtier, and/or repetitive jobs in remanufacturing and refurbishment - easier disassembly and cleaning etc.).

[5] The CCC recommends the Sixth Carbon Budget for 2033-2037 is set at 965 $MtCO_2e$ and calculates to meet this will require average annual reductions of UK emissions of 21 $MtCO_2e$ (3).
[6] Remanufacturing has been defined as "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"

- Immersive tech (for instance as an enabler for remote diagnostics and assessment, training etc.).

Based on existing evidence, it is estimated that the value retention activities outlined above already generate around £5bn in revenue, with a significant capacity to grow. There are also considerable societal and environmental benefits as laid out in a 2018 UN report (4) 'Redefining Value: The Manufacturing Revolution'. As an example, remanufacturing is well established in the automotive sector and has potential for significant growth, but we also need to understand the opportunities offered by the transition to Net-Zero technologies.

## 2.2 Aims

Innovate UK, KTN, BEIS and Defra wish to explore the development of a potential joint strategy for a future of UK manufacturing that is based on circularity and enhanced value to users.

*This study aims to provide the evidence base to inform technology and innovation needs, and to develop policy options and a set of recommendations to develop a national Value Retention Strategy in the UK.*

The resulting strategy would include innovations and policy aspects and consider innovative approaches throughout the life of a product, supporting a more sustainable, lower carbon and more circular economy, as well as creating high quality jobs in a digitally-enabled future.

VRPs are defined in the 2018 International Resource Panel study (4) as

> *"…activities, typically production-type activities, that enable the completion of and/or potentially extend a product's service life beyond traditional expected service life. These processes include arranging direct reuse, repair, refurbishment, comprehensiverefurbishment, and remanufacturing."*

For the purposes of this study, we are defining VRPs as 'Remanufacturing, Repair, Refurbishment, Reconditioning and Direct reuse'. Key enablers to VRPs include sustainable product design, business model innovation (5), through-life engineering services (6), and servitization[7], which this study consider.

*This project set out to investigate a cluster of topics that collectively represent the tighter loops of the circular economy where the value retained in products and materials is optimised. This goes beyond the typical focal point for many discussions on circular economy, namely what to do with waste.*

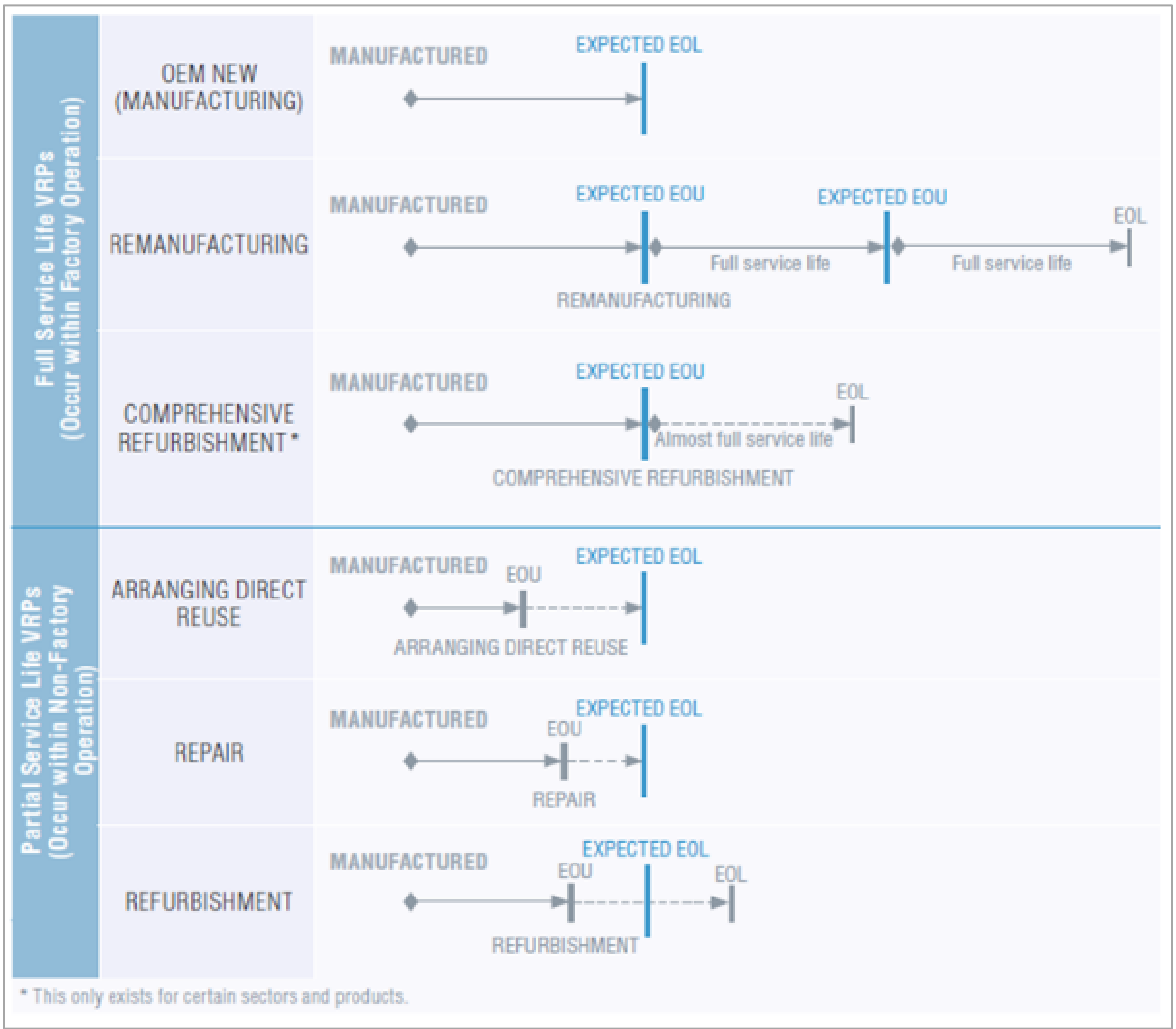
VRPs can be assigned to one of two broad categories: full service-life and partial service-life. As shown in *Figure 12*, full service-life VRPs are executed at the end of a full product service life, are comprehensive and take place within factory operations, extending the life of the product by a period at least equal to that of the original service life. In contrast, partial-service life VRPs are executed usually due to a failure before end of expected life, are limited in scope and take place outside of factory operations and only extend the service life of the product to its conceived duration (4).

VRP-related products offer a variety of environmental benefits over newly produced products, including reduced new material input requirements, reduced embodied energy, reduced production emissions and lower production waste. In addition, VRPs are associated with economic benefits such as job creation, reduced production costs, increased export opportunities and access to new market segments. While the

[7] In its simplest terms, **servitization** refers to industries using their products to sell "outcome as a service" rather than a one-off sale. Netflix and Spotify are good examples of this, delivering media as a service, rather than customers buying the CDs, DVDs etc that produce those outcomes.

value retention framework used in this study captures a large fraction of activities that seek to extend the life of products, we recognise that there other activities that will contribute to this goal (such as maintenance and managed services), which are not as readily captured via this framework. As such, we recognised that value retention activities represent a sub-set of circular activities that can be applied to products within the sectors studied (Figure 12).

*Figure 12: Value retention framework*




*Source: UNEP IRP study* (4)

Bocken et al. (7) characterise the CE approach as follows:

> *"Circular economy supports sustainable development by aiming to secure the resources to sustain our current and future generations. This is achieved by minimising resource inputs and waste, emission and energy leakage of products over time, using four distinct strategies: narrowing, closing, slowing and regenerating resource loops."*

Of the four strategies identified, value retention processes align with slowing resource loops, by keeping products in use for longer. Bocken et al. also note:

> *"Slowing the loop is potentially the most impactful environmental strategy, but it's also the most challenging one to implement because it requires a significant rethink of the business model focusing on 'value over volume' and from faster to slower forms of consumption."* (7)

## 2.3 Objectives

While the ultimate objective of this study is to enable and support the long-term circular industrial growth in the UK, there is still a need to assess the current state and better understand the future potential of VRPs across various UK manufacturing sectors and regions. This baseline information is crucial for the development of a meaningful strategy. However, the scope and size of the UK's remanufacturing industry is not well understood and there is little socio-economic information for this industry that is currently available on a national scale.

The objectives of this study are outlined below, with a reference to where in this report the related outputs can be located:

- Define and describe the current state of remanufacturing and other VRP sectors in UK (section 5).
- Provide a quantitative account of the environmental and socio-economic cost and benefits of remanufacturing and other VRPs (sections 5.1 and 5.2).
- Provide a SWOT analysis of UK's capability in remanufacturing and other VRP sectors (section 9.1).
- Identify and describe the key technologies and innovations that underpin remanufacturing and other VRPs and provide an overview of their maturity (section 10.1).
- Identify and describe the barriers to growth in the remanufacturing and other VRP sectors in UK (section 9.2.1) and potential options (technological and policy) to overcome these challenges (section 11).
- Provide case studies on VRP in specific industry sectors in UK (see separate case study file).
- Identify industrial sectors in the UK that would benefit the most from remanufacturing and other VRPs, and those sectors where it may not be best value for public money (section 11.2).
- Include an international benchmarking of the UK against the situation in the EU, Canada, USA and key Asian markets (section 6.1).
- Provide a summary of international best practices in the area of remanufacturing (section 6) and highlight opportunities for international research and innovation collaborations (section 6.2).
- Identify barriers to trade (section 9.2.1) and provide recommendations to address the challenges (section 12).
- Suggest potential policy instruments and incentives that could be implemented in the UK to further develop the remanufacturing and other VRP sectors (section 11).
- Provide quantitative and/or qualitative evidences to support the above listed objectives (throughout).
- Identify and prioritise innovation interventions supported by underpinning evidence (section 12).

## 2.4 Scope

The investigation has targeted the following key themes related to insight, policy options and focusing action.

***Market opportunity – current potential and future growth***

Evidence of the existing market size and the opportunity for growth from existing literature and new evidence.

An estimate of the current and projected markets for VRPs across sectors and products/services including an analysis of the sectors ready for adoption or increased uptake of VRP techniques.

Industry sectors or categories of products/services which have the best potential to develop or expand remanufacturing and VRPs across the UK and key factors that could impact future production, markets and competitiveness, providing forecasts over the next ten years.

**Benefit analysis (Environmental and Socio-economic)**

A quantitative cost-benefit analysis of wider adoption of value retention including Net-Zero ($CO_2$ reduction), societal benefits (e.g. jobs created/safeguarded) and resilience benefits (e.g. in relation to supply chains for critical raw materials) by sector.

A future projection for increasing remanufacturing and other VRPs in identified industry sectors in UK.

***UK's strategic position (strengths, weaknesses, opportunities and threats)***

Evidence of the current UK position regarding exploitation of value retention approaches including context, UK industrial capability, and UK research and innovation capability.

Evidence of UK strengths (e.g. product design, customer journey, services, business model innovation, finance), and its alignment with the value retention topic including high-level international benchmarking of the current state of VRPs sectors in other countries, including the industry sector(s) where they are the most prevalent, and synergies and/or relationships between the UK and other countries.

**Barriers and opportunities**

Opportunities and barriers (technology, socio-economic and environmental) to the adoption of value retention approaches and any region-specific differences.

The balance between innovation barriers as opposed to the barriers to adoption of existing technology, including industrial digital technologies.

***Intervention options (innovations and policy)***

Interventions or levers that government and non-government stakeholders may adopt (to include BEIS, Defra, Innovate UK and KTN), including research funding, Innovate UK innovation support, programmes for knowledge transfer/adoption/diffusion, provision of access for manufacturers to demonstrators or expertise, public procurement policy, legislation, standardisation etc.

The relative impact of these levers on the adoption of value retention approaches and options for how the UK Government could support growth of remanufacturing and VRPs across sectors and regions.

An overview and assessment of emerging technologies, processes, and other innovations that underpin significant growth in remanufacturing and other VRPs.

Regulatory, behavioural and financial incentives needed to increase uptake of remanufactured products and services and a description and summary of international best practices and potential policy instruments and incentives.

***Gap analysis***

The current programmes in this area, what they address and the gaps requiring increased focus. Current programmes include those in productivity and competitiveness (Growth Hubs, Be the Business, Peer Networks, National Manufacturing Competitiveness Levels [NMCL], Made Smarter, etc.), Adoption of Industrial Digital Technologies (Made Smarter), existing innovation programmes like Manufacturing Made Smarter, Aerospace Technology Institute (ATI), Advanced Propulsion Centre, Faraday, etc.

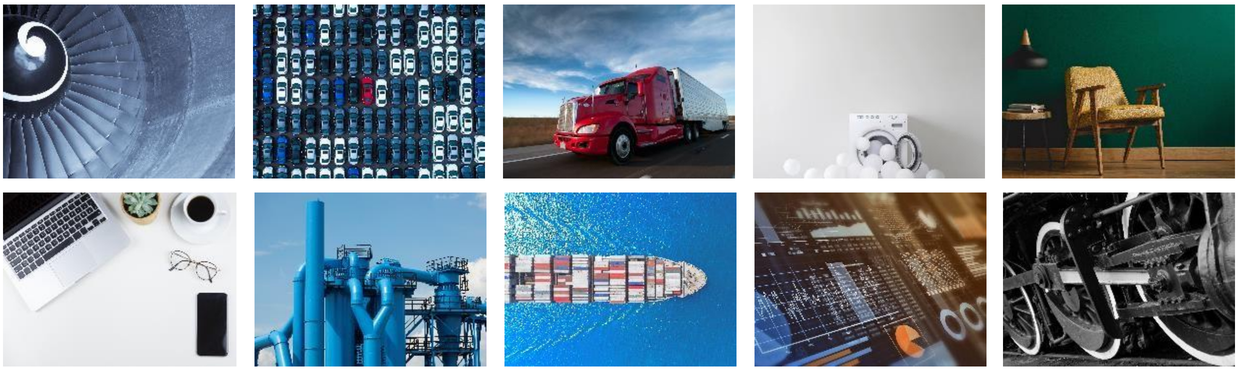
How the current system would need to be changed to support future growth in remanufacturing and other VRPs.

***Recommendations***

Recommendations for key stakeholders and detail specific intervention actions such as technologies and innovations, policies, supply chain etc.

Evidence-based inputs are provided to support an qualitative, outline business case for innovation priorities following the format of the 5 Case Model (the Executive Summary).

Not every industrial sector can be covered in this study. The work coversten sectors in detail: aerospace, automotive, domestic appliances, heavy duty and off-road, electronics, furniture, ICT, industrial equipment, marine, medical equipment and rail.



These sectors have been chosen because:

- They are of significance to the UK, broadly comprising around 70% of the expected economic activity that might be related to VRPs.
- They are a comparable set to those which appear in the limited number of international surveys (of remanufacturing, largely) and thus provide a degree of cross-reference across nations or regions.
- They cover both established, emergent and sectors of growth potential, both in business-to-business (B2B) and business-to-consumer (B2C) markets.

Based on previous the experience of previous studies, this is highly likely to reveal commonalities and differences in barriers seen, possible enablers, technology requirements, productive business models and – not least – where the weight of effort should be focused to promote the most relevant and impactful VRP approach in the short and longer term.

# 3 Method and approach

- We used a range of approaches to collect information in this study including **literature review**, **interviews, workshops**, and a **survey**.
- **Stakeholder engagement** and **modelling** were important elements of this work due to the **lack of statistical data** for some VRP activities.
- The interview approach sought to continue engagement until **consistent responses** were being found.

## 3.1 Summary of component activities in this study

### Literature review

Review of existing literature and collated information on the project thematic objectives, including: the current state of VRP activities in the UK, SWOT analysis, barriers and enablers (to trade and growth), international benchmarking of the UK, international best practice, and potential policy instruments and incentives.

### Survey

Multi-mode engagement was vital to producing high quality outputs for this project. Surveys can highlight "left-field" issues because they attract those with opinions. The survey outputs contributed towards objectives of describing the current state of VRP activities in the UK, and barriers and opportunities.

### Interviews

1-to-1 engagement was the primary means for gathering data and insights on the current market opportunity, the UK's strategic position for VRPs, and barriers and opportunities. Interviews have also been used for gathering data to compile VRP case studies. Trade bodies were a primary route to target interviewees.

### Workshops

Workshops are useful for discovering unexpected issues, testing findings and revealing "trigger" issues, as well as for engaging multiple audiences in a collaborative, exploratory fashion and for building consensus. Two web-based workshops were held with approximately 100 delegates participating in total.

### Analysis

The description and distillation of the themes, trends and root causes that define UK VRP activity, limits and prospects from the wide range of data and insights gathered from the five other methodological approaches. This then fed into the development and prioritization of interventions to form robust recommendations.

### Modelling

Modelling is needed to quantify the status and impacts of current VR activities (due to the limits of socio-economic and environmental data) and to project future potential impacts. This project has redeployed comprehensive Excel-based models of current and projected VRP activities and impacts for GDP, jobs, GHGs and materials savings.

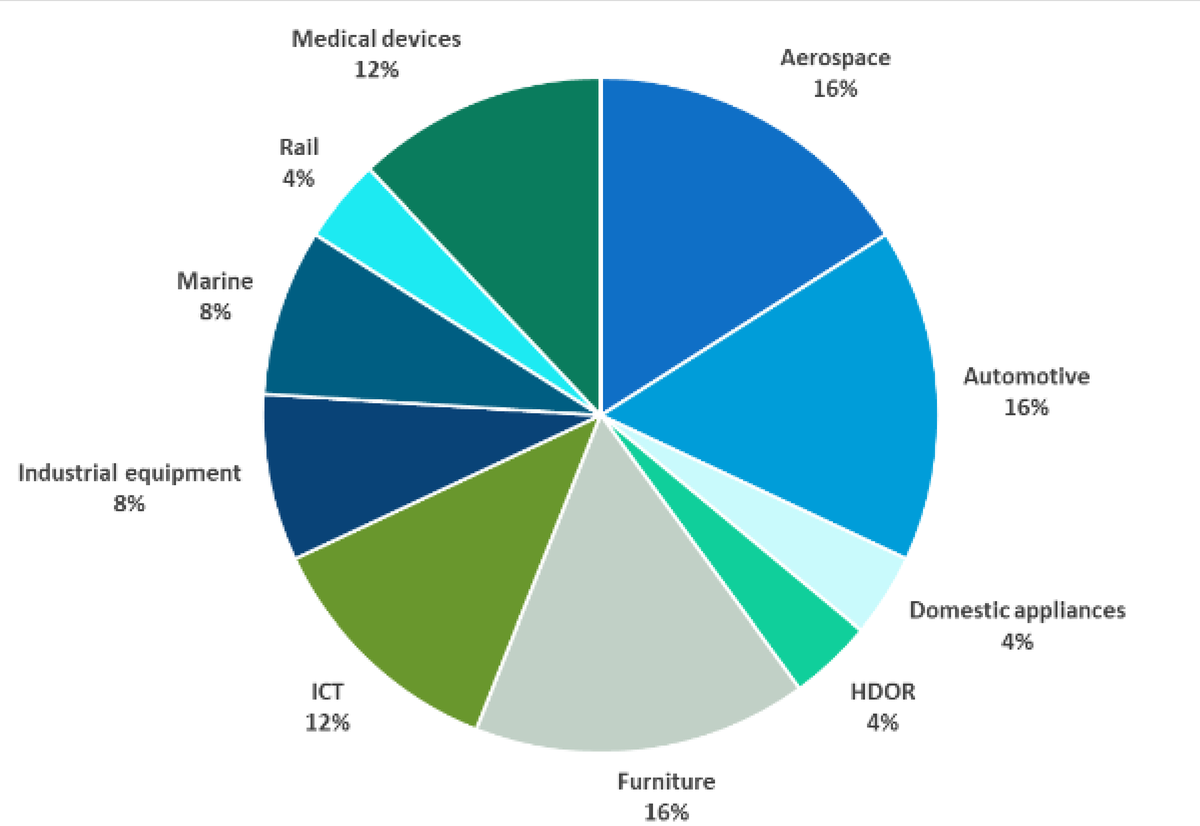
The stakeholder engagement aspects of the approach are described in more detail in the following sections.

## 3.2 Interviews

The purpose of one-to-one interviews was to gather primary information regarding the markets, barriers, opportunities, technical issues and potential enablers of further remanufacturing across the target sectors. One-to-one interviews have proven to be the most productive means of obtaining this information and can be managed in the light of cumulative responses to target areas of information deficiency.

The interview process distinguishes between the different sectors being studied. The approach followed was a semi-structured one, based on an interview questionnaire that we created (see Appendix B ). 26 interviews were conducted; participants included trade associations, companies, government representatives and academics. These organisations included those involved in value retention processes and those that were exploring the possibilities of developing value retention products in their sector.

*Figure 13: Distribution interviews across sectors*




The insights gained from these interviews can be found in Section 3.3.

## 3.3 Survey

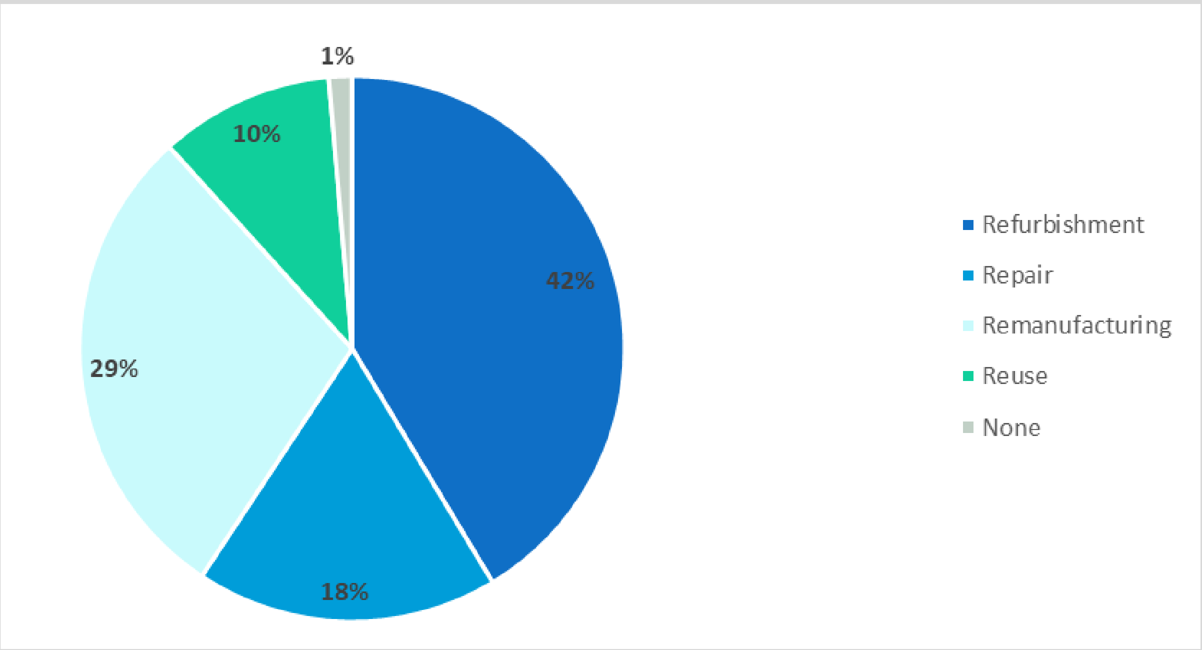
Historically, surveys have not proved to be effective means of collecting comprehensive data because of relatively low uptake (around 2-5% - similar levels seen in mailshot marketing campaigns); however,  they do have a confirmatory role; they can also highlight 'left-field' issues, because they tend to attract those with strong opinions. The University of Brighton (UoB) has conducted a survey into certain aspects of remanufacturing practice on behalf of BEIS; as a project partner UoB has built on its work to cost-effectively extend the scope of enquiry to non-remanufacturing VRP activities. The orginal BEIS commissioning team has had representation on our project Expert Group to maximise coordination. UoB contracted Marketing Means to conduct the survey,the intention being to avoid survey fatigue for those who might be inclined to respond to only one or other of the surveys.

The full survey questionnaire is available in Appendix C .

- The survey was distributed to its originally intended audience of around 190 participants.
- In line with the proposed (BEIS) methodology, a spot-check of 12 telephone interviews were held to test likely response rate. Of these 12, one responded.
- At its completion, 46 survey interviews had been completed. This consisted of both telephone interviews (63%) and online questionnaires (37%).

In terms of the diversity of types of VRPs, the most common practice by participants was refurbishment.

*Figure 14: Types of VRPs taken by survey respondents*




All ten sectors under investigation were covered in the survey in addition to 13 interviews in the construction sector as the survey was open to respondents from any sector. The survey results contributed to the analysis of general barriers for value retention processes in this study.

## 3.4 Workshops

Two workshops were proposed in the research schedule. The outputs from these workshops have informed the rest of the study, particularly focusing on the interventions and recommendations. An overview of the workshops is presented here.

### *3.4.1 Workshop 1, 21 July 2021*

The first workshop was an engagement and discovery workshop. The aim of the workshop was to capture the vision of what the UK VRP industry could look like in 2050 as part of the UK's *NetZero* and *Build Back Better* agendas and to define a roadmap to get there.

On 21 July KTN and Oakdene Hollins delivered the workshop *'Value Retention Processes - the art of the possible'* to an invited attendee list representing a range of sectoral organisations involved in value retention activities.

A mural (using web-app Mural) was designed to take users on a journey from the current status of VRP activities within the UK towards a 2050 ambition according to the schedule described in Appendix E . A list of potential interventions to assist the transition between the present and desired industry status in 2050 were then identified.

After an introduction, the participants and facilitators split into two breakout groups to explore the topics of the agenda. The findings of these are available as Post-its which KTN subsequently clustered. A text and graphical summary of the 'murals' is provided in Appendix E .

### 3.4.2 *Workshop 2, 19 November 2021*

The second workshop was held in collaboration with the NICER CE-Hub. The aim of the workshop was to promote the concept of value retention within the circular economy agenda. Our team collaborated with the CE-Hub, rather than holding an independent event, as we recognised the hub's valuable and extensive network, the risk of 'event fatigue' for participants, and the mutually beneficial opportunity to raise the profile of VRPs with the CE-Hub and Centre communities.

The speakers for the event included the co-directors of the CE-Hub, Prof. Peter Hopkinson and Prof. Fiona Charnley. Abishek Ramesh from Innovate UK and David Parker and Rachel Waugh from Oakdene Hollins introduced the purpose of the study. The government perspective was provided by Steven le Roux from BEIS. Industrial perspectives for the session were provided by Richard Loretto from Amazon, James Barry from Renewable Parts and Catriona Cory from Topolytics.

The workshop session consisted of three breakout rooms. Workshop participants could choose which room to join. The purpose of these rooms was to gain insights on creating value across the product value chain. The workshop was attended by over 75 people.

A summary of the key insights from the workshop can be found in Appendix F .

# 4 Value retention processes[8]

- Value retention processes **extend a product's service life** beyond the expected service life.
- The **definitions** of value retention processes used in this study are taken from the framework developed by the **UNEP International Resources Panel**.
- **Value** can be measured in different ways, including, for example, in terms of **revenue, $CO_2$e, materials** and **energy**.
- The value retention processes considered in this study include **remanufacturing, refurbishment, repair and reuse**. This includes also **through-life engineering services**.

Internationally, value retention processes (VRPs) are seen as playing an important role in the transition to a circular economy. VRPs are defined in the 2018 International Resource Panel study (4) as:

> *"Activities, typically production-type activities, that enable the completion of and/or potentially extend a product's service life beyond traditional expected service life. These processes include arranging direct reuse, repair, refurbishment, comprehensive refurbishment, and remanufacturing".*

The definitions of the distinct VRP activities covered in this study are presented below, distinguishing between those that extend the life of products by a full-service life (remanufacturing and comprehensive refurbishment) and those that extend life by less than a full-service life (repair, refurbishment, direct reuse). Additional information on the differences in terminology can be found in Appendix A .

## 4.1 Full-service life VRPs

### 4.1.1 *Remanufacturing*

> *"A standardized industrial process that takes place within industrial or factory settings, in which cores are restored to original as-new condition and performance or better. The remanufacturing process is in line with specific technical specifications, including engineering, quality and testing standards, and typically yields fully warranted products. Firms that provide remanufacturing services to restore used goods to original working condition are considered producers of remanufactured goods."*

Remanufacturing is a full-service life VRP that yields products that are 'as good as' or 'better than' new. To qualify as remanufacturing, products must be at a minimum, disassembled, cleaned, tested and documented. These products must also be sold with a warranty befitting the 'as good as' or 'better than' new condition (4).

### 4.1.2 *Comprehensive refurbishment*

Comprehensive refurbishment activities are conducted within industrial or factory settings and exceed the standards of refurbishment of all other refurbishment activities. The UNEP VRP report defined comprehensive refurbishment as:

> *"Refurbishment that takes place within industrial or factory settings, with a high standard and level of refurbishment."*

[8] This section borrows from a report written by Oakdene Hollins and Dillon Consulting on the behalf of the Canadian Government. The original work is; Socio-economic and environmental study of the Canadian remanufacturing sector and other value-retention processes in the context of a circular economy (15)

## 4.2 Partial-service life VRPs

### *4.2.1 Repair*

The definition of product repair as given by the UNEP 2018 report is:

> *"Fixing a specified fault in an object that is a waste or a product and/or replacing defective components, in order to make the waste or product a fully functional product to be used for its originally intended purpose."*

From this definition the repair of a product is not limited to end-of-life (EoL) or end-of-use (EoU) items and can include both repairs to products so that they may meet their original expected lifespan, and maintenance activities that if not undertaken would limit the product's expected lifespan.

### *4.2.2 Refurbishment*

As with repair activities, refurbishment can be undertaken on both EoL and pre-EoL products. Refurbishment can be characterised as exceeding the level of material replacement and renewal activity achieved during product repair, but not meeting the level of structure, industrialisation or quality expected from comprehensive refurbishment activities.

Refurbishment can be further distinguished from repair activities by the fact that they modify the product unit such that the usable product life can extend past the designed lifespan.

Within UNEP's 2018 report, refurbishment is defined as:

> *"Modification of an object that is waste or a product to increase or restore its performance and/or functionality or to meet applicable technical standards or regulatory requirements, with the result of making a fully functional product to be used for a purpose that is at least the one that was originally intended."*

Product refurbishment will usually take place within repair or maintenance facilities and will be accompanied with some form of warranty on major wearing components, although these will tend to be less comprehensive than for newly manufactured or remanufactured parts.

### *4.2.3 Arranging direct reuse*

Arranging direct reuse is separate from cascading reuse activities that occur between customers. This process was defined within the UNEP 2018 report as:

> *"The collection, inspection and testing, cleaning and redistribution of a product back into the market under controlled conditions (e.g. a formal business undertaking)."*

Under this definition, no disassembly, addition or removal of components can take place and activity is limited to the inspection and simple aesthetic reconditioning. As such, this VRP process is only possible for products that are in working condition. These products will often be offered with a very limited or no warranty and resold at a price much below the market value.

## 4.3 Through-life engineering services

Through-life engineering services (TES) are defined as:

*Product support strategies through each stage of the product lifecycle, including design, manufacture, operational life, and end-of-life disposal*

Within the context of this project, there is significant cross-over between through-life engineering services and other VRPs. While it will not be possible to separate out economic activity between TES and other VRPs, where specific insights related to TES are identified, they will be highlighted in the report.

# 5 VRP activity in the UK

- VRP activity in the UK in 2020 is estimated to have generated over **£75 billion in revenue** and supported over **500 thousand jobs**.
- VRP activities in the UK in 2020 are estimated to have prevented at least **620 kt of waste** and avoided at least 4**.7 Mt $CO_2$e**.
- The market size estimate from this study is significantly larger than that from previous studies due to its broader scope, updated methodology and improved data sources.

## 5.1 Socio-economic analysis

A summary of the estimated size of VRP activities for the ten sectors considered within this study are shown in the table below. This analysis estimates that VRP activities in 2020 generated over £75 billion in revenue. Detail descriptions of the sources of these data can be found in Section 8.

*Table 5: Estimated size of VRP markets (2020)*

<table>
<tr><th>REVENUE</th><th>Remanufacturing</th><th>Comprehensive refurbishment</th><th>Refurbishment</th><th>Repair</th><th>Reuse</th></tr>
<tr><td>Aerospace</td><td colspan="4">£15,400 m</td><td>N/A</td></tr>
<tr><td>Automotive</td><td colspan="2">£600 m</td><td colspan="2" rowspan="2">£21,500 m<br>(+£560 m HDOR)</td><td>£21,400 m</td></tr>
<tr><td>HDOR</td><td colspan="2">£747 m</td><td>No data available</td></tr>
<tr><td>Domestic appliances</td><td>N/A</td><td colspan="2">No data available</td><td>£470 m</td><td rowspan="3">£143 m</td></tr>
<tr><td>Furniture</td><td colspan="3">£30 m</td><td>£13 m</td></tr>
<tr><td>ICT</td><td colspan="2">£271 m</td><td>No data available</td><td>£5,928 m</td></tr>
<tr><td>Industrial equipment</td><td colspan="2">£112 m</td><td>No data available</td><td>£3,795 m</td><td>No data available</td></tr>
<tr><td>Marine</td><td>£8.1 m</td><td colspan="2">No data available</td><td>£1,269 m</td><td>£945 m</td></tr>
<tr><td>Medical devices</td><td>£ 0 m</td><td colspan="2">No data available</td><td>£370 m</td><td>N/A</td></tr>
<tr><td>Rail</td><td colspan="2">£16.9 m</td><td>N/A</td><td>£1,049 m</td><td>N/A</td></tr>
</table>

*Source: Oakdene Hollins analysis*

The breakdown of activity by VRP and sector is presented in the charts on the following pages. The analysis shows that the largest fraction of VRP activity occurs in the automotive sector (69%) followed by aerospace (21%) and ICT (8.4%). Based on the data available, the largest VRP activity is in repair (47%), though this assessment is subject to the greater uncertainty around data on remanufacturing and reuse compared to manufacturing.[9]

[9] Repair activities are captured under industrial statistics while for other VRP activities data have been collated through bottom-up analysis and modelling and may be (sometimes significantly) underestimated.

*Figure 15: Breakdown of UK VRP activity by sector (2020)*

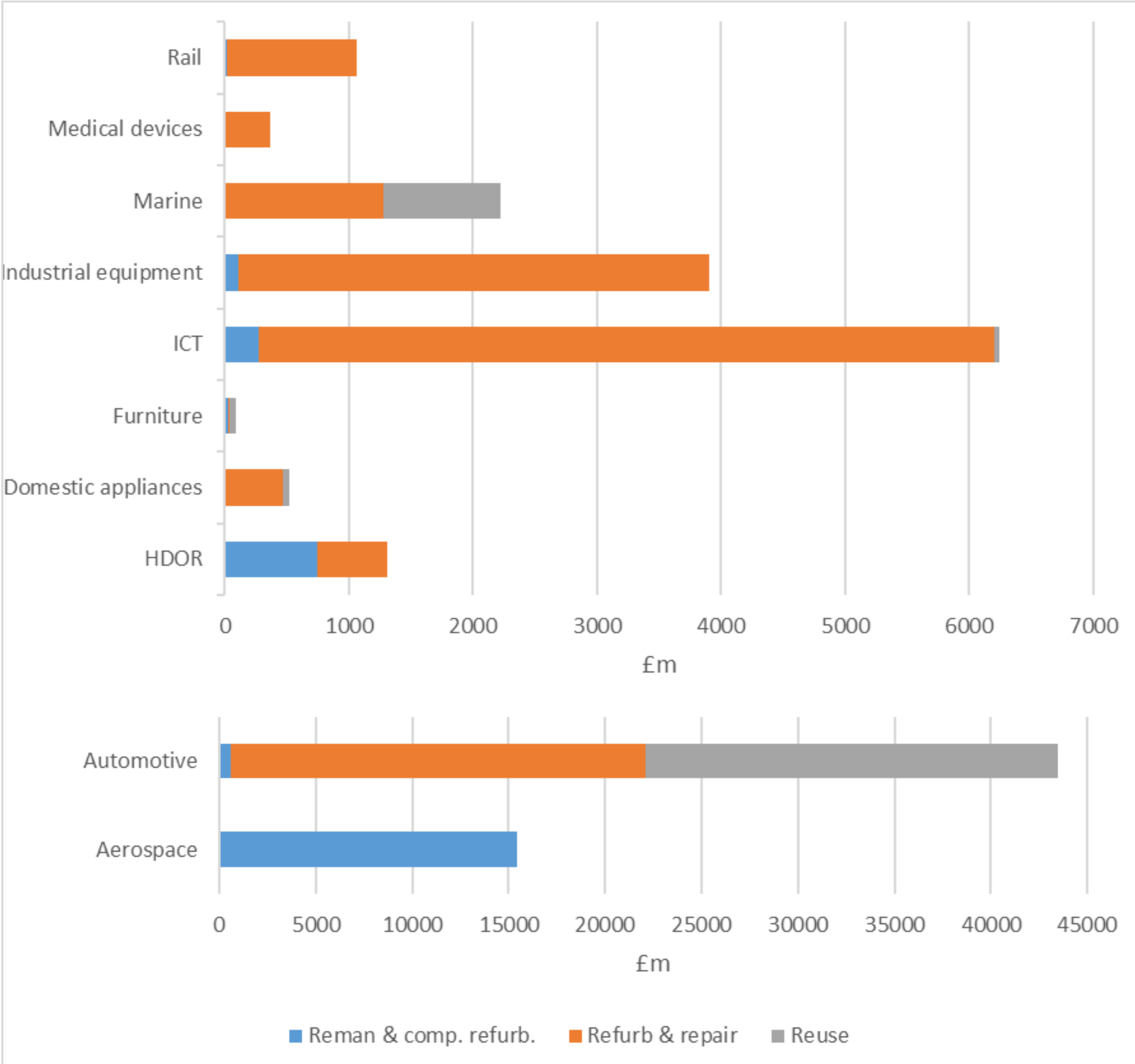
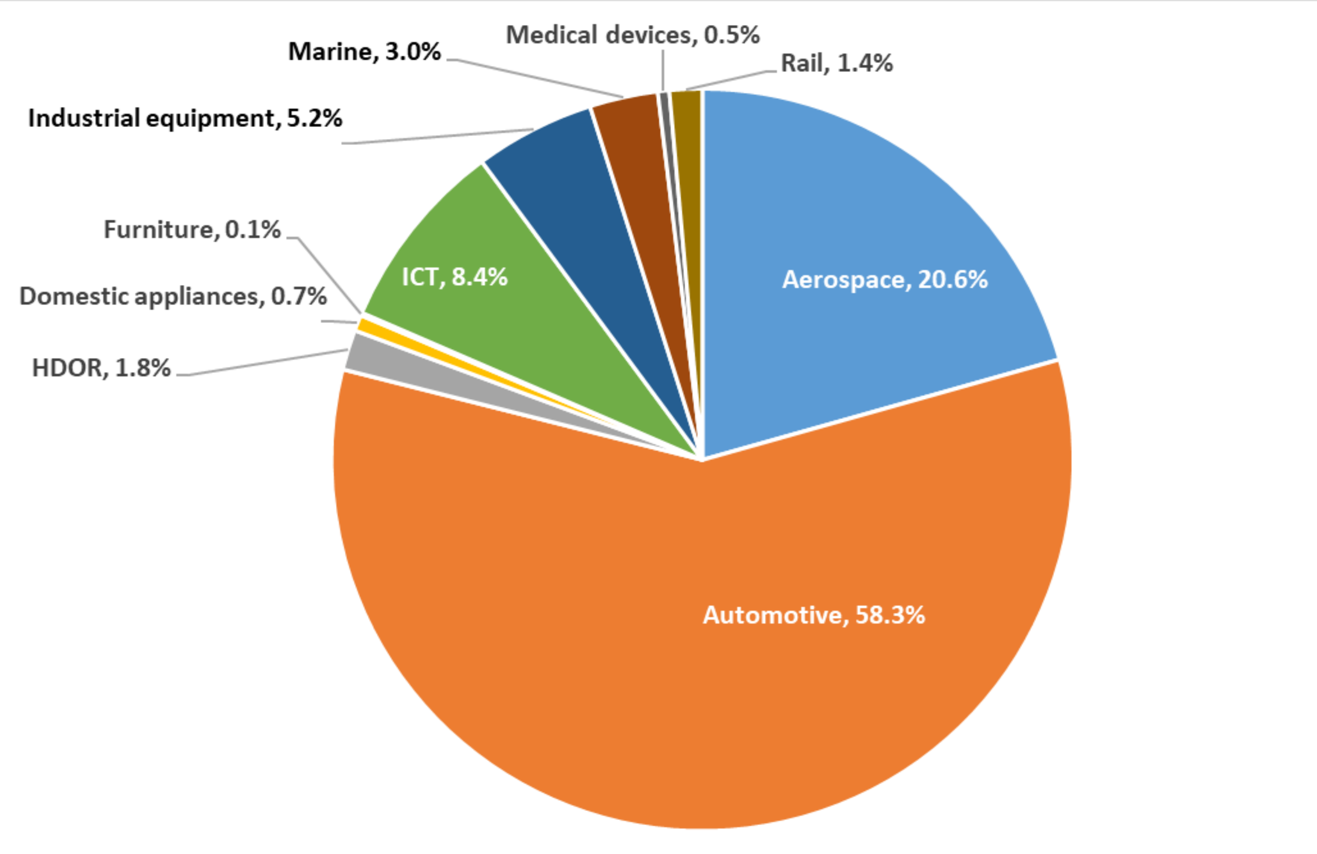


*Figure 16: Share of all UK VRP activity by sector (2020)*




The availability of economic data on imports and exports of VRP products is poor. The only economic data available for imports/exports of VRP products is for imports of retread tyres, summarised in the table below. Detail descriptions of the sources of these data can also be found in Section 8.

*Table 6: Estimated size of VRP product trade (2020)*

| IMPORTS | Remanufacturing & comprehensive refurbishment | EXPORTS | Remanufacturing & comprehensive refurbishment | Repair |
|---|---|---|---|---|
| Aerospace | £6.2 m (tyres) | Aerospace | £11.7 m (tyres) | £1,522 m |
| Automotive | £0.2 m (tyres) | Automotive | £6.5 m (tyres) | - |
| HDOR | £9.1 m (tyres) | HDOR | £16.3 m (tyres) | - |
| Marine | - | Marine | - | £77.1 m |

*Source: Oakdene Hollins analysis*

This study estimates that VRP activities employee over 500 thousand jobs in the UK. Where VRP activities can be allocated to defined Standard Industrial Classification (SIC) codes, the related employment has been identified using statistics. For some activities, desk-based research and/or stakeholder insights were able to provide estimates of employment. Where primary data was not available, the employment of VRP activities is estimated by scaling economic activity (and indicated in italics). The following table summarises the data available by VRP activity and sector.

*Table 7: Estimated employment by VRP product market (2020)*

<table>
<tr><th>JOBS</th><th>Remanufacturing</th><th>Comprehensive refurbishment</th><th>Refurbishment</th><th>Repair</th><th>Reuse</th></tr>
<tr><td>Aerospace</td><td colspan="4">49,000[a]</td><td>N/A</td></tr>
<tr><td>Automotive</td><td colspan="2">7,100[c]</td><td colspan="2" rowspan="2">255,200[b]</td><td>50,000[d]</td></tr>
<tr><td>HDOR</td><td colspan="2">8,900[c]</td><td>No data available</td></tr>
<tr><td>Domestic appliances</td><td>N/A</td><td colspan="2">No data available</td><td>18,100[e] (includes ICT repair)</td><td rowspan="3">41,200[f]</td></tr>
<tr><td>Furniture</td><td colspan="3">7,800[h]</td><td>3,400[g]</td></tr>
<tr><td>ICT</td><td colspan="2">770[i]</td><td>No data available</td><td>18,100[e] (includes domestic appliance repair)</td></tr>
<tr><td>Industrial equipment</td><td colspan="2">1,150[k]</td><td>No data available</td><td>39,000[j]</td><td>No data available</td></tr>
<tr><td>Marine</td><td>50[m]</td><td colspan="2">No data available</td><td>7,900[o]</td><td>2,200[n]</td></tr>
<tr><td>Medical devices</td><td>N/A</td><td colspan="2">No data available</td><td>No data available</td><td>N/A</td></tr>
<tr><td>Rail</td><td colspan="2">240[p]</td><td>N/A</td><td>14,800[o]</td><td>N/A</td></tr>
</table>

*Sources: ONS and Oakdene Hollins analysis*

*Employment estimates from* (8) *scaled by ONS 33.16; [b]ONS class 45.2 (UK); [c]scaled from automotive refurbishment/repair activity; [d]ONS sub class 45.11/2 (GB only); [e]ONS class 95.2 (UK); [f]ONS sub class 47.99/9 (GB only); [g]ONS class 95.24 (GB only); [h]scaled from repair of furniture but likely an overestimate as only a few remanufacturers operating with higher value products; [i]scaled from ONS class 95.2; [j]ONS class 33.12/0 (GB only); [k]scaled by industrial equipment repair; [l]ONS class 33.15/0 (GB only); [m]scaled with marine repair; [n]scaled with automotive reuse as considered less labour intensive than repair; [o]ONS class 33.17/0 (GB only) this is likely an overestimate as this category includes a broader range of transport applications than rail; [p]scaled from rail repair*

The breakdown of employment by VRP and sector is presented in the following charts. The analysis shows a similar profile to revenue, with the largest employment occurring in the automotive sector (58%) followed by aerospace (21%). For some sectors the employment allocation is less certain; for example, data for reuse employment in the domestic appliance, furniture and ICT sectors is aggregated, so for this chart an equal split has been assumed between the three sectors. Similarly for repair of domestic appliances and ICT an equal split has been assumed. Based on the data available, repair activities support the greatest employment. As with data on revenue, this may be in part due to the lack of employment data for remanufacturing and reuse activities.

*Figure 17: Share of all UK VRP employment by sector (2020)*

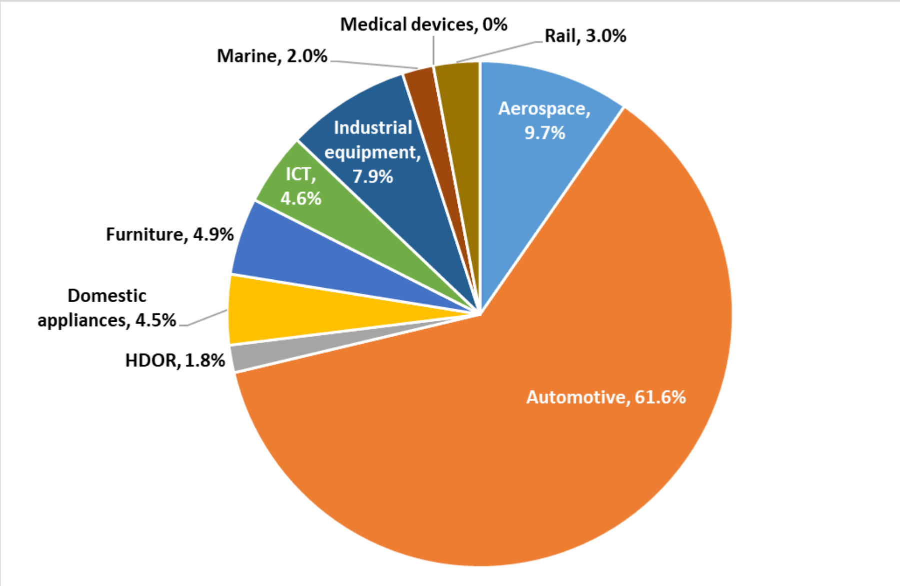
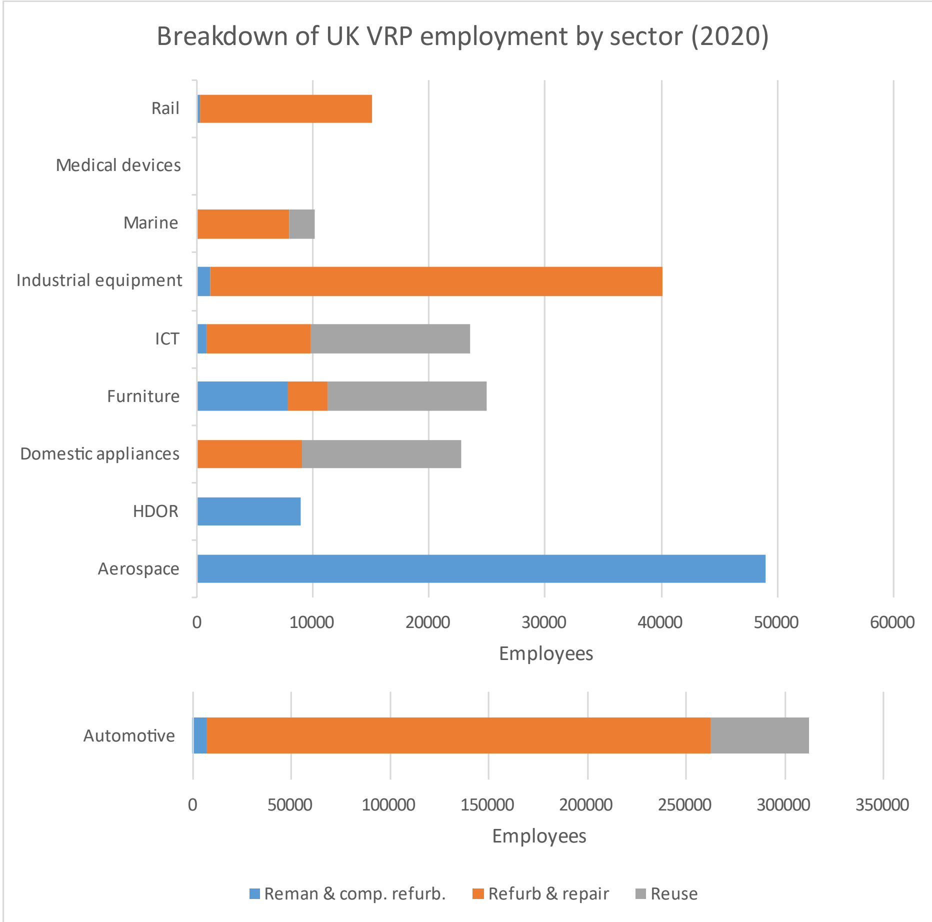



*Figure 18: Breakdown of UK VRP employment by sector (2020)*



## 5.2 Environmental analysis

Our analysis of the environmental impacts of VRP activities focuses on two main metrics: waste prevented and $CO_2$ avoided. The results of this analysis is presented in the following section. Detailed descriptions of the sources of these data by sector can also be found in Section 8. For three sectors (industrial equipment, marine and rail) we consider the analysis of environmental impacts to be less robust than for the other sectors (and indicated in *italics*).

*Table 8: Estimated waste prevented by VRP activity and sector (2020)*

<table>
<tr><th>WASTE PREVENTED</th><th>Remanufacturing</th><th>Comprehensive refurbishment</th><th>Refurbishment</th><th>Repair</th><th>Reuse</th></tr>
<tr><td>Aerospace</td><td colspan="4">122 kt</td><td>N/A</td></tr>
<tr><td>Automotive</td><td colspan="2">14 kt (parts)<br>0.2 kt (tyres)</td><td colspan="2" rowspan="2">36.3 kt<br>(+ 1.3 kt HDOR)</td><td>0 kt</td></tr>
<tr><td>HDOR</td><td colspan="2">10.3 kt (parts)<br>35 kt (tyres)</td><td>No data available</td></tr>
<tr><td>Domestic appliances</td><td>N/A</td><td colspan="2">No data available</td><td>100 kt</td><td rowspan="3">112 kt</td></tr>
<tr><td>Furniture</td><td colspan="4">13 kt</td></tr>
<tr><td>ICT</td><td colspan="2">7 kt</td><td>No data available</td><td>156 kt</td></tr>
<tr><td>Industrial equipment</td><td colspan="2">1.5 kt</td><td>No data available</td><td>8.6 kt</td><td>No data available</td></tr>
<tr><td>Marine</td><td>0.1 kt</td><td colspan="2">No data available</td><td>2.9 kt</td><td>No data available</td></tr>
<tr><td>Medical devices</td><td>N/A</td><td colspan="2">No data available</td><td>No data available</td><td>N/A</td></tr>
<tr><td>Rail</td><td colspan="2">0.2 kt</td><td>N/A</td><td>0.8 kt</td><td>N/A</td></tr>
</table>

*Source: Oakdene Hollins analysis*

The breakdown of waste prevention by VRP and sector is presented in the following charts. The analysis shows significant waste prevention in the ICT and domestic appliance sectors; however, data was not available for several sectors (e.g. industrial equipment and marine) and so a true comparison between the different sectors and different VRP activities is not possible. This analysis estimates that at least 620 kt of waste is prevented through VRP activities.

*Figure 19: Share of waste prevented by all UK VRPs by sector (2020)*

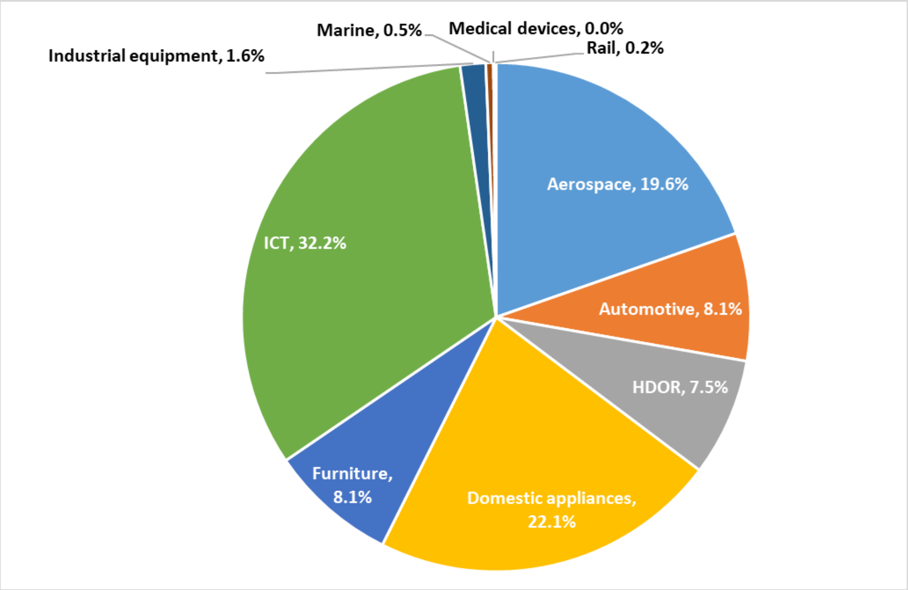



*Figure 20: Breakdown of waste prevention by UK VRP by sector (2020)*

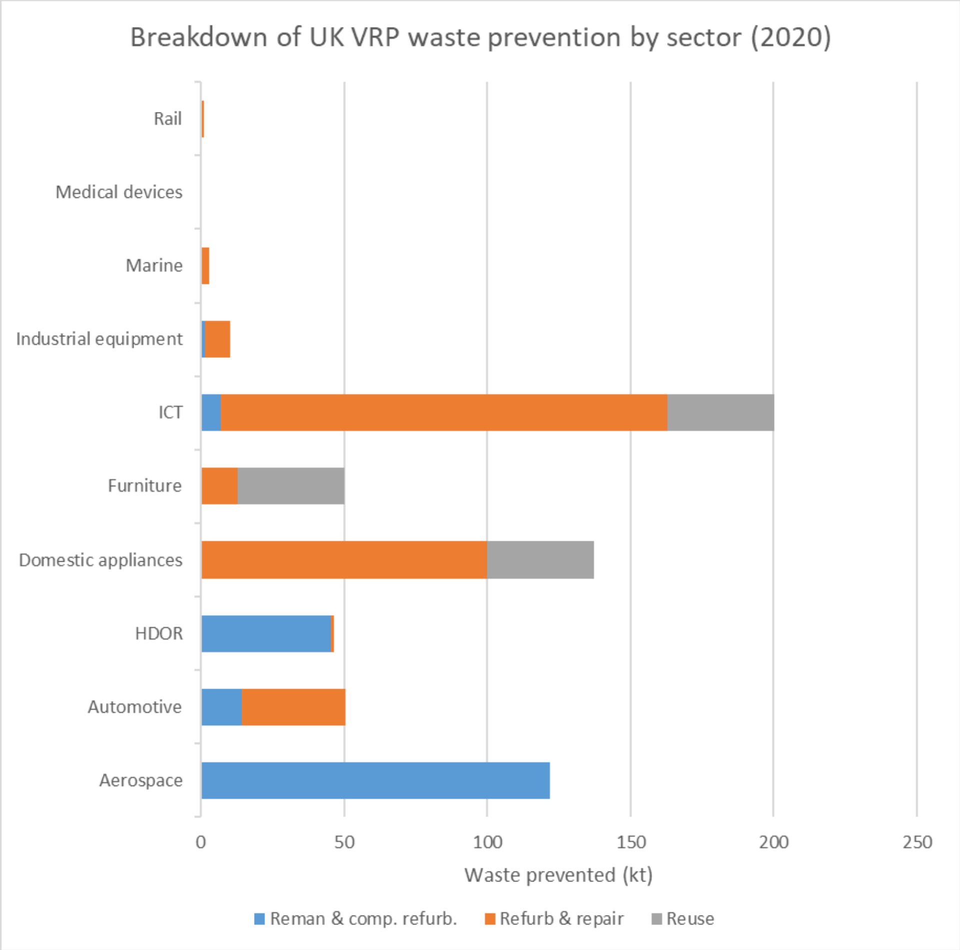


*Table 9: Estimated $CO_2e$ avoided by VRP activity and sector (2020)*

<table>
<tr><th>$CO_2e$ AVOIDED</th><th>Remanufacturing</th><th>Comprehensive refurbishment</th><th>Refurbishment</th><th>Repair</th><th>Reuse</th></tr>
<tr><td>Aerospace</td><td colspan="4">681 kt $CO_{2e}$</td><td>N/A</td></tr>
<tr><td>Automotive</td><td colspan="2">49 kt $CO_2e$ (parts)<br>0.26 kt $CO_2e$ (tyres)</td><td colspan="2" rowspan="2">328 kt $CO_2e$<br>(+ 10 kt $CO_2e$ HDOR)</td><td>1,560 kt $CO_2e$</td></tr>
<tr><td>HDOR</td><td colspan="2">36 kt $CO_2e$ (parts)<br>42 kt $CO_2e$ (tyres)</td><td>No data available</td></tr>
<tr><td>Domestic appliances</td><td>N/A</td><td colspan="2">No data available</td><td>251 kt $CO_2e$</td><td rowspan="3">123 kt $CO_2e$</td></tr>
<tr><td>Furniture</td><td colspan="4">26 kt $CO_2e$</td></tr>
<tr><td>ICT</td><td colspan="2">39 kt $CO_2e$</td><td>No data available</td><td>1,400 kt $CO_2e$</td></tr>
<tr><td>Industrial equipment</td><td colspan="2">5.4 kt $CO_2e$</td><td>No data available</td><td>69 kt $CO_2e$</td><td>No data available</td></tr>
<tr><td>Marine</td><td>0.4 kt $CO_2e$</td><td colspan="2">No data available</td><td>23 kt $CO_2e$</td><td>No data available</td></tr>
<tr><td>Medical devices</td><td>N/A</td><td colspan="2">No data available</td><td>No data available</td><td>N/A</td></tr>
<tr><td>Rail</td><td colspan="2">2.4 kt $CO_2e$</td><td>N/A</td><td>19 kt $CO_2e$</td><td>N/A</td></tr>
</table>

*Source: Oakdene Hollins analysis*

The breakdown of $CO_2e$ emissions avoided by VRP and sector is presented in the following charts. The analysis shows significant emissions avoided in the aerospace, automotive and ICT sectors; however, as for waste prevention, data were not available for several sectors and so a true comparison between different sectors and different VRP activities is not possible. This analysis estimates that at least 4.7 Mt $CO_2e$ was avoided through VRP activities in 2020.

*Figure 21: Sector share of $CO_2e$ avoided per VRP activity (2020)*

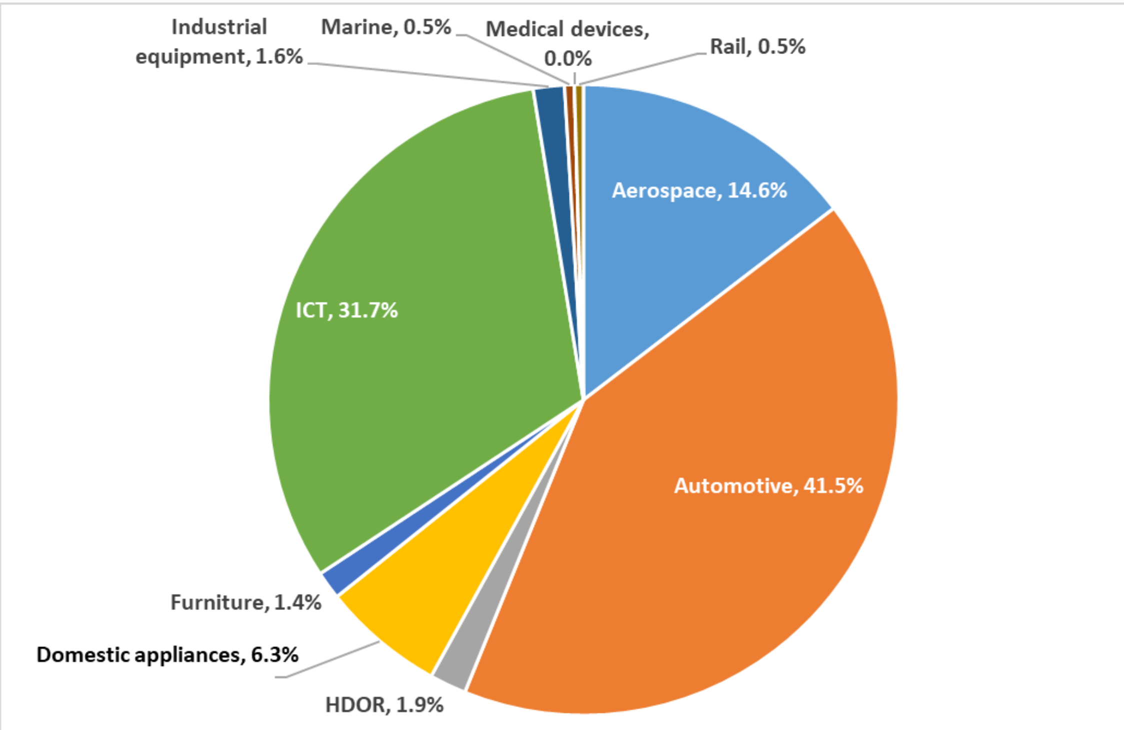
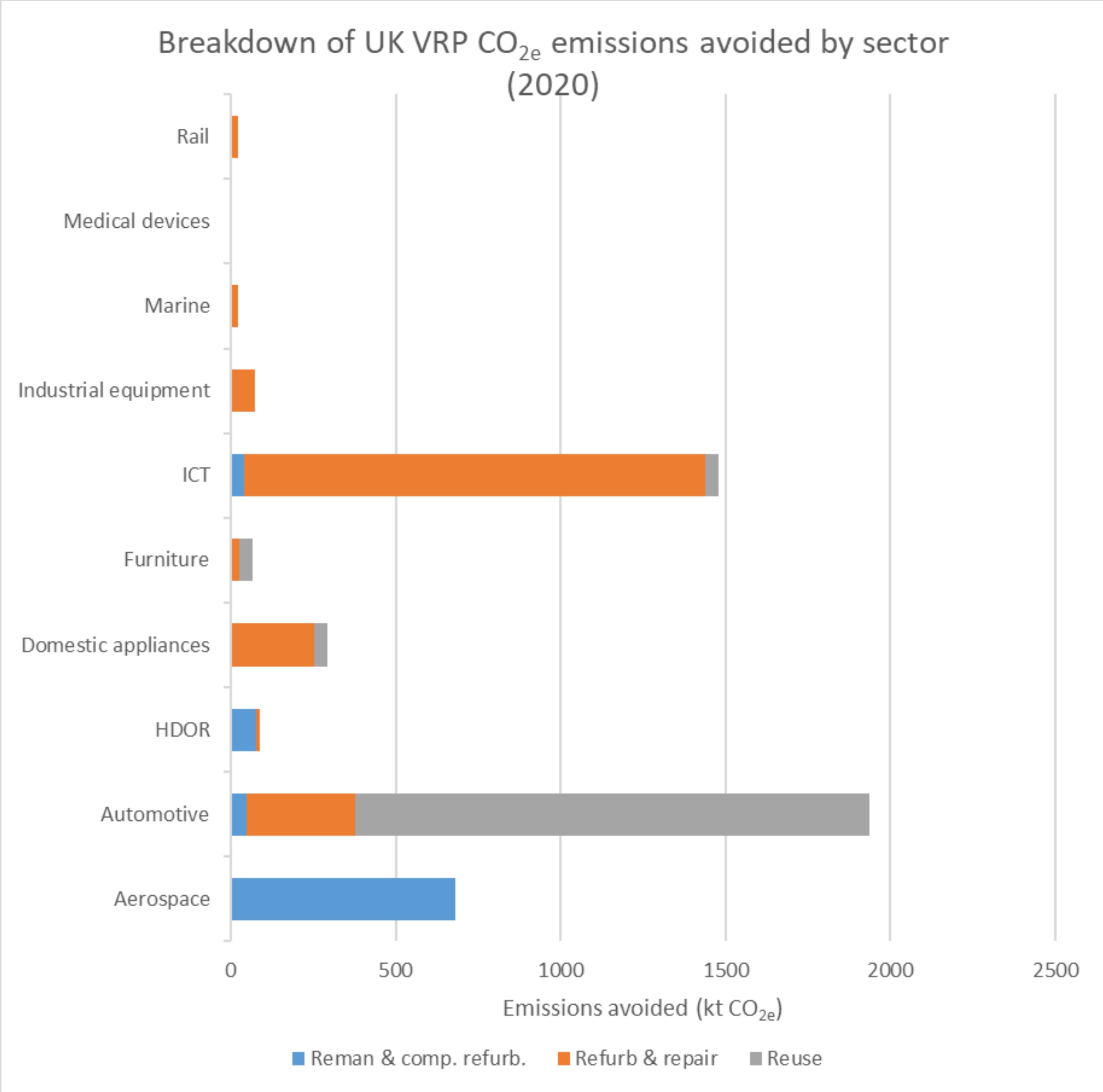


*Figure 22: Breakdown of UK VRP $CO_2e$ emissions avoided by sector (2020)*




## 5.3 Forecasts for future activity

Stakeholders provided little quantitative insight as to their ambitions for VRP activities in the different sectors, and insights from the workshops were also predominantly qualitative in nature. The following 'heat map' gives an indication of the potential for growth in each sector and the subsequent table provides a rationale for the outlook. In practice, in a business-as-usual scenario, VRP activity would likely experience a natural growth associated with the increasing focus of consumers and business on sustainability and GHG emissions. However, for step-changes in activity, a more systemic change - encompassing technological research and innovation, policy support, and behaviour change - would be needed (see Section 12 for recommendations).

*Table 10: Estimated potential for growth for VRP product markets over the next ten years*

| Sector | VRP activity | Growth profile rationale | Supported/driven by |
|---|---|---|---|
| **Aerospace** | Remanufacturing, comprehensive refurbishment, refurbishment, repair | Natural | post-Covid recovery |
| **Automotive** | Remanufacturing, comprehensive refurbishment | Strong | public procurement practices, greater consumer awareness, and fiscal measures that reduce the competitiveness of low-cost new imported parts |
| | Refurbishment, repair | Moderate | greater consumer awareness and marketing of ‘green parts’, and fiscal measures that reduce the competitiveness of low-cost new imported parts |
| | Reuse | Natural | normal market dynamics |
| **HDOR** | Remanufacturing, comprehensive refurbishment | Moderate | technological innovation for remediation of parts and fiscal measures that reduce the competitiveness of low-cost new imported parts |
| | Refurbishment, repair | Moderate | Scope 3 carbon reporting requirement, marketing of ‘green parts’, and fiscal measures that reduce the competitiveness of low-cost new imported parts |
| | Reuse | Natural | normal market dynamics |
| **Domestic appliances** | Remanufacturing | Strong | a move to service-based business models whereby the incentive to remanufacture would greatly increase. |
| | Comprehensive refurbishment, refurbishment | Moderate | greater consumer awareness, marketing of ‘green products’, and EPR |
| | Repair | Strong | right-to-repair |
| | Reuse | Moderate | improved consumer platforms for reused products |
| **Furniture** | Remanufacturing, comprehensive refurbishment, refurbishment | Moderate | public procurement (particularly in the office furniture sector) |
| | Repair | Strong | community-led initiatives |
| | Reuse | Moderate | improved consumer platforms for reused products and diversion of waste from household waste recycling centres |
| **ICT** | Remanufacturing, comprehensive refurbishment | Strong | design for disassembly and the development of automation technologies to negate higher UK labour costs |
| | Refurbishment | Strong | design for disassembly and community-led initiatives |
| | Repair | Strong | right-to-repair |
| | Reuse | Moderate | improved consumer platforms for reused products |
| **Industrial equipment** | Remanufacturing, comprehensive refurbishment | Moderate | technological developments in digital technologies (digital twins, Industry 4.0) and remediation technologies |
| | Refurbishment | Moderate | technological developments in digital technologies (digital twins, Industry 4.0) and remediation technologies |

| | | | |
|---|---|---|---|
| | Repair | Moderate | technological developments in digital technologies (digital twins, Industry 4.0) and remediation technologies |
| | Reuse | Natural | market dynamics |
| **Marine** | Remanufacturing | Moderate | technological developments in digital technologies (digital twins, Industry 4.0) and remediation technologies |
| | Comprehensive refurbishment, refurbishment | Moderate | technological developments in digital technologies (digital twins, Industry 4.0) and remediation technologies |
| | Repair | Natural | market dynamics |
| | Reuse | Moderate | market dynamics (increased recreational boat market) |
| **Medical devices** | Remanufacturing | Strong | market demand – OEMs are looking to move into the remanufacturing space |
| | Comprehensive refurbishment, refurbishment | Natural | market dynamics |
| | Repair | Natural | market dynamics |
| **Rail** | Remanufacturing, comprehensive refurbishment | Moderate | technological developments in digital technologies (digital twins, Industry 4.0) and remediation technologies |
| | Repair | Natural | market dynamics |

*Source: Oakdene Hollins analysis*

## 5.4 Comparison to previous analyses

Previous analyses of the size of UK VRP activities have been undertaken in 2015, as part of the European Remanufacturing Network market study (9), and in 2009 (10) and 2004 (11). All these studies were conducted by Oakdene Hollins, using market surveys and stakeholder engagement to estimate the scale of VRP activity across various industries. *Table 11* below summarises how these previous analyses compare to the values from this study.

*Table 11: Comparison of market estimates with previous research (figures adjusted to 2020 values)*

| Study | Year published | Remanufacturing | Reuse | Repair |
|---|---|---|---|---|
| **Current study** | 2021 | £17 billion | £22 billion | £35 billion |
| **European Remanufacturing Network market study (9)** | 2015 | £7.0 billion | Not assessed | £26 billion |
| **Remanufacturing in the UK: a snapshot of the UK remanufacturing industry (10)** | 2009 | £2.1 billion | £1.1 billion | £1.3 billion |
| **Remanufacturing in the UK: a significant contributor to sustainable development? (11)** | 2004 | £7.9 billion | | Not assessed |

We see there is a significant discrepancy between market values for the different studies. This is driven by the evolving methodologies used to quantify the markets, by changes in data availability, and by changes in market dynamics. For example, about half of the difference in market size between this study and the 2015 study can be explained by the difference in aerospace activity. The ERN study estimated aerospace remanufacturing and repair to be £8.8 billion, while the publication of the UK Government study on UK maintenance, repair and overhaul (MRO) activity (used as the basis for this study) indicates that the activity back in 2015 was closer to £17.8 billion (8). Previous studies did not consider the reuse of second-hand vehicles (which makes up nearly all of the £22 billion reuse market in this study) and for some sectors, such as ICT, domestic appliances and automotive, there has been a 40-100% growth in repair activity from 2004 to 2020.

# 6 Review of international VRP activities[10]

- **Canada** was the first nation to evaluate the size of **all VRP activities**, with an estimated market of **£34 billion** in 2019.
- Leading nations for **remanufacturing** activities include the **USA (£34 billion** in remanufacturing sales in 2011), **China** (targeting a **£23 billion** remanufacturing market by 2025) and the **EU (£24 billion** remanufacturing market in 2015 (included UK)).
- Best practice examples include: China's **comprehensive policy framework**; the USA's use of **public procurement** to drive VRPs and the establishment of the REMADE Institute to focus on **technological innovation** for VRPs; Canada's ambition for a **national value retention strategy**; and the EU's **circular economy policy framework**.
- The most common **barriers** faced in growing VRP activities include **regulatory and trade** barriers, particularly related to **definitions of waste**; **cost pressures** relating to **reverse logistics** and **competition**; and **technological barriers** relating to the **value retention processes** themselves.

In this section we describe the current state of national VRP sectors in several other countries, with an emphasis on the industry sector(s) where they are the most prevalent, their current value and projected growth. An evaluation of the UK's strategic position is presented in Section 9.

## 6.1 The national state of VRP across the globe

### *6.1.1 USA*

The United States is a global leader in remanufacturing and had an estimated production value of USD43 billion (£33.5 billion) in 2011 (12). VRP activity spans many sectors including consumer products, locomotives, IT products, electrical apparatus, machinery, medical devices, office furniture, restaurant equipment, retreaded tyres, HDOR equipment, aerospace and automotive. Table 12 shows that the aerospace, HDOR equipment, automotive parts and machinery sectors have the largest production values, with an estimated cumulative value of USD32.8 billion (£25.6 billion) in 2011 (see Table 12).

*Table 12: US remanufacturing statistics, 2011 adjusted to Sterling (2020)*

| Sector [a] | Production £ thousands | Investment £ thousands | Employed (thousands FTE) | Exports £ thousands | Imports £ thousands | Intensity (%)[b] |
|---|---|---|---|---|---|---|
| **Aerospace** | 10,171,464 | 70,539 | 35,201 | 2,019,042 | 1,457,944 | 2.6 |
| **HDOR equipment** | 6,058,653 | 126,892 | 20,870 | 1,911,776 | 1,161,161 | 3.8 |
| **Motor vehicle parts** | 4,843,312 | 82,401 | 30,653 | 453,406 | 1,155,454 | 1.1 |
| **Machinery** | 4,518,389 | 554,366 | 26,843 | 1,051,595 | 209,157 | 1.0 |
| **IT products** | 2,090,821 | 13,647 | 15,442 | 202,745 | 2,149,198 | 0.4 |
| **Medical devices** | 1,140,931 | 24,373 | 4,117 | 380,495 | 86,316 | 0.5 |
| **Retreaded tyres** | 1,090,856 | 18,614 | 4,880 | 14,459 | 8,924 | 2.9 |
| **Consumer products** | 513,953 | 3,858 | 7,613 | 16,491 | 280,894 | 0.1 |
| **All other** [c] | 3,098,430 | 52,658 | 22,999 | 175,140 | 31,720 | 1.3 |
| **Wholesalers** [d] | See Note | 6,467 | 10,891 | 2,925,039 | 1,461,240 | See Note |
| **Total** | **33,526,809** | **1,223,326** | **179,509** | **9,150,188** | **8,002,008** | **2.0** |

[10] This section borrows from a report written by Oakdene Hollins and Dillon Consulting on the behalf of the Canadian Government. The original work is; Socio-economic and environmental study of the Canadian remanufacturing sector and other value-retention processes in the context of a circular economy (15)

*Source:* (12) (12)*; exchange rate & inflation adjusted*[11,12]
*Notes:* *a. Sector ranked by production value*
*b. Total value of shipments of remanufactured goods as a % of total sector sales*
*c. Includes remanufactured electrical apparatus, locomotives, office furniture, restaurant equipment*
*d. Wholesalers do not produce remanufactured goods, but sell or export/import them*

Remanufacturing has grown organically in the USA, largely driven by market demand, which in part has been aided by measures taken by the US Government to stimulate the consumption of remanufactured products. Key examples of these include programmes such as 'Safer Choice' run by the Environmental Protection Agency (EPA) and the 'remanufactured in the USA' label created by the Federal Trade Commission (FTC) in 1998 (13). Further to this, roughly 20 States have instituted tax credits and embedded the public procurement of remanufactured products (14).

In a 2011 report on US remanufacturing activity by the International Trade Commission, it was estimated that the industry supported 180,000 full-time jobs, of which the three largest industries (HDOR equipment, aerospace and automotive) accounted for 87,000 jobs. Small to medium-sized enterprises (SMEs) play a relatively large role in the US remanufacturing industry, being responsible for 25% of the total value of remanufactured goods, 17% of export value and 36% of employment (12).

Overall, the remanufacturing industry is a net exporter of remanufactured goods, trading USD11.7 billion (£9.15 billion) of remanufactured goods in 2011. The key destinations for these products were the EU, Canada and Mexico, although this varies somewhat by sector (see Table 13). (NB data for the UK component of EU is not available.)

An overview of the barriers to remanufacturing cited by firms operating within each sector can be seen in Table 14.

*Table 13: Leading export destinations and import sources for US remanufactured goods and cores, 2011*

| Sector (ranked by production value) | Leading destinations for US exports of remanufactured goods | Leading FTA markets for US exports of remanufactured good | Leading suppliers of remanufactured goods to the USA |
|---|---|---|---|
| **Aerospace** | EU, Canada, Japan | Canada, Singapore, Mexico | EU, Canada, Japan |
| **HDOR equipment** | Canada, Australia, Mexico | Canada, Australia, Mexico | Mexico, Canada, EU |
| **Motor vehicle parts** | Canada, Saudi Arabia, Mexico | Canada, Mexico, Australia | Mexico, EU, Canada |
| **IT products** | EU, Canada, Hong Kong | Canada, Mexico, Singapore | Mexico, China, Canada |
| **Medical devices** | EU, Canada, Brazil | Canada, Singapore, Mexico | EU, Mexico, Canada |
| **Retreaded tires** | Mexico, Canada, Vietnam | Mexico, CAFTA-DR[a], Canada | Canada, EU, Korea |
| **Other remanufacturing sectors**[b] | Mexico, EU, Canada | Mexico, Canada, CAFTA-DR | Switzerland, China, Mexico |

*Source:* (12)
*Notes:* *a. Dominican Republic-Central America-United States Free Trade Agreement partners.*
*b. Includes (in alphabetical order) the consumer products, electrical apparatus, locomotive, machinery, office furniture and restaurant equipment remanufacturing sectors.*

[11] Figure has been converted from U.S. Dollars to Sterling using an average exchange rate in 2011 of £1-$1.6032, sourced from Average Sterling exchange rate: U.S. Dollar. 2020. Office for National Statistics. Available from: https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/auss/diop
[12] Figure has been inflation adjusted from 2011-2020 using an average annual inflation rate of 2.5%, sourced from Inflation calculator. 2021. Bank of England. Available from:https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

*Table 14: Factors cited by US remanufacturers as important in determining their ability to compete domestically and globally*

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

*Source:* (15) *derived from* (12)
*Notes:* *a. Neither foreign markets nor factors reported by respondents*
*b. Includes electric apparatus, locomotives, office furniture, restaurant equipment*

The USA is also home to the Reducing Embodied Energy and Decreasing Emissions (REMADE) Institute, which also identifies as 'The Circular Economy Institute'.

> *"Founded in 2017, the REMADE Institute is a 130-member public-private partnership established by the U.S. Department of Energy with an initial investment of $140 million.*
> *Part of the Manufacturing USA network of 16 advanced manufacturing institutes, REMADE is dedicated to accelerating the U.S.'s transition to a circular economy."* (16)

The REMADE Institute is led by remanufacturing pioneer, Dr Nabil Nasr, who was also lead author on the International Resources Panel report (see the definitions in Section 4) from which the VRP framework used in this study was taken. The Institute invests in early-stage R&D projects, and the technologies that are subsequently developed aim to increase the reuse, remanufacturing, recovery and recycling of four "hard-to-abate" materials: metals, plastics/polymers, fibres/paper and e-waste. It also hosts training which includes:

- Outreach training providing high-level overviews of REMADE technologies, industries and best practices.
- Tiered certificate pathways for three competency levels: Awareness, Practitioner and Expert.
- 3-day virtual remanufacturing bootcamp.

The Institute has recently announced its latest funding round[13] and has now launched 84 projects with a total combined value of USD85.6 million of investment. The Institute's 2021 impact report reported that the technologies developed in the first 39 funded projects (at an investment of around USD20 million) were expected to generate up to USD50 billion in new opportunities within a five-year period, once implemented, creating 700,00 new direct and indirect jobs in the USA (16).

### 6.1.2 Canada

The Canadian Government, in partnership with Dillon Consulting and Oakdene Hollins, has recently completed a survey of all VRP activity across several sectors in Canada. This work estimated that in 2019 the VRP activity in Canada was worth CAD56 billion (£33.6 billion).[14,15] Of this, the study estimated 10% was attributable to remanufacturing and comprehensive refurbishment activity, 25% was attributable to reuse and 65% was from refurbishment or reuse activity (15).

The full results of this investigation can be viewed in *Table 15*, which displays the estimated sales income from each VRP sector studied. It must be noted that this study estimated that the ten sectors accounted for 70% of the potential revenue available from 'feasible VRP services'.

As is evident from *Table 15*, the VRP sector in Canada is dominated by the automotive refurbishment and repair industry, which makes up 30% of the total VRP sales revenue. This activity is dispersed across the whole country and is undertaken mainly by small and micro businesses. Similarly, the automotive remanufacturing industry is thought to consist primarily of SMEs; however, nearly half of these are concentrated in Ontario, with the rest being in Alberta, British Columbia, Manitoba, Newfoundland and Labrador, Nova Scotia, Quebec and Saskatchewan (15).

*Table 15: Summary of Canadian VRP sales incomes by sector in 2019 (£ billions per year)[15,14]*

| | Remanufacturing | Comprehensive Refurbishment | Refurbishment | Repair | Direct Reuse | TOTAL |
|---|---|---|---|---|---|---|
| ***Refined sector analysis*** | | | | | | |
| **Aerospace[a]** | 0.30 | 2.10 | -/- | 2.40 | Unknown | 4.79 |
| **Automotive** | ~1.08 (includes tires) | | 10.37 | | 8.21 | 19.66 |
| **HDOR** | 0.38 | | 0.07 | 0.07 | Unknown | 0.51 |
| **Electronics** | 0.08 (including toner/print cartridges) | | 0.37 | | 0.37 | 0.84 |
| **Home Appliances** | Not Applicable | | 0.07 | 0.48 | Unknown | 0.55 |
| **Furniture** | Limited | | 0.23 | | Unknown | 0.23 |
| ***Initial sector analysis*** | | | | | | |
| **Marine** | (0.04, included in repair) | | 2.70 | | Unknown | 2.76 |
| **Medical devices** | Unknown in detail; around 0.02 remanufacturing | | | | | 0.02 |
| **Industrial equip't** | 4.43 (min) | | | | Unknown | 4.43 |
| **Rail** | (~0.04, included in refurbishment) | | 0.60 | | Unknown | 0.66 |
| **TOTAL** | **~£33.6 billion** | | | | | |

*Source:* (15)

[13] Press release, 1 Dec 2021 Link

[14] Figure has been converted from Canadian Dollars to Sterling using an average exchange rate in 2011 of £1-$CAD1.6938, sourced from: Average Sterling exchange rate: Canadian Dollar. 2020. Office for National Statistics. Available from: https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/ajfb/mret

[15] Figure has been inflation adjusted from 2019-2020 using an average annual inflation rate of 1.5%, sourced from: Inflation calculator. 2021. Bank of England. Available from:https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

Notable also from *Table 15* is the relatively high level of remanufacturing and comprehensive refurbishment taking place within the Canadian aerospace sector. This activity accounts for around 7% of the total sales revenue and is conducted primarily by OEM, OEM-contracted and independent VRP operators. The aerospace VRP activity in the country is comparable to that in other developed nations in that it has developed to support substantial domestic and international airline travel. The skew towards higher quality VRP activity such as remanufacturing and comprehensive refurbishment is due to the high safety standards of these operations. A summary of VRP drivers in the Canadian aerospace sector can be seen in *Table 16*.

*Table 16: Map of VRP practice and drivers in the aerospace sector*

| Remanufacturing | Comprehensive Refurbishment | Refurbishment | Direct Reuse | Repair | Cascading Consumer to Consumer |
|---|---|---|---|---|---|
| Safety driven | | Does not meet quality needs | Does not meet quality needs | For non-qualified parts | Not applicable |

*Source:* (15)

*Note:* *a. Boxes with no comment indicate activity is generally applicable across all markets or requires no caveat,*
*b. Cascading between consumers – the handing on of goods to users with similar or lower expectations of performance.*
*c. 'Non-qualified' means 'not requiring aviation authorisations or certifications on processes employed'*
*d. Pink = VRP activity not applicable or insignificant.*

The same study by Dillon Consulting and Oakdene Hollins identified the barriers to VRPs listed in Table 17, noting the similarity to the barriers present across many economies. In addition to these more generic barriers, Canada also has a sparser population of remote and rural economies which present a more novel barrier to VRPs, as these populations have greater logistical challenges and may require bespoke solutions that match the local context. Similarly, Canada's system of federal government was identified as a unique contextual barrier, with the implementation of policy strategies and tactics devolved down to individual provincial and territorial administrations who can develop their own VRP initiatives (some of which can be observed in Table 18). The report identified this status quo as a potential barrier and recommended that the central government gives a stronger 'steer' by harmonizing VRP policy across provincial governments, setting priorities and targets, as well as coordinating education and messaging.

To this end, the recent work of the Waste Management Task Group of the Canadian Council of Ministers of the Environment (CCME) in the promotion of VRPs in Canada must be noted. As a forum for federal, provincial and territorial environmental departments this body has created a number of country-wide initiatives to promote VRPs and the circular economy, examples of which include a Canada-wide strategy for EPR (17) and the Canada-Wide Strategy on Zero Plastic Waste (18) (19). Going forward, the Canadian Government has committed to developing a national extended producer responsibility strategy to "encourage remanufacturing and other VRPs in Canada" as part of the country's efforts to move towards a circular economy. The study by Dillon Consulting and Oakdene Hollins formed the first step in the development of this strategy and was open to comment and consultation until 31 August 2021, after which the process continued to a discussion paper containing a proposed approach to the national strategy, a draft and then a final strategy (20).

*Table 17: Barriers to VRP activity in Canada* (15)

| Types of barriers | Examples | Description of barrier impact |
|---|---|---|
| **Regulatory and access barriers** | Complicated regulatory definitions for remanufacturing that affect import, export and domestic production-consumption activities.<br>Lack of clear understanding and differentiation between remanufacturing and other value retention processes.<br>Inputs to remanufacturing (product cores) often reflected as 'waste' under regulatory definitions. | Affects flows of finished remanufactured products from producers to customers in domestic and/or international markets (forward-logistics). |
| **Market structure barriers** | Intermediaries between (re)manufacturers and end-users frustrate ability to implement VRPs. | Particularly with consumer goods, retailers have no interest in boosting the remanufacturing market as this negates new sales, despite willingness of some manufacturers to explore VRPs. |
| **Collection infrastructure barriers** | Lack of policy requiring diversion of EoU products from entering the waste stream.<br>Lack of efficient and/or effective diversion and collection infrastructure.<br>Cost-burden of reverse-logistics if left to individual organizations. | Affects flows of EoU products and components from the customer/user back into the secondary markets and/or to the OEM to be used as inputs to remanufacturing (reverse-logistics) |
| **Customer market barriers** | Lack of awareness of VRP offerings and benefits.<br>Lack of standards/certifications for remanufacturing and remanufactured products.<br>Perceived lower-price = lower-quality of remanufactured products.<br>High customer risk-aversion.<br>High perceived cost of repair.<br>Lack of support in self-repair.<br>Consumer distaste of 'used' consumer goods. | Creates capacity constraints for the domestic remanufacturing/repair customer market. |
| **Technological barriers** | Increased production complexity with reverse-logistics and supply-chain considerations.<br>Specialised labour and equipment requirements.<br>Cost-burden of investment and R&D on individual organizations. | Creates adoption and capacity constraints for domestic remanufacturers. |

*Source:* (15)

*Table 18: Examples of policies intended to support VRPs in Canadian Provinces and Territories* (15)

| Location | Policy or Activity |
|---|---|
| **Nova Scotia** | Has in place **trade agreements that incorporate environmental footprints**. This is a good measure for rational comparison of service impacts, and is a strong signal to suppliers. |
| **New Brunswick** | **Government website** has suggestions for citizens on reuse and reduction. This could be extended to a host of VRP-related support services. |
| **Quebec** | **Repair cafés** and **online sharing platforms** are in operation. This is a useful model for home- and community-based VRP operations such as repair and reuse.<br><br>A **Residual Materials Management Policy** gives priority to reduction and reuse.<br><br>The **Regulation Respecting the Recovery and Reclamation of Products by Enterprises** requires EPR programs to consider reuse before recycling for electronics, batteries, household appliances.<br><br>The academic base, through organizations such as Institute EDDEC (IEDDEC) and the Centre d'études et de recherches intersectorielles en économie circulaire (CERIEC), is also active in circular economy research. |
| **Ontario** | The **EPR and Resource Recovery and Circular Economy Act, 2016** (RRCEA) sets targets for re-treading of tyres and incentives for refurbishment/reuse of EEE. |
| **British Columbia** | **Repair Cafés**, **Turo C2C car sharing**, **Tool Library online** sharing platforms all feed into extended or more intensive use of products.<br><br>The **Building Deconstruction and Reuse initiatives** (Vancouver Economic Commission Upcycle Design Project) mandate extraction of valuable sub-systems before demolition. |
| **Yukon** | Engaging the public on CE with **communications campaign** 'Do the Heavy Lifting' to raise awareness on reduction/reuse. This shows openness to changing public perceptions and behaviours.<br><br>**Using LCA** to determine best practice for dealing with wastes. This could be extended to products to inform policy. |
| **Various** | **EPR and product stewardship programs** (tyres, WEEE…). Particularly those with a product focus should be examined for their impacts, strengths and transposability. |

*Source:* (15)

### 6.1.3 *Mexico*

In 2015, Mexico had 60 known remanufacturing firms which were active chiefly in the electronics, IT and automotive sectors (9). Mexico hosts many US firms that centre their operations in the country to take advantage of lower labour and transportation costs. In2011, Mexico was the largest market for exports of core from the US, accounting for 43% of the total value for exports in that year; and in the same period Mexico was the source of 30% of US imports of remanufactured goods (12). Notable examples of remanufacturers in the country include Caterpillar (HDOR), Daimler (HDOR), Cummins (HDOR) and (Automotive) (21).

Aside from the 2008 'Three Rs' initiative to promote sustainability and industrial waste reduction, there are no laws that specifically regulate remanufacturing activity and there is little data on the status of VRPs within the country (9).

### 6.1.4 EU

#### 6.1.4.1 Overview

Germany, the United Kingdom,Ireland, France and Italy account for around 70% of the value of remanufacturing within the EU in 2015. Of these, Germany undertakes the largest proportion of European remanufacturing (30%) with a particularly prominent presence in the aerospace, automotive and HDOR sectors (9). The remanufacturing industries of France, the UK and Ireland are similarly composed to that of Germany, although each is roughly half the size. Notably, the remanufacturing industry in Italy is smaller than would be expected when considering the size of its manufacturing industry: cultural preferences regarding remanufactured automotive components and the fact that Germany, France and the UK are major global hubs for aerospace maintenance, repair and overhaul activities could account for this (9).

Within the remanufacturing-intensive sectors identified in Table 19, remanufacturing accounts for around 1.9% of the €1.57 trillion total sector value (£1.28 trillion (2020)) (9). The aerospace, automotive and HDOR sectors are the largest in Europe, together accounting for roughly 80% of total market value (42%, 25% and 14% respectively) (9; 22). These sectors are the more established remanufacturing operations within Europe, and are focussed primarily on substantive high-value metal fabrications.

The size of these sectors has been growing in recent years, with growth in the aerospace remanufacturing sector in particular being propelled by increasing air travel in combination with higher demand for overhaul and maintenance from aging aircraft fleets. All three sectors are expected to continue to grow in the near future (9).

Further to this, the increasing integration of electronics into product systems is also driving growth within manufacturing sectors such as EEE and medical equipment. However, there is a skills shortage of employees capable of servicing integrated electronic systems and this has constrained the ability of remanufacturers to meet the growing demand. The European Remanufacturing Network's (ERN) 2015 market study provides one example of this, citing a discussion with an automotive remanufacturer that was turning away business due to a lack of staff capable of servicing electronic interfaces (9).

*Table 19: Market size for European remanufacturing by sector, 2015 adjusted to Sterling (2020)*

| Sectors | Income (€bn 2020) | Firms | Employment ('000) | Core [a] ('000) | Intensity [b] |
|---|---|---|---|---|---|
| **Aerospace** | 10.2 | 1,000 | 71 | 5,160 | 11.5% |
| **Automotive** | 6.1 | 2,363 | 43 | 27,286 | 1.1% |
| **EEE** | 2.5 | 2,502 | 28 | 87,925 | 1.1% |
| **Furniture** | 0.2 | 147 | 4 | 2,173 | 0.4% |
| **HDOR** | 3.4 | 581 | 31 | 7,390 | 2.9% |
| **Machinery** | 0.8 | 513 | 6 | 1,010 | 0.7% |
| **Marine** | 0.1 | 7 | 1 | 83 | 0.3% |
| **Medical equipment** | 0.8 | 60 | 7 | 1,005 | 2.8% |
| **Rail** | 0.2 | 30 | 3 | 374 | 1.1% |
| **Total** | **24.4** | **7,204** | **192** | **132,405** | **1.9%** |

*Source:* (9)
*Note:* *a. Relates to number of unit items collected and processed back onto the market*
*b. Intensity refers to percentage of sector activity attributable to remanufacturing by revenue*

To date, there has been little quantification of the wider VRP sector within Europe, although an indication of the scale of VRP activity may be reached using using production of manufactured goods (PRODCOM) statistics published by the European Union for the total value of repair and maintenance activities. Using this methodology, the total value of repair and maintenance activities within the EU27 in 2019 can be estimated at €111 billion ( £99.4 billion)[16,17,18]. It can be further inferred that the largest sector is for the repair and maintenance of civil aircraft and aircraft engines[19], which had a production value in 2018 of €22.4 billion (£20 billion)16,18 (23).

### 6.1.4.2 Barriers

Skills shortages are just one of the factors that have been identified as barriers to the growth of remanufacturing within Europe. Table 20 depicts all the barriers to remanufacturing identified by the ERN in its 2015 market report.

*Table 20: Barriers to remanufacturing identified by ERN in 2015*

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

*Source:* (9)

[16] Figure has been converted from Euros to Sterling using an average exchange rate in 2019 of £1-€1.1405, sourced from: Average Sterling exchange rate: Euro. 2020. Office for National Statistics. Available from:https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/thap/mret
[17] Calculated using PRODCOM codes 33111200, 33111300, 33111900, 33121100, 33121210, 33121220, 33121400, 33121500, 33121800, 33121990, 33122110, 33122120, 33122200, 33122300, 33122400, 33122500, 33122600, 33122700, 33122800, 33122910, 33122990, 33131110, 33131120, 33131200, 33131300, 33131900, 33141120, 33141150, 33141900, 33151010, 33151030, 33161000, 33171100, 33191020
[18] Figure has been inflation adjusted from 2019-2020 using an average annual inflation rate of 1.5%, sourced from Inflation calculator. 2021. Bank of England. Available from:https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator
[19] PRODCOM code 33161000 'Repair and maintenance of civil aircraft and aircraft engines'

Broadly speaking, many of the barriers identified within Table 20 are not unique to remanufacturing and are indicative of the wider landscape of the VRP sector in Europe. For example, competition from low-cost imports is cited as a reason for purchasers choosing alternatives amongst manufacturers and remanufacturers alike.

In a 2018 workshop conducted by the International Resource Panel and the European Commission on the promotion of Remanufacturing, Refurbishment, Repair and Direct Reuse (RRRDR) (24), it was highlighted that policy makers must reduce the barriers for the sector by creating a 'level playing field', removing legislative barriers and facilitating greater international trade for product cores.

Some specific examples of how this may be achieved included providing clarity on the distinction between products that may undergo product retention processes and those that are 'true waste', mandatory Green Public Procurement schemes (e.g. Article 19 of Italy's 2015 'Collegato Ambientale' law (25)[20]) and national educational plans to raise awareness of the circular economy.

Further to this, the workshop identified the following as areas that should be of high research priority, such as:

- Global market trends in the value of RRRDR.
- The barriers in trade and consumer perception to RRRDR and those of SMEs.
- A stock-take of the current best practices and policies related to RRRDR.
- The effectiveness of support instruments intended to promote RRRDR.
- The economic benefits from large-scale economic change from product-supply to service-provision business models (24).

#### 6.1.4.3 *Policy and action*

Previously the European Commission has notionally supported the growth of VRP activity with policies such as the Waste Framework Directive, the End of Life Vehicle (ELV) Directive and Waste Electrical and Electronic Equipment (WEEE) Directive (9). Each of these has set targets for reuse, recycling and recovery. Recently, various waste directives have also been amended under the new Circular Economy Package to include greater emphasis on product VRPs such as reuse, although the impact of these amendments is yet to be observed. These amendments include the following changes to the Directive on Waste (26):

> *"Member States shall take measures, as appropriate, to promote preparing for reuse activities, notably by encouraging the establishment of and support for reuse and repair networks" – Amendment to Article 11 of Directive 2008/98/EC*
>
> *"Member States should encourage the setting up of systems promoting reuse activities, including in particular for electrical and electronic equipment, textiles and furniture" – Amendment to Article 9 of Directive 2008/98/EC12*

Within the EU, there has also been some support for VRP activity in recent years through the Circular Economy Action Plan (2015-19) (27). Under this plan, Ecodesign standards have been updated to facilitate greater levels of product repair and the European Commission is developing a product repairability scoring system. This Action Plan included measures to promote the development of remanufacturing via research and innovation financing from Horizon 2020 and Cohesion Policy funds. More recently, the EU has adopted the 'new' Circular Economy Action Plan which included proposals for a sustainable product policy legislative initiative to amongst other things, enable greater remanufacturing

[20] A synthesis report as a follow-up activity of the G7 Alliance on Resource Efficiency

and "high quality recycling" through widening the existing Ecodesign Directive (28). At implementation level, France has recently enacted enabling legislation supporting 'right-to-repair' by consumers (29). This mandates publication by manufacturers and retailers of a 'repairability' index for five classes of product: washing machines, smartphones, laptops, televisions and electric lawnmowers.

Future developments in policy are anticipated to include extending the Ecodesign Directive to different product groups, including non-energy consuming goods and the introduction of digital product passports[21].

Due to a lack of data it is difficult to gauge the impact these measures have had on VRP activity though, using the PRODCOM statistics for repair and maintenance activities, we observe that in the period between the implementation of the Circular Economy Action Plan in 2015 and 2018 the total production value grew by 11%, an increase on the 7% growth rate of the three years prior to 2015 (30).

There is no current means to quantify the impact these policies have had on the remanufacturing sector, although we believe that the industry has not changed significantly since the implementation of the Circular Economy Action Plan in 2015.

Despite these recent developments ,we know that several EU policies are also acting to hinder the European remanufacturing sector (9). The Restriction of the Use of Certain Hazardous Substances (RoHS) Directive is an example of one such policy. As the ERN 2015 remanufacturing market study outlines, this policy which regulates the use of certain substances in electrical and electronic equipment may have disproportionatly affected IT remanufacturers, by driving up costs and reducing the circularity of some products by prohibiting the reuse of certain components.

More widely it has been recognised that the European remanufacturing sector suffers from a lack of coherent legislation and offical recognition (9; 24). In its recommendations report, ERN recommended that policymakers consider the following supporting actions:

- Set escalating targets for EU level remanufacturing.
- Collect structured economic data on European remanufacturing.
- Create financial incentives to support remanufacturing.
- Clarify legal definitions of what constitutes waste vs products to be remanufactured.
- Develop extended producer responsibility to strengthen take-back obligations for products.
- Clarify and disseminate international definition on remanufacturing and related standards.
- Identify and remove the regulatory barriers to remanufacturing.
- Promote remanufacturing through public procurement policy.
- Create a certified mark for remanufacturing and clarify liabilities.

Alongside the political activity there has been growing activity amongst academic and advocacy bodies (e.g. the ERN, Scottish Institute of Remanufacturing, Centre for Remanufacturing and Reuse). As an example, since July 2020 the University of Trier has been running a series of bi-monthly symposia on innovation and automation in remanufacturing, covering topics listed in Table 21.

[21] EU plans 'digital product passport' to boost circular economy, Euractiv.com accessed December 2021 Link

*Table 21: Innovation and automation topics covered at European remanufacturing symposium*

| Innovations and Automation in Remanufacturing symposium topics |
|---|
| • **Agile production control in dynamic remanufacturing systems** |
| • **Remanufacturing future (electronic devices)** |
| • **Robotic disassembly research at the University of Birmingham** |
| • **Automatization and mechanisation in engine remanufacturing** |
| • **Passenger car electrification and key challenges for remanufacturing** |
| • **Disassembly research of lithium batteries at the University of Trier** |
| • **Remanufacturing and additive manufacturing** |
| • **Sensor and artificial intelligence supported identification and evaluation of used parts in remanufacturing** |
| • **Remanufacturing of end-of-life wind turbines in a closed-loop supply chain** |
| • **The pathway to circular wind turbine blades** |
| • **Remanufacturing and refurbishment in the wind turbine aftermarket** |

### 6.1.5 China

#### 6.1.5.1 Overview

Foreign trade, employment and production statistics are largely unavailable for the Chinese remanufacturing sector, which was relatively undeveloped before 2008 (9).

The three stages of development of remanufacturing in China can be classified as scientific research stage (before 2005), legislative stage (2005-2009) and industrial practice/implementation stage (after 2009):

**Scientific research stage (before 2005):** Remanufacturing engineering disciplines are developed and the topic is included in the national medium and long-term science and technology development plan.

**Legislative stage (2005-2009):** Remanufacturing is included in the circular economy promotion law and various remanufacturing policies and regulations are issued by the state council.

**Industry implementation (2009-):**

- Listed as the national strategical emerging industry, 2009
- Included in 12th five-year plan in 2010
- National remanufacturing standard committee in 2011
- Approval and preparation of remanufacturing industry centre, 2012
- Financial subsidies for “Swap the Old for Remanufacturing” (2013)
- Release of the High-end Smart Manufacturing Action Plan (2018-20) by the Ministry of Industry and Information Technology of China (MIIT)

Two government departments are responsible for the policies for remanufacturing industry: the National Development and Reform Commission (NDRC) for the automotive industry and Ministry of Industry and Information Technology (MIIT) for other industry sectors. Since the start of the implementation stage NDRC has approved 14 remanufacturing enterprises into automotive sector in 2008 and 28 in 2013, and MIIT has approved 35 and 76 remanufacturing enterprises in 2009 and 2016 respectively.

These pilot schemes have been supported by subsidies offered via the policy 'Swap the Old for Remanufacturing' adopted in 2013. These subsidies are offered on collected generators, vehicle starters, gearboxes, engines and transmissions (see Table 22) and it is expected that the subsidies will lower the market price for these remanufactured products by 10%. Firms are also supported via a further subsidy on the number of complete scrapped vehicles collected, which has been credited with helping to increase the collection of scrapped vehicles from 1% at the start of the implementation stage in 2013 to 4-6% in 2016 (31).

*Table 22: 'Swap the Old for Remanufacturing' subsidies adjusted to sterling (2020)*[22]

| Item | Generator | Vehicle starter | Gearbox | Engine | Transmission |
|---|---|---|---|---|---|
| **Subsidy (£/unit)** | £2.20 to £16.80 | £2.20 to £9 | £168.30 to £280.50 | £112.20 | £95.90 to £180 |

*Source:* (31)

From the list of pilot enterprises, seven major product categories are represented below:

*Table 23: Products remanufactured within the 76 pilot enterprises*

| Classes | Items |
|---|---|
| **Construction machinery** | Excavator, Grader, Forklift, Scraper, Bulldozer, Road Roller, etc. |
| **Mechanical and electrical equipment** | Lathe, Electric Machinery, Textile Machinery, Gear, Rotator etc. |
| **Mining machinery and equipment** | Coal Equipment, Oil Equipment, Petrochemical Equipment, Metallurgical Equipment etc. |
| **Transportation facilities** | Bearing Housing, Trail Wheel, Axle Bearing, Railway Carriage, Bogies etc. |
| **Combustion engine and automobile components** | Engines, Steering gear-box, Transmission, Car-Frame, Front/Rear Axle etc. |
| **Electronic information devices** | Hard Drive, Electro-medical Equipment, Vacuum Tube, High Voltage Power Supply etc. |
| **Office equipment** | Printer, Copier, Projector, Scanner, Fax etc. |

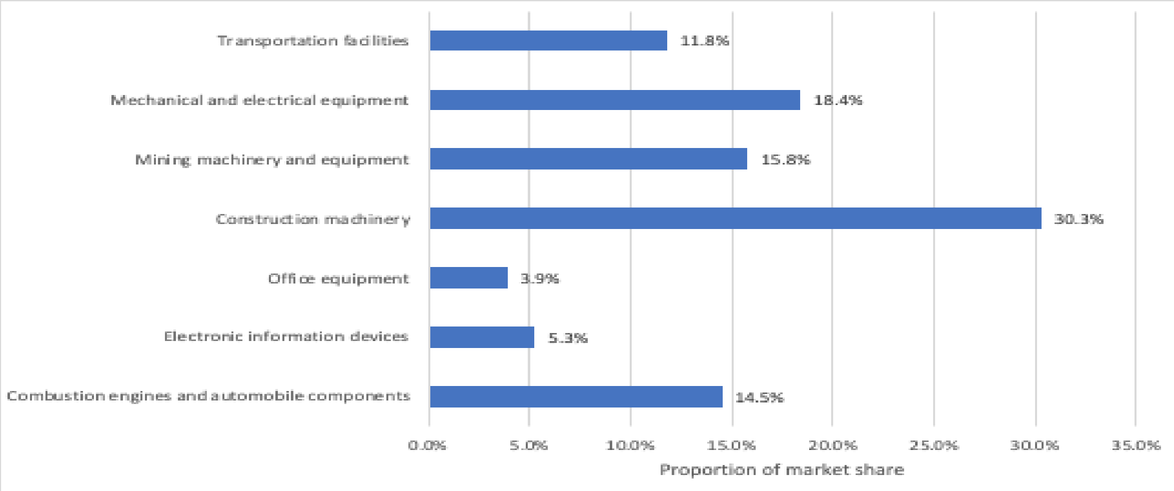
*Source:* (31)

A survey of remanufacturing activities by the Institute of Remanufacturing Industry Technology, Jing-jin-ji estimated that a total ouput of £2.5 billion[22,23] was generated in 2019. Key remanufacturing sectors in the survey included automotive parts/components (47% of revenue), rolling stock (21% revenue) and metallurgical power equipment (14%).

Apart from these officially sanctioned pilot projects, China also supports roughly 1,000 firms that undertake tyre retreading activities, although these firms are often low output, with only a few generating a total annual output in excess of 100,000 units (9).

[22] Figure has been converted from US Dollars to Sterling using an average exchange rate in 2020 of £1-$1.2832, sourced from Average Sterling exchange rate: US Dollar. 2020. Office for National Statistics. Available from: https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/auss/diop
[23] Figure has been inflation adjusted from 2016-2020 using an average annual inflation rate of 2.7%, sourced from Inflation calculator. 2021. Bank of England. Available from:https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

*Figure 23: Product class market share 2016*




*Source:* (31)

### 6.1.5.2 Barriers

The 2015 ERN market study identified several barriers to growth in the Chinese remanufacturing industry as shown in Table 24 (9).

*Table 24: Barriers to expansion of remanufacturing in China*

| Barrier | Commentary |
|---|---|
| **Inadequate official definitions** | Inadequate official definitions of remanufacturing acting to complicate the process for firms seeking to register their operations for approval. |
| **Import constraints** | Import constraints, regulations on disassembly and requirements to melt down certain components hindering the collection of cores for remanufacturing. |
| **Definitions of imported goods** | Remanufactured mechanical and electronic products are categorised as 'used' during importation and depending on the product are prohibited, restricted or freely imported. As a result, remanufactured automotive parts and HDOR equipment cores must be sourced domestically in order to be sold into the Chinese market. Further to this the Chinese customs service does not have a separate definition for remanufactured goods which makes it difficult for officials to apply correct import duties (Cao, et al., 2020). |
| **Tax burdens** | Remanufacturing can be hindered by existing tax burdens. |
| **Pilot programme regulations** | *Remanufacturing within the OEM warranty period is prohibited under the regulations of the pilot programmes.* (This barrier no longer applies as it was abolished in 2017.) |

There is little available data from which to estimate the scale of the wider VRP sector within China, but it can be seen to be a major global player in some VRP sectors. Examples include the global ship repair industry, in which China accounts for 30% of the global market; and the commercial aircraft MRO industry, in which China is the fifth largest region by total spend. This latter industry is of particular interest, as the total spend on commercial aircraft MRO activity in China is projected to grow to £15.1 billion by 2031 - up from a projected £6.46 billion[24] in 2021, growing to account for 16% of the global market (32).

### 6.1.5.3 Policy and action

Overall, the Chinese remanufacturing sector is still considered to be in its early stages of development, showing strong technological development on a par with that of more advanced nations but currently

[24] Converted from US Dollars to Sterling using an average exchange rate in 2020 of £1-$1.2832, sourced from Average Sterling exchange rate: US Dollar. 2020. Office for National Statistics. Available from: https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/auss/diop

lacking in industrial scale. More recently, the Chinese Government has tackled several critical barriers above, de-stigmatising remanufactured imports and exports and establishing Remanufacturing Parks dedicated to the activity. In the 14th Five Year Plan for Circular Economy Development the Chinese Government moved to further support VRPs by pledging the establishment of a recycling system for waste materials and the creation of a recycling society by 2025. More specifically, this plan will "promote the high-quality development of the remanufacturing industry" through a number of initiatives including;

- Supporting the construction of a trading platform for remanufactured products.
- Cultivating specialised remanufacturing and recycling companies.
- Supporting the exploration and development of remanufacturing and re-export businesses for aviation, CNC machine tools and communication equipment.
- Improving the level of remanufacturing for automotive parts, construction machinery, machine tools, cultural and office equipment.
- Promoting customised remanufacturing services for large electromechanical equipment and the combination of remanufacturing technology and equipment digital transformation.

In part, these initiatives will be achieved through efforts to support the extensive use of remanufactured products and services by tunnelling, coal mining and oil extraction industries, as well as within maintenance, insurance, commerce, logistics and leasing markets for automotive parts and office furniture. Alongside this, efforts will be made to widen the scope of remanufacturing for machine tools, industrial motors, and industrial robots. Finally, the Chinese Government will also guide the formation of ten remanufacturing industry clusters and cultivate a group of leading remanufacturing enterprises with the aim of achieving a remanufacturing industry output value of CNY200 billion (£22.6 billion[25]) (33).

As part of its development strategy, China has been pursuing what would now be considered to be circular economy initiatives since 2002. The main framework is the 2009 Circular Economy Promotion Law. A brief overview of the implementation structure of China's CE initiatives can be viewed in Table 25. Most recently the CE has been included in the 13th five-year plan, in which the Chinese Government stated its intention to develop remanufacturing and implement extended producer responsibility systems. Due to a lack of technical data, it has been difficult to quantify the impact these measures have had on China's VRP sector.

*Table 25: Overview of China's CE policy framework*

| Area | Micro (Enterprise) | Meso (Inter Firms) | Macro (Province, Region, State, Cities) |
|---|---|---|---|
| **Design** | Ecodesign | Environmentally friendly design | Environmentally friendly design |
| **Production** | Cleaner production | Eco-industrial park | Eco-city<br>Eco-municipality<br>Eco-province |
| **Consumption** | Green purchase and consumption | Environmentally friendly park | Renting service |
| **Waste management** | Product reuse and recycle system | Waste trade market industrial symbiosis | Urban symbiosis |

*Source:* (34)

[25] Converted from Yuan to Sterling using an average spot exchange rate in 2020 of £1- ¥8.8511, sourced from Daily spot exchange rates against Sterling. 2021. Bank of England. Available from: https://www.bankofengland.co.uk/boeapps/database/Rates.asp?TD=31&TM=Dec&TY=2015&into=GBP&rateview=A

### 6.1.6 Japan

The Japanese remanufacturing sector is relatively well developed, but the size of this sector is not well characterised. In the 2015 market study the ERN estimated the size of the Japanese remanufacturing sector to be JPY500 billion (£3.05 billion)[26,27] (9; 35). Of this, the report authors estimated that automotive remanufacturing accounted for JPY109 billion (£665 million), retread tyres for JPY20 billion ( £122 million), photocopiers for JPY15 billion (£91.6 million) and toner cartridges JPY30 billion (£183 million)26,27.

Although the remanufacturing sector has been supported via the Japanese Government's environmental policies designed to reduce pollution and waste generation (e.g. 3Rs initiative) (9; 35), the government has enacted few laws and policies specifically related to remanufacturing and the sector suffers from a lack of legal recognition, which has acted to hamper potential growth (13; 14).

In lieu of official standards, some private entities such as the Nippon Good Parts Group, the Automotive Parts Recyclers Association and the Association of Japan Cartridge Recyclers have developed their own remanufacturing quality assurance standards.

The remanufacturing sector within the country is largely driven by the private sector, with automotive parts, ink cartridges and photocopiers being the main industrial areas of remanufacturing (14). Notably, Japan's large photocopier manufacturers (Fuji Xerox, Ricoh and Canon) collaborate to collect used photocopiers and have invested in design for remanufacturing (9). The remanufacturing sector for single-use cameras is also well developed within the country, with Fujifilm having operated a fully automated remanufacturing production line for these products since 1998 (36). Heavy duty and construction equipment OEMs such as Komatsu and Hitachi also undertake remanufacturing operations (9; 22).

Remanufacturing also takes place in the automotive and printer cartridge sectors, although these are undertaken by independent remanufacturers rather than OEMs. As the average age of passenger vehicles in Japan increases, the remanufacturing of automotive parts is likely to also grow (9).

### 6.1.7 South Korea

The South Korean Government has actively sought to foster the growth of remanufacturing via the "activation strategy for the remanufacturing industry" in 2011 and the "boom-up strategy for the remanufacturing industry" in 2013 (14). South Korea was also the first country to implement national guidelines for quality certification of remanufactured products via the Korean Agency for Technology and Standards (KATS) in 2006 (13; 14).

Most of the South Korean remanufacturing activity is in the automotive parts (80%) and the ink and toner cartridge (17%) sectors. However, there is also some activity within the defence, medical device, HDOR and IT equipment sectors (9; 13).

The remanufacturing sector in South Korea was worth around KRW840 billion (£548.3 million)[28,29] (9) in 2015 and grew by an average rate of 11% per year in the five years prior to this. While the market value of the remanufacturing sector increased, in the same period the number of firms active in the sector declined from 1,500 down to 1,100 (9) and employment in the sector fell by a corresponding 30% (13).

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[26] Converted from Yen to Sterling using an average exchange rate in 2015 of £1-¥185.0475, sourced from Average Sterling exchange rate: Japanese Yen. 2020. Office for National Statistics. Available from: https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/timeseries/ajfo/diop

[27] Inflation adjusted from 2015-2020 using an average annual inflation rate of 2.5%, sourced from Inflation calculator. 2021. Bank of England. Available from:https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

[28] Figure has been converted from Japanese Yen to Sterling using an average spot exchange rate in 2015 of £1- KRW1731, sourced from Daily spot exchange rates against Sterling. 2021. Bank of England. Available from: https://www.bankofengland.co.uk/boeapps/database/Rates.asp?TD=31&TM=Dec&TY=2015&into=GBP&rateview=A

[29] Figure has been inflation adjusted from 2015-2020 using an average annual inflation rate of 2.5%, sourced from Inflation calculator. 2021. Bank of England. Available from:https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator

## 6.2 Opportunities for international research and innovation collaboration

We suggest the following opportunities for international research and innovation collaboration would be beneficial to the UK as it develops native VRP markets.

- Explore policy options to support VRPs, e.g. via a policy roundtable.
- Extend collaborative research programmes to VRPs as has been done for agriculture and manufacture at Innovate UK.

- Maintain strong academic links through the Universities of Brighton and Birmingham on topics of autonomous remanufacturing.
- Potential to repeat the Remanufacturing Mission undertaken in May 2016.

- Collaborate on Horizon Europe research projects related to VRPs.
- Priority partners would include Germany, France, Sweden, and the Netherlands where academic expertise on circular economy and remanufacturing can be found.

- Explore mechanisms to align with research activities at the REMADE Institute.
- Priority topics include novel non-destructive testing and remediation techniques (see Section 10.2 for more details).

- Explore opportunities to build on “Making Things Last” strategy and ambition and Scottish Institute for Remanufacturing activities. (See Section 7.4 for more details.)

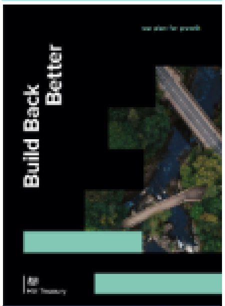
- Explore opportunities to build on “Beyond Recycling” strategy and ambition. (See Section 7.5 for more details.)

# 7 Policy context for the UK and devolved nations

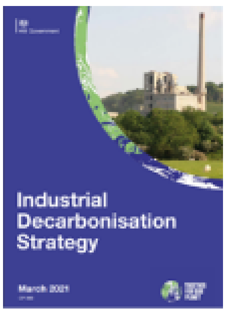
- The UK has a **strong policy base** from which VRPs could be supported, aligned with the **Net-Zero** agenda.
- While **Scotland** was a **first mover** in the topic of circular economy, **Wales** now has **the most comprehensive**, connected, and well-developed **circular economy strategy** with explicit focus on VRP activities.

## 7.1 United Kingdom

The UK government has produced a range of legislation, commitments and publications related to VRP activities. The key connections between these are presented below.








**The Climate Change Act 2008 (2050 Target Amendment) Order 2019** (37) includes a legally binding target for the UK to reach Net-Zero emissions by 2050. Where VRP activities can demonstrably contribute towards reductions in greenhouse gas emissions (with no negative economy impacts), UK policy could look to support the development of these markets. This study seeks to update and disaggregate the impact assessment from the Committee on Climate Change report (3), which assessed the potential emissions impact of resource efficiency measures.

The UK's '**Build Back Better – our plan for growth**' (38) and '**Ten point plan for a Green Industrial Revolution**' (39) both have connections to VRP activities. The three pillars of the plan for growth (infrastructure, skills and innovation) could all be applied to VRP activities. Skills associated with VRPs is a theme commonly highlighted by stakeholders as an area of concern. The investment in key industries, such as wind and hydrogen, may also create new markets for VRPs to be applied. The shift to zero emissions vehicles, which the 'Ten point plan' seeks to accelerate, will have significant implications on remanufacturing activities in the automotive sector as the market for remanufactured components evolves. VRP activities may also play a significant role in developing resilience against global manufacturing challenges associated with supply chain disruption (c.f. Suez Canal disruption and global chip shortages in 2021) and critical raw material scarcity (e.g. associated with the rapid growth of renewables and EVs) through the retention of key materials and components within the UK.

The UK's **Industrial Decarbonisation Challenge** (40) outlines five key barriers to further efficiency, which relate to VRPs:

- Awareness and capacity – from both industry and consumers, e.g. product life extension through reuse and repair.
- Access to expertise and talent – skills shortages are a commonly cited barrier to VRP growth.
- Access to finance – e.g. higher payback times and internal competition for finance.
- Measurement and data – while explicitly related to energy efficiency in this report, better measurement and data would also help improve VRP activities, e.g. better informing through-life engineering services.
- Incentives to adopt circular solutions – to encourage uptake of initiatives such as product sharing and reuse.


The **Energy-Related Products Policy Framework** (41) included as one of its four objectives *"Building a circular economy in which products are more repairable, durable and recyclable, ensuring maximum retention of value in the economy for as long as possible."* Ecodesign measures have already been used as a mechanism for supporting the VRP activity of repair, through the provision of spare parts and information on repair as part of a 'right-to-repair' initiative. Measures currently being considered that could further support VRPs include design for disassembly, circular economy principles for chemical and hazardous substances, and product information and labelling requirements. A 2022 consultation is also planned on the potential impact of modulating EPR under the WEEE Regulations.


The **UK Innovation Strategy** (42) lays out seven technology families of UK strength and opportunity. Of specific relevance to VRPs include:

- Advanced Material & Manufacturing – e.g. additive manufacturing techniques.
- AI, Digital & Advanced Computing – e.g. augmented and virtual reality for use in VRP training applications, and digital twins for condition monitoring.
- Energy & Environment Technologies – e.g. new VRP markets for renewables and hydrogen technologies.
- Robotics & Smart Machines – e.g. automation of VRP activities to reduce costs and increase quality.


The UK's **Net-Zero Research and Innovation Framework** (43) outlines resource and energy efficiency as one of three categories for decarbonisation of industry. In addressing the challenge of improving resource and energy efficiency, the frame identifies two key research and innovation needs related to VRPs falling under the short- to medium- term timeline (up to 2030):

- Using ecodesign to design products for disassembly, remanufacture or recycling of end-of-life parts or products so that they can return to like-new or better performance, or new products that can be made with reused/recycled and alternative materials.
- Increasing product lifetime or switching to/creating reuseable products where possible.

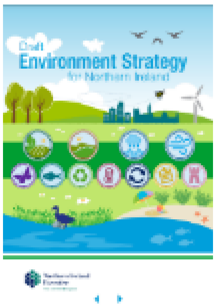
## 7.2 England


The proposed approach for implementing the action in the Industrial Decarbonisation Challenge related to "*Support increased resource efficiency and material substitution within industry, by driving the transition towards a circular economy model and increasing reuse, repair and remanufacturing*" is described for England in the **Resources and Waste Strategy** (44)**.** Of relevance to VRPs it includes *"improving product designs to ensure durability, repairability and recyclability with the use of selective product bans to drive this improvement."*

The **Waste Prevention Programme** (45) for England went out for consultation in March 2021 and included the aim *"to ensure there is a well-functioning system of public, private and third sector organisations and services operating at the local level that facilitate reuse, repair, refill and remanufacture of products."* The actions proposed focused on improving the resource efficiency of Household Waste Recycling Centres, enhancing the role of the third sector in reuse, and supporting local authorities to pilot and report on circular economy activities, including on reuse and repair.

## 7.3 Northern Ireland

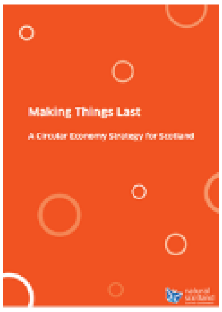
In 2020, the Waste (Circular Economy) (Amendment) Regulations NI was introduced to transpose the EU 2020 Circular Economy Package into law. The Northern Ireland Resources Network (NIRN) report that as yet, no policy to increase reporting and reuse/preparation for reuse requirements has since been implemented (46). In 2015, research indicated that moving towards a circular economy could create 13,000 jobs in Northern Ireland (47).




Following consultation, the **Draft Environment Strategy for Northern Ireland** (48) is currently open for comment. One of six strategic environmental outcomes considered is "Zero Waste & Highly Developed Circular Economy". The strategy indicates that the Department for Economy is currently developing a Circular Economy Strategic Framework for Northern Ireland. The strategy refers to the VRP activities of reuse and repair; however, the only reference to refurbishment is in the context of building and no reference is made to remanufacturing.

## 7.4 Scotland

Scotland's **Making Things Last: A Circular Economy for Scotland** (49) highlighted remanufacturing as one of four priority areas, citing its annual contribution of £1.1 billion to the economy and potential to grow by £620 million by 2020. Design for longer product lifetimes and growth of reuse and repair were also discussed. A focus on the role of producer responsibility to drive VRPs was also identified for exploration. Scotland has developed a quality standard for second-hand stores in Scotland, called Revolve, with 115 stores certified to date[30]. Through Zero Waste Scotland, businesses can access support through the Circular Economy Investment Fund and the Circular Economy Business Support Service. Zero Waste Scotland is also lead partner for the Resource Efficient Circular Economy Accelerator Programme in the current round of European Structural Funds in Scotland. This programme, targeting SMEs, has a total value of £73 million, is funded by the European Regional Development Fund (ERDF) and runs to December 2022[31].





The **Update to the Climate Change Plan** draws out Scotland's circular economy ambitions, citing an economy that by 2032 will be designed to reduce, reuse and repair materials. The actions listed under "Building the circular economy" and relevant to VRPs identify Zero Waste Scotland and Scottish Environment Protection Agency (SEPA) as the key agents to work with industry on the topic of resource efficiency. More detailed actions were reported on the topics of food waste, landfill, and single use items.

Scotland has a strong R&D presence in VRP activity, being home to the Scottish Institute for Remanufacture and the National Manufacturing Institute Scotland.

Scotland is unique in that it has a Minister for Green Skills, Circular Economy and Biodiversity. The role has been held by Lorna Slater MSP since August 2021[32].

[30] https://www.zerowastescotland.org.uk/revolve
[31] https://www.zerowastescotland.org.uk/content/european-funding-environmental-projects
[32] https://www.gov.scot/about/who-runs-government/cabinet-and-ministers/minister-for-green-skills-circular-economy-and-biodiversity/

## 7.5 Wales

The **Beyond Recycling** (50) strategy in Wales seeks to lay out plans *"to make the circular economy in Wales a reality."* The strategy builds on the historic investment in recycling infrastructure in Wales and is part of a comprehensive and cohesive programme across government. There has been a shift away from focus on individual sectors, and instead on business value, with themes such as innovation, building economic and supply chain resilience, and resource efficiency and waste minimisation. While most of the projects funded through the Circular Economy Fund in the last year have focused on recycling, VRP activities are to be considered in future funding rounds. Of the eight headline actions outlined, perhaps the most relevant to VRPs is the commitment to *"procure on a basis which prioritises goods and products which are made from remanufactured, refurbished and recycled materials or come from low carbon and sustainable materials like wood."*


Other VRP-relevant actions cited in the strategy include:

- Investing in green skills such as ecodesign, reuse, repair, remanufacture and reprocessing through the establishment of courses and diplomas (e.g. Green apprenticeships).
- Working with the other UK nations to improve the legislation for waste electrical and electronic equipment (WEEE) and ensure a right-to-repair, encouraging durability and increasing access to modular parts in products is promoted.
- Supporting the reuse, repair and remanufacturing sectors in communities and town centres.
- Piloting a reuse platform which will allow those in reuse markets to connect with the public and third sectors to access refurbished, recycled and remanufactured goods.
- Working in partnership with Local Authorities to develop regional 'eco-park' hubs where collected materials are recycled, reprocessed, and remanufactured into new products.


The Welsh government report **A Manufacturing Future for Wales** (51) identifies the work to promote the reuse and remanufacture of products as a medium- to long-term action, owned by regions, resource efficiency and circular economy, industrial transformation division and the innovation departments within government. The report also highlights the need to develop circular economy infrastructure to enable reuse, and the role that value retention could play in building supply chain resilience.

WRAP Cymru is a focal point for business and public sector support on the topic of circular economy, and the organisation manages the Circular Economy Fund[33]. Insights from WRAP Cymru suggested there is a need for both financial and technical support for businesses looking to develop remanufacturing capabilities. Transition finance could play a useful role in enabling businesses to move into VRP activities, for example, cashflow support e.g. via development banks, government guaranteed finance, blended finance and equity. Technical support, for example with universities, could help in sourcing materials, testing and evaluating carbon footprints. Experience has shown that it can be hard for businesses to get machine time for trialling new processes, and the lack of capacity and knowledge to test these can hinder progress.

[33] https://wrapcymru.org.uk/taking-action/grants/circular-economy-fund-recipients

Other initiatives related to VRPs in Wales include Circular Revolution[34] – the first business-led hub in the UK focused on ‘circular thinking’. The work programme includes SME outreach and six pilot projects on the themes of supply chain, blockchain and legal issues.

[34] https://circularrevolution.wales/

# 8 Sector analysis

- The automotive and aerospace sectors are the largest markets for VRP activities in the UK.
- Data on repair is the most robust market data available coming from industry statistics.
- Stakeholders engaged in other VRP activities were able to offer little insight on the size and impact of these markets with estimates relying on modelling.

This section provides an overview of the ten sectors examined in this study. Estimates of the size of the market for different VRP activities have been quantified along with estimates of the environmental impacts. Key insights from stakeholder engagement on the motives for, barriers to and prospects for VRP activities are presented, along with stakeholder recommendations for innovation and policy. (NB these recommendations represent stakeholder opinions. The recommendations of this study can be found in Section 12.)

## 8.1 Aerospace

The aerospace industry includes activities around the design, development and the production of military and civil aircraft and their associated systems, parts, and equipment. The products in the sector are often described as highly durable and long-lasting.

The UK aerospace industry is the second largest in the world. In 2017, the sector contributed £35 bn to the country's GDP[35] and employed an estimated 114 thousand[36] people (direct). Although no large aircraft are produced in the UK, 90%[37] of the aircraft components manufactured in the UK are exported. It has a reputation as a global centre of excellence for designing and producing engines, aircraft systems, helicopters, wings and structures. In addition to manufacturing, the UK has a flourishing maintenance, repair and overhaul (MRO) sub-sector. This study includes discussions with stakeholders from both the manufacturing and MRO sub-sectors.

The sector is made up of OEMs and non-OEMS. The OEM group include subsidiaries of airline operators such as British Airways Maintenance and Engineering, along with several third-party organizations who operate in this space. In addition to these operations, OEMs can offer service-based purchasing agreements which include the services often provided by MROs.

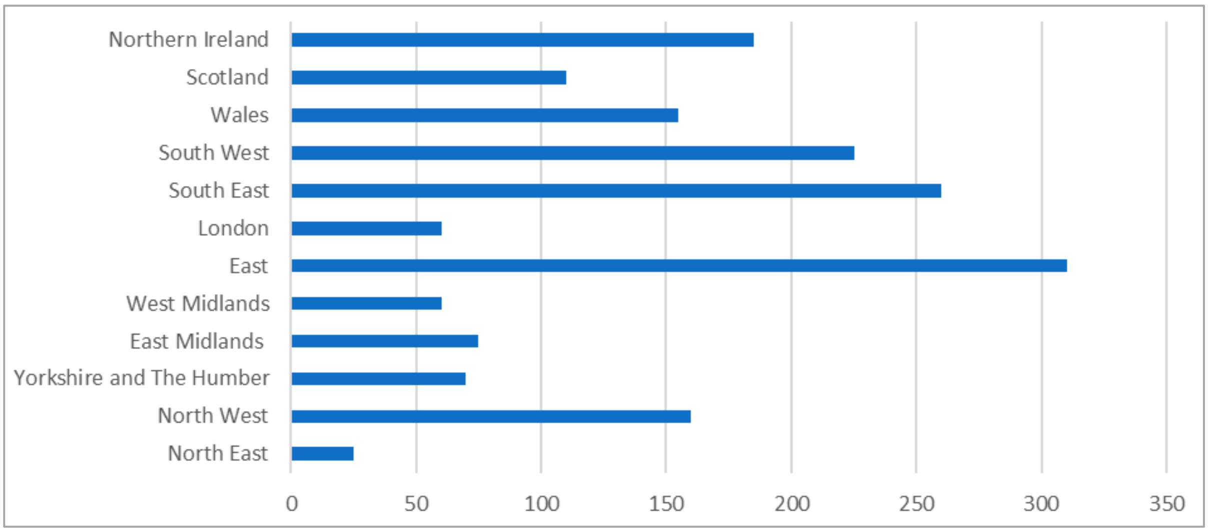
Aerospace companies can be found in all four nations of the UK. In 2021 there were 1,695 businesses in the UK operating under SIC code 33.16 (Repair & maintenance of aircraft & spacecraft) with a regional breakdown as follows:

[35] Figure has been taken from the UK Department of International Trade (2021). Available at: https://www.great.gov.uk/international/content/about-uk/industries/aerospace/

[36] Figure taken from an article published in The Manufacturer titled What does the future hold for UK aerospace? By Jonny Williamson (2020). Available at: https://www.themanufacturer.com/articles/what-does-the-future-hold-for-uk-aerospace/

[37] Figure taken from the US Department of International Trade Administration (2021). Available at: https://www.trade.gov/country-commercial-guides/united-kingdom-aerospace-and-defense

*Figure 24: Regional distribution of companies operating under SIC 33.16 in 2021*

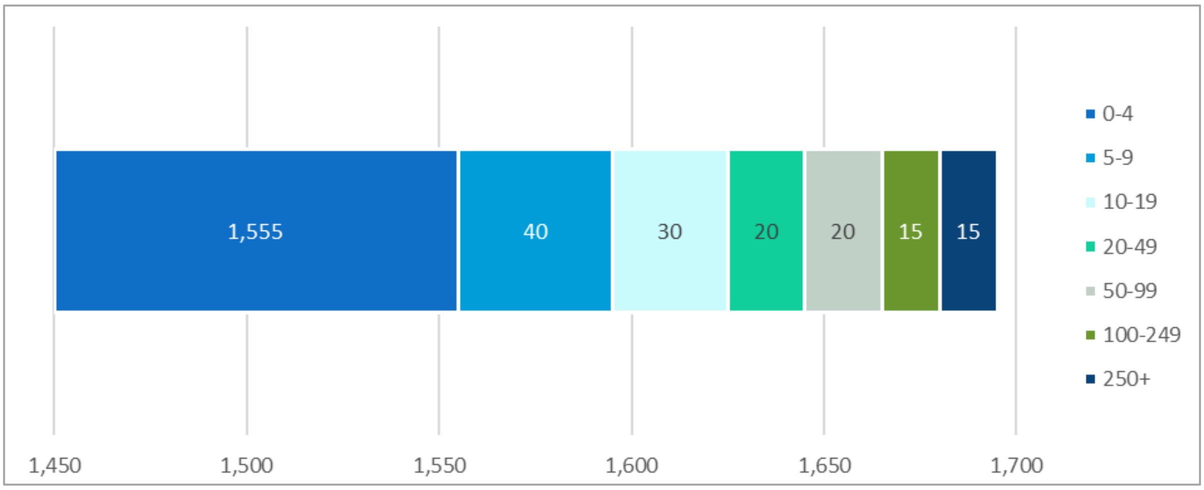



*Source: ONS UK Business: Activity, Size and Location - 2021*

As is to be expected, these businesses are clustered around areas of aviation activity, e.g. Glasgow, Edinburgh, Aberdeen and Inverness (to support North Sea operations), Belfast, Londonderry, Newcastle upon Tyne, Blackpool, Liverpool, Manchester, Cheltenham, Cardiff, Bristol, Bournemouth, Southampton, Brighton and around London (8).

The majority of these businesses are SMEs, as shown in the following chart.

*Figure 25: Frequency of companies in aerospace by employee number band, 2021*




*Source: ONS UK Business: Activity, Size and Location - 2021*

Total employment data was only available for SIC code 33.16 and only for Great Britain – in 2020 there were 20.6 thousand people employed in this activity[38]. The 2016 study on UK MRO activity (8) estimated employment of 57 thousand employees. Scaling this by 33.16 activity suggests a figure of 49 thousand employees would be more representative and include employment of those undertaking MRO activities in businesses operating under SIC codes outside of 33.16.

In 2021, the UK Department of Transport announced a consultation on their Jet Zero Strategy, a plan to help the industry deliver Net-Zero aviation by 2050. Their ambition is to decarbonise aviation while still preserving the benefits that the industry brings and to maximise the opportunities that decarbonisation

[38] ONS Industry (2, 3 and 5 - digit SIC) - Business Register and Employment Survey (BRES): Table 2 Link

can bring to aviation. The document outlines several policies that cover five measures, none of which covers value retention processes.

As an industry, sustainability conversations focus on two pillars. The first is reducing emissions from flight and the second is a focus on manufacturing processes. Currently, there is a large emphasis on the reduction of emissions with OEMs researching heavily into alternative fuels and electric planes.

### *8.1.1 Industry insights*

The value retention processes that take place in this industry include 'overhaul', 'repair', 'reconditioning', 'repurposing' and 'refurbishing'. These processes are regulated by the European Air Safety Authority (EASA) and the Component Maintenance Manual (CMM): their regulations ensure that aircrafts remain airworthy.

#### *8.1.1.1 Market analysis*

A summary of the most recent market data collated in this study is presented in the table below:

*Table 26: Aerospace VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Remanufacturing** | £13.6 m (sold production)<br>£7.9 m (imports)<br>£14.8 m (exports) | 2016 | EUROSTAT – PRODCOM database: sold production, imports and exports.<br>22112090 - Retreaded tyres of rubber (including of a kind used on aircraft; excluding of a kind used on motor cars; buses or lorries). |
| **Remanufacturing** | £10.7 m (sold production)<br>£6.2 m (imports)<br>£11.7 m (exports) | 2020 | 2016 data from above has been scaled to 2020 data using the change in SIC UKProdTO: 33.16 - Repair & maintenance of aircraft & spacecraft TOTAL (£m). |
| **Remanufacturing and comprehensive refurbishment** | £30.7 m (sold production) | 2018 | EUROSTAT – PRODCOM database: sold production, imports and exports.<br>30306070 - Reconditioning of civil aeroplanes and other aircraft (excluding helicopters, aircraft engines). |
| **Remanufacturing and comprehensive refurbishment** | £20.4 m (sold production) | 2020 | 2018 data from above has been scaled to 2020 data using the change in SIC 33.16 Repair and maintenance of aircraft and spacecraft. |
| **All VRPs** | £17,800 m (revenue) | 2015 | Total UK MRO Sector Revenue (8). Includes maintenance, repair, overhaul and logistics and includes activities in airframe, engine, component and specialised services. |
| **All VRPs** | £15,400 m (revenue) | 2020 | 2015 data from above has been scaled to 2020 data using the change in SIC 33.16 Repair and maintenance of aircraft and spacecraft. |
| **Repair** | £3,476 m (total production)<br>£1,522 m (exports) | 2020 | ONS UKProdTO: 33.16 - Repair & maintenance of aircraft & spacecraft. |

The aerospace sector has been dramatically affected by the Covid-19 pandemic and therefore market values prior to 2019 are likely to represent an overestimate of the current market activity. Furthermore, the terminology used in the aerospace sector does not map as easily to the VRP framework as it does for other sectors. Activities classified under the MRO banner are likely to have significant overlap with longer life-extension activities like remanufacturing. For example, while repair and maintenance of aircraft engines fall under SIC 33.16, overhaul and conversion of aircraft or aircraft engines falls under SIC 30.30 'Manufacture of air and spacecraft and related machinery'. However, it is not possible to disaggregate the VRP activity from manufacturing activity and so this activity is not captured in the industry statistics above and will represent an underestimate in the scale of remanufacturing. For this study we have therefore chosen to use data from the 2016 study on the UK MRO sector and have scaled this to 2020 levels. The disadvantage of using this data set is that it is not possible to disaggregate between different VRP activities.

#### 8.1.1.2 Motives

Respondents in this sector have commented that profile margins on the sales of aircraft components are quite low, however offering MRO services allows companies to increase the lifespan of components, build strong relationships with clients and ultimately increase profit margins. MRO services are primarily driven by the need to mitigate risk through several regulations and restrictions.

Aerospace operators are motivated to take on these services as they want their aircraft to operate at peak performance. This encourages manufacturers to design components in a modular way and to develop repair and remanufacturing capabilities.

One of the most successful examples of this offering is the Rolls Royce ‘Power-by-the-hour’ service which offers a fixed cost per hour of flying. This was a novel model which competitors are now emulating. Larger manufacturers that offer such a service invest heavily in data management and predictive maintenance to ensure that the best service is offered. Larger companies will often choose this model while smaller operators may choose SMEs to perform MROs.

At the end of their life, alloys can be recycled and reused in the industry. However, for safety reasons, there are strict regulations regarding the percentage of recycled content allowed in components. There is currently an industry-wide initiative to find EoL options for composites used in propellers and aircraft wings.

#### 8.1.1.3 Barriers

Repair and overhaul operations are limited to mechanical components. Electrical components that contain critical raw materials are often discarded and there is no existing technology to create a closed loop process for this. There lies an opportunity in building these capabilities in the UK. There needs to be more visibility of where these non-alloy components originate from so that it can be determined whether the material can be used in the industry again.

The industry is very risk adverse which means it cannot be agile. This in turn can stifle innovation.

#### 8.1.1.4 Prospects

Newer engines are being designed so that components can be easily retrofitted to alternative fuels thus ensuring a smooth transition.

As companies put more R&D emphasis on electric planes, governments need to work with industry to create a roadmap or strategy to build remanufacturing capabilities for electric planes and for dealing with critical raw materials.

Like many other industries, the aerospace industry is slowly moving towards more service-offering models to increase both profitability and component health.

### 8.1.2 Environmental benefits

Respondents working with engine manufacturers and MROs have reported that, from a weight perspective, 50% of the alloy material is within a closed loop system in which value is retained.

No additional information on the environmental impacts of VRPs in the UK aerospace sector was found in the literature or from stakeholder engagement. Therefore, to estimate the impact of VRP activities at a sector level we evaluated the impacts per revenue from our study on Canadian VRP impacts (15) and scaled these to UK revenue. This gave a value of 122 kt waste avoided and 681 kt $CO_2e$ avoided.

### 8.1.3 Innovation and policy recommendations

Interview respondents were asked what areas they believe required support from government.

#### 8.1.3.1 Legislation

Standards should be set before innovation occurs, to help guide innovation in the right direction in terms of reaching the goal of Net-Zero as an industry. The key stakeholders for this would be BSI on a national level, and Eurokai and ISO at a global level.

A UK Government strategy at a regional level is required to help build up the right infrastructure and to create targets for companies strive towards.

Emissions reporting at a Scope 3 level is recommended for all players in the value chain, as is using a Scope 3 passport to trace where emissions originate from.

#### 8.1.3.2 Technology

Use Industry 4.0 technology to track material from its origin to its end of life to better understand what is reused and where it is used.

#### 8.1.3.3 Collaboration

As this is an industry that cannot change or disappear overnight, UK Government needs to invest in centres that promote collaboration between government and industry to find Net-Zero solutions to the industry. This approach can help to develop national strategies around propulsion systems and identify where support is needed.

## 8.2 Automotive

The automotive industry plays a vital role in the UK economy with a turnover of £78.9 billion[39] in 2019 and employing over 1.04 million[39] people (direct and indirect). This sector includes motorised road vehicles, motorbikes and vans. One critical sub-sector of this industry is remanufacturing, which has a long history in the UK and was formed by the need to conserve natural resources and rebuild a post-war economy.

In terms of organizations physically doing the remanufacturing operations, the industry can be broken down into OEMs, Tier 1 suppliers that remanufacture their own products, independent remanufacturers and local rebuilders. In some cases, Tier 1 suppliers and independent remanufacturers may be contracted out by OEMs to remanufacture components.

[39] Figure taken from SMMT (2021), Available at: https://www.smmt.co.uk/industry-topics/uk-automotive/

### 8.2.1 Industry insights

#### 8.2.1.1 Market analysis

A summary of the most recent market data collated in this study is presented in the table below:

*Table 27: Automotive VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Remanufacturing** | £0.6 m (sold production)<br>£0.3 m (imports)<br>£7.8 m (exports) | 2018 | EUROSTAT – PRODCOM database: sold production, imports and exports<br>22112030 - Retreaded tyres of rubber of a kind used on motor cars |
| **Remanufacturing** | £0.5 m (sold production)<br>£0.2 m (imports)<br>£6.5 m (exports) | 2020 | 2018 data from above has been scaled to 2020 data using ONS 07.2.3 Vehicle maintenance and repair CP NSA £m |
| **Remanufacturing** | £600 m (consumer prices) | 2020 | Oakdene Hollins analysis on European automotive remanufacturing market and assuming UK remanufacturing makes up the same proportion of remanufacturing activity as in the 2015 ERN market study (10% of the total market). |
| **Repair** | £21.5 b (consumer prices) | 2020 | ONS 07.2.3 Vehicle maintenance and repair CP NSA £m |
| **Reuse** | £23.7 b (turnover) | 2018 | ONS Regional analysis sale of used vehicles – Turnover for enterprises 45.11/2 Sale of used cars and light motor vehicles |
| **Reuse** | £21.4 b (turnover) | 2020 | 2018 data from above has been scaled to 2020 data using the number of used car sales in 2018 and 2020. |

Automotive reuse and repair sub-sectors are mature and significant compared to other VRP activities. Reuse in the automotive sector should not be considered as product life extension in the same way as in other sectors: the sale of used vehicles is an established market activity and further interventions are not required. The data for repair activity is much broader than the definition in the VRP framework as it includes maintenance and service elements rather than solely quantifying the activity around part repair. This suggests the figure of £21.5 billion is an over-estimate of the true value of part repair.

#### 8.2.1.2 Motives

Historically, remanufacturing operations in the UK were driven by profitability in the aftermarket, with no focus on sustainability. From conversations, this driver has not shifted; however, some stakeholders believe that the push for Net-Zero will motivate more actors to take up remanufacturing operations.

#### 8.2.1.3 Barriers

Industry 4.0 has led to many technological advancements in automotive component manufacturing, adding software to connect the component with the whole vehicle and store data has become a standard in the industry. This software is owned by OEMs and therefore remains one of the biggest challenges for Tier 1 suppliers and independent remanufacturers that are not contracted out by OEMs to remanufacture. New customs regulations from EU Exit have also made it increasingly difficult to access core from outside the UK, with a lot of core being held at Customs.

High costs associated with labour and core logistics have decreased the profit margin in remanufactured component sales. While low cost 'copy' components have resulted in a decrease in the remanufactured market share.

#### 8.2.1.4 Prospects

With the rise in electric vehicles (EVs), a handful of potential candidates for remanufacturing have emerged. These components include lithium batteries, e-axles, e-boosters, electrical motors, xEV transmissions and 48-volt systems. New regulations on the sales of internal combustion engine (ICE) sales will have a long-term impact on the industry as markets for ICE components disappear.

The increase in mobility-as-a-service offerings will have a consequences for vehicle ownership models. Vehicles will no longer be owned by individuals but by companies. To reduce maintenance and repair costs, fleet owners may opt for cheaper remanufactured products.

Independent actors are known to have the most agile remanufacturing operations; it will be beneficial for OEMs to pursue opportunities for collaboration so that both parties can benefit from the partnership.

### 8.2.2 Environmental benefits

Assuming that UK automotive remanufacturing is responsible for 10% of the environmental benefits of European automotive remanufacturing, component remanufacturing leads to approximately 14 kt of waste prevented and 49 kt $CO_2$ avoided.

Based on EUROSTAT PRODCOM data, 44,560 retreaded tyres were sold in the UK in 2018. Scaling this to 2020 levels (using revenue values from 8.2.1.1) gives an estimated number of retreaded tyres of 36,950 in 2020. Assuming the average mass of a passenger car tyre is 7kg and the same proportion of steel and rubber could be retained during retreading as for HDOR tyres, approximately 220 tonnes of waste was prevented and 260 $tCO_2$ was avoided in 2020 from tyre retreading.

No additional information on the environmental impacts of the repair/refurbishment and reuse VRPs in the UK automotive sector was found in the literature or from stakeholder engagement. Therefore, to estimate the impact of repair and reuse activities at a sector level we evaluated the impacts per revenue from our study on Canadian VRP impacts (15) and scaled these to UK revenue. For refurbishment and repair, this gave a value of 36.3 kt waste avoided and 328 kt $CO_2e$ avoided. For reuse, this gave a value of 1,560 kt $CO_2e$ avoided but we consider that no additional waste is avoided in practice as reuse is an established function of the automotive market.

### 8.2.3 Innovation and policy recommendations

#### 8.2.3.1 Legislation

Altering market conditions to enhance collaboration between OEMs and independent remanufacturers.

## 8.3 Heavy duty/off-road equipment and commercial vehicles

The heavy duty/off-road equipment (HDOR) and commercial vehicle sector consists of four sub-sectors:

- Commercial vehicles: Trucks and buses.
- Lifting/ handling equipment: Cranes, hoists, forklift trucks, lifts and escalators.
- Off-road: Mining, quarrying, forestry and agriculture vehicles and equipment (motorised and unpowered).
- Tyre retreading: Tyres used on equipment in this sector.

Stakeholder insights indicate that, in 2020, the retreaded tyre sales represented 30% of all replacement tyre sales, with 700 thousand units retreaded. This represents a marked decline from 2012 levels when retread sales were in excess of 1 million units and representing approximately 50% of replacement tyre sales[40]. Historically, these processes were very localised; however, due to the high demand of these tyres and the lack of available casing in the UK, the procurement of feedstock is heavily dependent on imports.

### 8.3.1 Industry insights

#### 8.3.1.1 Market analysis

A summary of the most recent market data collated in this study is presented in the table below:

*Table 28: HDOR VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Remanufacturing** | £118 m (sold production)<br>£10.7 m (imports)<br>£19.2 m (exports) | 2019 | EUROSTAT – PRODCOM database: sold production, imports and exports.<br>22112050 - Retreaded tyres of rubber of a kind used on buses and lorries. |
| **Remanufacturing** | £100 m (sold production)<br>£9.1 m (imports)<br>£16.3 m (exports) | 2020 | 2019 data from above has been scaled to 2020 data using ONS 07.2.3 Vehicle maintenance and repair CP NSA £m. |
| **Remanufacturing** | £230 m | Not given | British Tyre Manufacturers Association - Retread. |
| **Remanufacturing** | £517 m (consumer prices) | 2020 | Oakdene Hollins analysis on European automotive remanufacturing market and assuming UK remanufacturing makes up the same proportion of remanufacturing activity as in the 2015 ERN market study (12% of the total market). |
| **Repair** | £21.5 b (consumer prices) | 2020 | ONS 07.2.3 Vehicle maintenance and repair CP NSA £m. |
| **Repair** | £659 m (sold production) | 2019 | EUROSTAT – PRODCOM database: sold production, imports and exports.<br>Including: 33121500 - Repair and maintenance of lifting and handling equipment; 33122110 - Repair and maintenance services of agricultural tractors; 33122120 - Repair and maintenance of agricultural and forestry machinery; 33122400 - Repair and maintenance of machinery for mining, quarrying and construction. |
| **Repair** | £560 m (sold production) | 2020 | 2019 data from above has been scaled to 2020 data using ONS 07.2.3 Vehicle maintenance and repair CP NSA £m. |

It is likely that there is some crossover between the value of repair activities, as the term 'vehicle' encompasses passenger cars and commercial vehicles, like buses and trucks, that would fall under this sector category of heavy-duty and off-road vehicles. Additional data on repair activities associated with lifting and handling equipment, agricultural tractors, agricultural and forestry machinery and machinery for mining, quarrying and construction (other products considered to fall under this sector category) were available from EUROSTAT.

#### 8.3.1.2 Motives

The remanufacturing of HDOR equipment and tyre retreading has been driven by organisations for economic and time sensitive reasons. Tyres have a high value in this sector, which makes the cost of reverse logistics financially viable. More than half of the truck and bus industry operates on a servitization

[40] Stakeholder interview

model. This is a mature model that combines the collection of real time information to predict when tyres need replacing to minimise down-time and reduce the likelihood of unexpected tyre failure.

Remanufacturing of HDOR components is also driven by fleet management contracts (with the aim of reducing down-time and total lifetime costs) and the high value of individual components, which allows for a greater profit margin, even after labour costs are accounted for.

#### 8.3.1.3 Barriers

For tyre retreading, the largest challenge is the sale of single-life tyres that cannot be retreaded. Since 2012, the industry has seen a sharp decrease in sales due to competition from single-life tyres from Asia, many of which are supplied at a subsidised price. For example, a single-life tyre may cost £180 in comparison to a retread at £260 or more. This barrier is less severe for tyres purchased through service-based models; however, this model is only financially feasible for organisations that own large fleets.

Another barrier to the industry is the availability of used tyres to input into the retreading process. High-quality retreading cannot be performed on imported single-life tyres and so support for retread activity must include incentivizing the purchase of retreadable tyres to act as future core.

For remanufacturing of components, key barriers include complex and expensive core logistics, exacerbated by problems with transboundary movement of core following EU Exit. Furthermore, increasingly stringent regulations around tailpipe emissions may limit the ability of remanufacturers to process older parts, unless they are able to upgrade performance to the latest standard.

#### 8.3.1.4 Prospects

The British Tyre Manufacturer's Association is optimistic that there is the potential to increase market share by at least 50%, back to its historical market penetration of more than 45% (corresponding to a total market of approximately 1.1 million retread tyres per year). With developments in tyre design for retread and improved in-service tyre condition monitoring, this penetration could increase to over 50% of replacement tyre sales.

For component remanufacturing, stakeholder insights indicate a stable market is anticipated in the medium term. Beyond 2030, there is greater uncertainty around the outlook for the market as the transition to alternative powertrains, such as battery electric and fuel-cell electric powertrains, may affect the portfolio of products in demand for remanufacturing.

### 8.3.2 Environmental benefits

The British Tyre Manufacturers Association reports that 85% of a used bus or truck tyre is reused during retreading, saving 30kg of rubber and up to 20kg of steel. These savings correspond to avoiding the emissions of 60 kg of $CO_2e$ (52). For 700 thousand units remanufactured in 2020, this corresponds to up to 35 kt of waste prevented and 42 kt $CO_2e$.

An additional benefit of retreading tyres is reducing the demand for natural rubber, which is on the list of EU Critical Raw Materials and makes up about 30% of a bus or truck tyre (52).

Assuming that UK HDOR remanufacturing is responsible for 12% of the environmental benefits of European HDOR remanufacturing, component remanufacturing leads to approximately 10.3 kt of waste prevented and 36 kt $CO_2e$ avoided.

No additional information on the environmental impacts of the repair in the UK HDOR sector was found in the literature or from stakeholder engagement. Therefore, to estimate the impact of repair activities at a sector level we evaluated the impacts per revenue from our study on Canadian VRP impacts (15) and scaled these to UK revenue. For repair, this gave a value of 1.3 kt waste avoided and 10 kt$CO_2e$ avoided.

### 8.3.3 Innovation and policy recommendations

#### 8.3.3.1 Legislation

Incentives to purchase retreated tyres are needed to ensure there is both an availability of feedstock and a market to sell retreaded tyres to.

Introducing a carbon tax that takes into account the full lifecycle of tyres would increase the price of single-life tyres; however, it would be challenging to define a single-life (non-retreadable) tyre.

An EPR scheme that sets the scheme operator an objective of increasing retreading as a recovery outcome and allowing them to apply a 'single-life levy' on all new tyres that could be repaid to manufacturers of tyres that are retreaded. Retreaders already record the brand of each tyre they retread. This could then allow the redistribution of the 'single-life levy' to those manufacturers whose tyres have been retreaded. This ex-post reporting would overcome the problem of defining up-front what is a 'retreadable' tyre. By rewarding the manufacturer, regardless of who retreaded the tyre, the incentive mechanism achieves its intended target to improve the attractiveness of purchasing retreadable tyres as compared to single-life tyres. Furthermore, it avoids motivating the retreader who might otherwise be tempted to retread unsuitable used tyres to increase subsidy receipt. By only rewarding tyres that are retreaded, we motivate manufacturers of 'retreadable' tyres to pursue improved stewardship of their products by vehicle operators.

An economic modelling study is needed to examine the feasibility of such a model considering observed price elasticity of demand, etc. Would the levy required be so great as to be politically unacceptable? Is the mechanism sustainable? As retreading increases, the number of new tyres declines, reducing the aggregate levy for distribution across a larger number of retreaded tyres thereby reducing the incentive for further growth in retreading.

#### 8.3.3.2 Technology

There are two processes used for retreading of tyres and their characteristics are described below:

*Table 29: Comparison between hot and cold cure processing* (52)

| Hot cure process | Cold cure process |
|---|---|
| High investment costs | Lower investment costs |
| Longer production runs | Production flexibility |
| Lower unit cost | Higher unit costs |
| Processes used in six plants, of which three are large | Used by 21 micro and SME enterprises in the UK |
| Process accounts for over 65% of UK production | Most operate under one of two international franchisers |

The industry has recently invested over £30 million to improve skills, production flexibility and plant performance (52). Stakeholders identified a potential opportunity for innovation in technology as developing automated inspection processes for retreaded tyres as current processes are manual.

## 8.4 Domestic appliances

In 2020, the estimated value of the UK home appliances sector was £8 billion[41]. The main value retention processes in this sector are in-warranty repairs, out-of-warranty third party repairs and the sales of used appliances. The first is controlled by OEMs that either replace appliances or have contracted repairers who repair broken appliances.

### 8.4.1 Industry insights

#### 8.4.1.1 Market analysis

A summary of the most recent market data collated in this study is presented in the table below:

*Table 30: Domestic appliances VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Repair** | £470 m (consumer prices) | 2020 | 05.3.3 Repair of household appliances CP NSA £m. |
| **Reuse** | £143 m (turnover – for furniture and electricals) | 2020 | An estimated 3.4 million electrical and furniture items were reused in 2020, with a reported saving of nearly £430 m for UK households[42] or an average of £126 per item. Assuming this saving represents 75% of the cost of purchasing new, the turnover associated with the sale of these reused items is estimated to be £143 m. |

No instances of remanufacturing activities for domestic appliances were identified during this project. While there are examples of both OEMs and independent actors participating in (comprehensive) refurbishment activities for domestic appliances, there is no market data available to quantify these activities and stakeholders were not able to provide an assessment from their perspective. Refurbishment activities are likely to be small in comparison to repair activities due to their low profile. Quantifying the value of reuse activities is also a challenge. Reuse activities cover a wide range of transactions, from consumer-to-consumer sales, e.g. through on-line marketplaces like Facebook Marketplace, eBay and Gumtree, to sales via charitable and voluntary organisations. The little market data that is available is most often aggregated at the level of second-hand goods, rather than disaggregated into individual product categories.

#### 8.4.1.2 Motives

There is little motivation for OEMs to extend the life of home appliances beyond the warranty period. However, new regulations such as the right-to-repair will change this. This Regulation will ensure that manufacturers have control on how repairs are done through supplying spare parts to qualified and authorised agents, thus reducing the risk of fire or shock from unauthorised repairs. (Other stakeholders note that the current right-to-repair regulations may prevent some non-safety-critical repairs being undertaken at home, which may increase waste where the labour costs of commercial repair are prohibitive.)

#### 8.4.1.3 Barriers

Interview respondents mention that focusing on value retention processes are not conducive to reaching Net-Zero. The current industry roadmap for Net-Zero focuses on increasing product efficiency and encouraging recycling.

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[41] Figure taken from the AMDEA website. Available at: https://www.amdea.org.uk/industry-information/market-information/
[42] Reuse Network Social impact report 2020

Current consumer behaviour favours buying new home appliances. Even if refurbished models were an option, consumers are likely to choose newer options. One recent exception is Dyson's refurbished units. High-end brands have an opportunity to attract a new market of people who want high-quality brands but cannot afford new products.

There has been a steady decline in the number of individuals with the right expertise to perform repairs on home appliances. Within the next few years this could result in a skills shortage in this sector.

Many advocates of right-to-repair regulations are critical of the current policy approach, as it favours professional repair over self-repair.

#### 8.4.1.4 Prospects

New Smart products can collect information about product usage and predict when products need a service. This can enable more maintenance and repair activities. However, from current sales of Smart devices, only 40% of consumers have set up this functionality making it difficult to develop a business case around maintenance operations.

Service models in which manufacturers retain the ownership of components would motivate them to develop value retention strategies to ensure they get the full value out of materials. However, despite long being advocated, these have not yet taken off.

### 8.4.2 Environmental benefits

No additional information on the environmental impacts of the repair in the UK domestic appliances sector was found in the literature or from stakeholder engagement. Therefore, to estimate the impact of repair activities at a sector level we evaluated the impacts per revenue from our study on Canadian VRP impacts (15) and scaled these to UK revenue. For repair, this gave a value of 100 kt waste avoided and 251 kt $CO_2$e avoided.

For reuse, information from the Reuse Network was used (53) which reported the waste and emissions avoided through reuse of items corresponding to the domestic appliances, furniture and ICT sectors in this study. We consider that the environmental impacts of reuse for these sectors is likely to be an underestimate as it does not account for the significant volumes of consumer-to-consumer reuse occurring.

### 8.4.3 Innovation and policy recommendations

Development of repairability and durability labelling c.f. initiatives currently being developed in France and the EU.

Minimum guarantee lengths, e.g., a five-year parts and labour warranty for small appliances would revolutionise the market.

It was noted that current conversations in the industry focus on energy efficiency of products.

## 8.5 Marine

The marine sector encompasses recreational and freight vessels. The UK is one of the leading markets for recreational marine craft which annually generates around £2.7 billion[43] of revenue. Of this, it is estimated that the second-hand market accounts for 30-40%[44]. Although it is a small sector, it has a mature value retention market. As inland marine vessels and yachts have a lifespan of 70 to 100 years, it is often common practice for these crafts to be refurbished and resold. In many cased, the internals are

[43] Figure taken from the Roadmap of the Decarbonisation of the European Recreational Marine Craft Sector. Available at: https://prod-drupal-files.storage.googleapis.com/documents/resource/public/Roadmap-for-decarbonisation-vessels_v13.pdf
[44] Stakeholder insights

refurbished while the mechanics and externals remain as is. The standards of refurbishments and remodifications are mandated by an EU Directive 2017/2018 on safety. This Directive requires vessels to be re-certified.

### 8.5.1 Industry insights

#### 8.5.1.1 Market analysis

A summary of the most recent market data collated in this study is presented in the table below:

*Table 31: Marine sector VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Remanufacturing** | £6.8 m | 2015 | European Remanufacturing Network market study (9). |
| **Remanufacturing** | £8.1 m | 2020 | 2015 data from above has been scaled to 2020 data using UKProdTO: 33.15 – Repair & maintenance of ships and boats TOTAL (£m). |
| **Repair** | £1,269 m (total)<br>£ 77.1 m (exports) | 2020 | ONS: UKProdTO: 33.15 - Repair & maintenance of ships and boats TOTAL (£m); UKProdTO: 33.15 - Repair & maintenance of ships and boats EXPORT (£m). |
| **Reuse** | £945 m | 2020 | Stakeholder insights report that, for recreational vessels, the second hand market accounts for 30-40% of the total market (£2.7 billion). We assume a value of 35% for this analysis. |

No primary data was available to update the assessment of the size of remanufacturing activities, and so we have opted to scale the market based on trends in the market for repair and maintenance. Remanufacturing activities of high value engineering components, such as engines and generators, are not expected to have undergone much change since the 2015 study and have crossover with other sectors; for example, remanufacturers of marine engines may also be involved in remanufacturing engines for other sectors such as industrial equipment, rail, HDOR and defence (see for example MTU – the power solutions and life-cycle support provider for Rolls-Royce[45]).

Reuse data was limited to recreational vessels with equivalent information for freight vessels not found. While stakeholders indicated that refurbishment is an important activity, disaggregated information on the size of this market could not be found.

#### 8.5.1.2 Motives

The refurbishment and resale market for recreational marine crafts is a mature market.

#### 8.5.1.3 Barriers

The boat industry is slower than the aerospace or automotive industries in terms of moving towards alternatives fuel sources and electrification. New regulations on e.g. low emission zones are unlikely to affect the recreational boat industry because so many boats are quite small. However, there is a move to retrofit boats with EV capabilities. Currently the industry is struggling to do this as there is a lack of infrastructure needed to update recreational boats.

The import and export of second-hand recreational boats require recertification; post-EU Exit, this process has become very expensive.

[45] MTU website, accessed December 2021 Link

#### 8.5.1.4 Prospects

Unlike for many other industries, the COVID-19 pandemic increased in the sales in recreational vessels. Stakeholders have predicted that this trend will continue to grow globally.

### 8.5.2 Environmental benefits

There is no available data on the GHG emissions for the recreational marine sub-sector but its impact is quite small in comparison to the rest of the industry. However, the reduction of emissions has been recognised as a key opportunity for development and a Clean Maritime Plan has been drawn up. This Plan includes all new vessels that will be sold in 2025, but lacks direction on how to support the retrofitting of old vessels to reduce the emissions produced from existing vessels.

A key environmental issue for the sector is the recycling of fibre reinforced plastics and glass reinforced plastic. This has become a major issue in situations where vessels cannot be retrofitted to reduce emissions. The recycling of these composites is complex and costly; therefore developing policies that support research and development into retrofit options is critical to the sector.

No information on the environmental impacts of VRP activities in the UK marine sector was found in the literature or from stakeholder engagement. The sector is also quite diverse in the type of products that are involved. Additionally, the environmental impacts of VRP activities in this sector were not evaluated as part of Oakdene Hollins' & Dillon Consulting's study on Canadian VRP impacts (15). Therefore, to estimate the impact of VRP activities at a sector level we evaluated proxy indicators for waste retained and $CO_2e$ avoided per £ revenue from the HDOR sector and scaled these to UK revenue for VRP activities in the marine sector. For remanufacturing, this gave a value of 0.1 kt waste avoided and 0.4 kt $CO_2e$ avoided. For repair, this gave a value of 2.9 kt waste avoided and 23 kt $CO_2e$ avoided.

No estimate of the environmental impact of reuse was made due to the lack of data to support this analysis.

### 8.5.3 Innovation and policy recommendations

#### 8.5.3.1 Legislation

Any future emissions policy for this industry needs to create support structures for the retrofitting of older boat models to ensure emphasis is placed on value retention.

## 8.6 Rail

The rail sector is a major contributor to the UK economy, delivering around £36 billion[46] annually and employing around 600 thousand people. The industry is made of two subsectors: rolling stock and infrastructure. The focus of this study is on examining the value retention processes for rolling stock (locomotives, carriages, wagons and other vehicles used on the railway).

Value retention in this industry is done through the refurbishment of rolling stock (physical carriages) which are controlled by companies called rolling stock operators (ROSCOs), as well as the remanufacturing of brake systems which occurs on a regular basis and is controlled by either the operator or the ROSCO.

[46] Figure taken from the RIA's Manifesto for a long term sustainable railway.(2019). Available at: https://www.riagb.org.uk/RIA/Newsroom/Publications%20Folder/RAII2050.aspx

### 8.6.1 Industry insights

#### 8.6.1.1 Market analysis

A summary of the most recent market data collated in this study is presented in the table below:

*Table 32: Rail sector VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Remanufacturing and comprehensive refurbishment** | £36.5 m | 2017 | EUROSTAT – PRODCOM database: sold production, imports and exports.<br>30209100 - Reconditioning of railway and tramway locomotives and rolling-stock. |
| **Remanufacturing and comprehensive refurbishment** | £16.9 m | 2020 | 2017 data from above has been scaled to 2020 by ONS series CPA 08:EU:EX:CVM:BOP:NSA: 30.2. Railway locomotives & rolling stock. |
| **Repair** | £1,592 m | 2019 | EUROSTAT – PRODCOM database: sold production, imports and exports.<br>33171100 - Repair and maintenance of railway and tramway locomotives and rolling-stock and of mechanical (and electro-mechanical) signalling, safety or traffic control equipment. |
| **Repair** | £1,049 m | 2020 | 2019 data from above has been scaled to 2020 by ONS series CPA 08:EU:EX:CVM:BOP:NSA: 30.2. Railway locomotives & rolling stock. |

Activity in the rail sector has been severely affected by the Covid-19 pandemic; while the activity in 2020 may have declined, we would anticipate this to recover in line with general activity in the rail sector.

#### 8.6.1.2 Motives

Extending the life of rolling stock is primary driven by economic incentives around reductions in whole-life operating costs. Trains are heavy and primarily made of metal: all rolling stock is required to meet a regulated weight which means there is a strong emphasis on material retention.

Rolling stock is treated in a cascading model, where once higher-income operators replace their trains, lower-income operators receive refurbished rolling stock.

#### 8.6.1.3 Barriers

The Department for Transport's (DfT) franchising policy favours the purchasing of new rolling stock through providing low cost finance.

Some respondents have reported that relying too much on VRPs will lead to technology lock-in. This is especially important as trains cannot easily be made lighter to reduce energy usage.

Cheaper imports have become a huge challenge for exporting refurbished rolling stock outside of the UK.

#### 8.6.1.4 Prospects

The electrification of trainlines is an incredibly expensive operation as much of the infrastructure requires retrofitting. This means that current rolling stock technology will still be is use in the next decade or two.

Including an export strategy in the cascading model can boost VRP operations.

### 8.6.2 Environmental benefits

No information on the environmental impacts of VRP activities in the UK rail sector was found in the literature or from stakeholder engagement. Additionally, the environmental impacts of VRP activities in this sector were not evaluated as part of Oakdene Hollins' & Dillon Consulting's study on Canadian VRP impacts (15). Therefore, to estimate the impact of VRP activities at a sector level we evaluated proxy indicators for waste retained and $CO_2e$ avoided per £ revenue from the HDOR sector and scaled these to UK revenue for VRP activities in the rail sector. For remanufacturing, this gave a value of 0.2 kt waste avoided and 2.4 kt $CO_2e$ avoided. For repair, this gave a value of 0.8 kt waste avoided and 19 kt $CO_2e$ avoided.

No estimate of the environmental impact of reuse was made due to the lack of data to support this analysis.

### 8.6.3 Innovation and policy recommendations

#### 8.6.3.1 Legislation

Changing weighting regulations for rolling stock that still meets crash regulations will allow for the use of alternative, more lightweight material.

The shift in public procurement practices to increase the importance of environmental impacts through the supply chain may present an opportunity to formalise VRPs within public procurement guidelines, c.f., the increased prominence of VRPs within sustainable ICT procurement frameworks, supported by practitioners like Circular Computing (see case study). However, this will only happen if those driving changes are aware of VRPs and may be in competition with other innovation and priorities, e.g., biodiversity and hydrogen are a current focus for the rail sector.

## 8.7 Medical devices

The medical device industry in the UK is primarily made of SMEs. The sector is made up of around two thousand companies that employ around five thousand people[47]. There are an estimated 10 thousand different types of medical devices that range from syringes, wheelchairs and blood prick tests to x-ray machines.

The industry is dominated by OEMs such as Johnson & Johnson, GE, Siemens, Philips, and hundreds of third-party providers the majority of which are SMEs.

### 8.7.1 Industry insights

These devices are either based on mechanical, electrical and/or material engineering; this means that the type of applicable value retention differs across different devices. There are very limited manufacturing or VRPs currently happening within the UK. Most refurbished or remanufactured products are therefore imported.

[47] Figures taken from the Association of British Healthcare Industries

#### 8.7.1.1 Market analysis

A summary of the most recent market data collated in this study is presented in the table below:

*Table 33: Medical device sector VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Repair** | £411 m | 2019 | EUROSTAT – PRODCOM database: sold production, imports and exports.<br>33131200 - Repair and maintenance of medical and surgical equipment. |
| **Repair** | £370 m | 2020 | 2019 data from above has been scaled to 2020 by ONS series CPA 08:RW:EX:CP:BOP:NSA: 32.5. Medical & dental instruments & supplies. |

#### 8.7.1.2 Motives

The remanufacturing of medical imaging devices is well-established and is controlled by ISO standards. This was driven by economic reasons and the need to meet the demand for imaging devices. The main driver for this is therefore access to medical care.

Most recently, some organisations have included VRPs within their sustainability strategy to reach their Net-Zero targets.

The NHS Net-Zero ambitions including supplier frameworks requiring carbon footprinting, changes to public accounting rules (PPN 06/21), and public procurement criteria are all likely to stimulate more VRP activities, due to associated emissions reductions.

Managed services can play an important role in repair and recovery of medical devices and their components, e.g., for parts harvesting. Managed services can support the reliability and performance of medical devices, as well as enhance the throughput of repair and recovery activities. These benefits may be more significant than the value from the VRP activity itself.

Some devices can be cascaded to other uses, e.g., vetinerary, as the performance demands are lower.

#### 8.7.1.3 Barriers

Medical devices cover a broad range of products which are incredibly complex. Finding 'one-size fits all' policies to address the standards needed for remanufactured products is impossible.

The NHS procurement process favours new and cheaper medical device options. Refurbished or remanufactured device options are not often chosen. Additionally, MHRA guidelines on remanufactured medical devices created by UK Government put sole responsibility on remanufacturers, thus dissuading them from investing in operations or sales in the UK.

There is no regulatory barrier to the procurement of refurbished machines, rather barriers around business culture and perception are greater challenges.

From an economies of scale point of view, there is a lack of available core for possible candidates for remanufacturing.

For single-use devices, OEMs often incorporate 'killer components'; this becomes a challenge for any independent remanufacturer. In addition, independent actors must design their own testing equipment.

Many top end medical devices are retired due to advances in technology and demands of medical treatments and/or are worked to the point where they become uneconomic to repair.

#### 8.7.1.4 Prospects

A technical committee on remanufacturing standards for medical devices has been formed under BSI. The development of standards for medical device remanufacturing could help drive the market.

Changing hospital procurement tenders to include emissions factors can encourage the purchasing of remanufactured components.

### 8.7.2 Environmental benefits

No information was available on the environmental benefits of VRPs for medical devices.

### 8.7.3 Innovation and policy recommendations

#### 8.7.3.1 Legislation

Policymakers need to ensure that regulations and policies created do not inhibit innovation.

Stakeholders have noted that creating policies around mandatory carbon reporting would force organisations to focus on sustainable design and value retention.

Expanding right-to-repair policies to medical devices would empower independent actors to remanufacture devices.

## 8.8 Furniture

The furniture industry includes three key sub-sectors where VRPs take place:

- Domestic furniture.
- Office furniture.
- Hospitality furniture.

Overall, there is not a large emphasis on value retention in this sector. The area where value retention is the most mature is the office furniture space, as organisations would often lease both real estate and furniture. This set-up has pushed companies that owned to furniture to invest in facilities to repair and refurbish furniture. The sub-sector is valued at around £600 million where 5% is made up of furniture from VRPs.

In the UK, the main VRP for domestic furniture is reuse. This is facilitated through second-hand charity shop sales and online marketplaces. The hospitality sector often purchases the cheapest and the most in-vogue furniture. At EoL, the furniture is completely worn, and value cannot be retained.

The industry is trying to focus efforts on dealing with EoL waste rather than promoting value retention processes. The main value retention process in this sector is refurbishment.

Second-hand online marketplaces often cater specifically to individuals selling or looking for second-hand goods such as furniture. In the UK, the most popular platforms are eBay, Gumtree and Facebook Marketplace. Unlike traditional platforms that prioritise a single vendor, these platforms provide space for multiple vendors and can host auction-style bidding.

These platforms have become increasingly popular in recent years. And although the sale of second-hand furniture has taken place in charity shops, garage sales and flea markets, these sites have extended the reach of second-hand sales.

### 8.8.1 Industry insights

#### 8.8.1.1 Market analysis

A summary of the most recent market data collated in this study is presented in the table below:

*Table 34: Furniture sector VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Remanufacturing, comprehensive refurbishment and refurbishment** | £30 m | 2020 | Stakeholder insights – VRPs make up 5% of the ~£600 m market for office furniture. |
| **Repair** | £13 m | 2020 | ONS series 05.1.3 Repair of furniture etc CP NSA £m. |
| **Reuse** | £143 m (turnover – for furniture and electricals) | 2020 | An estimated 3.4 million electrical and furniture items were reused in 2020, with a reported saving of nearly £430 m for UK households[48] or an average of £126 per item. Assuming this saving represents 75% of the cost of purchasing new, the turnover associated with the sale of these reused items is estimated to be £143 m. |

As described in Section 8.4.1.1 on domestic appliances, reuse activities cover a wide range of transactions, from consumer-to-consumer sales, e.g. through on-line marketplaces like Facebook Marketplace, eBay, and Gumtree, to sales via charitable and voluntary organisations. The little market data that is available is most often aggregated at the level of second-hand goods, rather than disaggregated into individual product categories.

#### 8.8.1.2 Motives

The reuse and refurbishment of office furniture is motivated by leasing or office logistic organisations getting the most value out of furniture before it is discarded.

Furniture collection is aggregated providing larger volumes of feedstock for VRPs.

There is still a significant market for restoration and repair of antiques, although sales have been in decline. Data on VRPs for antiques are elusive.

Much domestic furniture VRP will take the form of small scale repair and maintenance. The cost of such processes can be low and the value high.

#### 8.8.1.3 Barriers

Collecting office furniture for refurbishment requires large storage spaces. Manufacturing is often driven by just-in-time processes and there is limited warehousing space for new furniture.

As in many other sectors, low-cost imports are a notable challenge to promoting reused or refurnished products. Consumers also tend to focus on buying furniture that is currently on-trend.

Tender processes favour the purchasing of new furniture, especially when the tender is specifically asking for refurbished products. This is because information requested in tenders is often about material composition, and this is information that only OEMs possess.

[48] Reuse Network Social impact report 2020

Research funding into repair activities in the UK does not reflect the increase in interest and importance of this topic (e.g., the prospect of repairability labels).

#### 8.8.1.4 Prospects

Some organisations in the office furniture sector are examining the possibility of modular design options. This is still quite challenging due to consumer perception and challenges around re-upholstery.

Partnering with OEMs to become authorised refurbishers allows independent organisations to be commercially non-threatening. A prime example of this is Crown Workspace who are authorised refurbishers of Herman Miller office furniture.

Upcycling of furniture is a growth area, though often undertaken at home rather than in the formal economy.

Design for disassembly and using standardised components would support greater VRP activity in this sector.

There has been significant growth in research on repair, which will likely be fuelled further by the prospect of repairability labels.

### 8.8.2 Environmental benefits

No additional information on the environmental impacts of repair in the UK furniture sector was found in the literature or from stakeholder engagement. Therefore, to estimate the impact of remanufacturing, refurbishment, and repair activities at a sector level we evaluated the impacts per revenue from Oakdene Hollins' & Dillon Consulting's study on Canadian VRP impacts (15) and scaled these to UK revenue. For remanufacturing, refurbishment, and repair, this gave a value of 13 kt waste avoided and 26 kt $CO_2e$ avoided.

For reuse, information from the Reuse Network was used (53) which reported the waste and emissions avoided through reuse of items corresponding to the domestic appliances, furniture and ICT sectors in this study. We consider that the environmental impacts of reuse for these sectors is likely to be an underestimate as it does not account for the significant volumes of consumer-to-consumer reuse occurring. However, as discussed in the Canadian VRP study (15), the environmental impacts of reuse are predicated on assumptions around whether reuse displaces new sales (previous studies have indicated that only around 20% of new sales are displaced (54)). Therefore, a priority for policymakers would be to ensure that wooden furniture is diverted from landfill, where it may produce methane, and instead is sent for recycling or energy recovery, where it would be more likely to displace virgin material.

### 8.8.3 Innovation and policy recommendations

#### 8.8.3.1 Legislation

Providing tax benefits to companies that choose refurbished furniture over new furniture would encourage organisations to make sustainable choices based on economic reasons.

Similarly, a carbon tax on imports would ensure that these products are the same price or even more expensive than local second-hand or refurbished furniture.

#### 8.8.3.2 Technology

It is often difficult to identify the types of material in a product at the end of its life.

## 8.9 Industrial equipment and the energy sector

This section combines two VRP markets: industrial equipment and the renewable energy sector.

Industrial equipment encompasses a diverse range of products, often associated with high capital costs and customisation. The sector is relatively mature in terms of VRP activities because of the strong motivation to extend the life of assets and maximise retained value. Through-life engineering services are particularly relevant for this sector, with a strong focus on minimising downtime, particularly unexpected downtime, due to the potentially high costs associated. Because of the extremely diverse nature of this sector, it is challenging to quantify aspects of VRP activities, such as environmental impacts.

Related to industrial equipment is equipment associated with energy production. This sector is of particular interest as in the renewable energy sector demand for equipment is increasing rapidly, in line with decarbonisation ambitions. This could represent a significant new market for applying VRPs, as is starting to be evident in the wind sector. The wind sector is made up of various actors such as OEMs that can operate as component manufacturers, repairers, turbine operators or all three; independent players focusing on repair and maintenance; and independent players focusing on decommissioning. Within repair activity, some actors remanufacture components.

### *8.9.1 Industry insights*

#### *8.9.1.1 Market analysis*

A summary of the most recent market data collated in this study is presented in the table below:

*Table 35: Industrial machinery and energy generation devices sector VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source + notes |
|---|---|---|---|
| **Remanu-facturing** | £102 m | 2020 | European Remanufacturing Network market study (9) |
| **Remanu-facturing** | £112 m | 2020 | 2015 data from above has been scaled to 2020 data using the ONS Series: Repair Services of Machinery for Domestic Market |
| **Repair** | £3,726 m (sold production) | 2019 | EUROSTAT – PRODCOM database: sold production, imports + exports, including codes:<br>33111200 - Repair + maintenance of metal tanks, reservoirs, vats + other containers<br>33111300 - Repair + maintenance services of steam generators (excluding central heating hot water boilers) + of systems of metal pipes in industrial plants<br>33111900 - Repair + maintenance of non-domestic central heating boilers<br>33121100 - Repair + maintenance of engines + turbines (excluding aircraft, vehicle + cycle engines)<br>33121210 - Repair + maintenance of pumps + compressors<br>33121220 - Repair + maintenance of taps + valves<br>33121400 - Repair + maintenance of furnaces + furnace burners<br>33121800 - Repair + maintenance of non-domestic cooling + ventilation equipment<br>33121990 - Repair + maintenance of other general purpose machinery n.e.c.<br>33122200 - Repair + maintenance services of metalworking machine tools<br>33122300 - Repair + maintenance of machinery for metallurgy<br>33122500 - Repair + maintenance of machinery for food, beverage + tobacco processing<br>33122600 - Repair + maintenance of machinery for textile, apparel + leather production<br>33122700 - Repair + maintenance of machinery for paper + paperboard production |

| VRP category | Value (2020 inflation adjusted) | Year | Source + notes |
|---|---|---|---|
| | | | 33122800 - Repair + maintenance services of machinery for plastics + rubber<br>33122910 - Repair + maintenance service of machine tools for working wood, cork, stone, hard rubber + similar hard materials<br>33122990 - Repair + maintenance of other special-purpose machinery n.e.c.<br>33131110 - Repair + maintenance of instruments + apparatus for measuring, checking, testing, navigating + other purposes (excluding industrial process control equipment)<br>33131120 - Repair + maintenance of industrial time measure instruments + apparatus<br>33141120 - Repair + maintenance of electric motors, generators + transformers<br>33141150 - Repair + maintenance of electricity distribution + control apparatus |
| **Repair** | £3,795 m (sold production | 2020 | 2019 data from above has been scaled to 2020 by ONS series Repair Services of Machinery for Domestic Market |

No primary data was available to update the assessment of the size of remanufacturing activities for this sector, and so we have opted to scale the market based on trends in the market for repair and maintenance. However, based on anecdotal evidence, we believe the true value of remanufacturing activity for industrial equipment could be much larger. We know from SIC definitions that rebuilding or remanufacturing of machinery and equipment is excluded from the repair classes and instead included within the manufacturing class.

No economic data could be found on the reuse of industrial equipment, although we know this is occurring; for example, 70 dealers of used machinery stock and equipment are listed on the dedicated on-line marketplace, Machinery Classified (55).

#### 8.9.1.2 Motives

The high capital costs and variety of industrial machinery and equipment creates a strong incentive to retain this value through VRPs.

#### 8.9.1.3 Barriers

In the industrial equipment sector, there is a shortage of skills to find and train the right electrical engineering expertise. A strategy is needed to attract graduates to organisations. One organisation that does this well is Siemens, who uses its brand to attract top talent.

Components found in wind turbines often pass through several actors before they are installed in the turbine. In many cases serial numbers issued by Tier 1 suppliers are removed and replaced by numbers issued by OEMs. When independent repairers and remanufacturers attempt to reverse-engineer components, it is difficult to track the original drawings; and OEMs are often reluctant to supply parts needed for these processes.

### 8.9.2 Environmental benefits

No information on the environmental impacts of VRP activities in the UK industrial equipment sector was found in the literature or from stakeholder engagement. The sector is also extremely diverse in the type of equipment that is involved. Additionally, the environmental impacts of VRP activities in this sector were not evaluated as part of Oakdene Hollins' & Dillon Consulting's study on Canadian VRP impacts (15). Therefore, to estimate the impact of VRP activities at a sector level we evaluated proxy indicators for waste retained and $CO_2e$ avoided per £ revenue from the HDOR sector and scaled these to UK revenue for VRP activities in the industrial equipment sector. For remanufacturing, this gave a value of 1.5 kt waste avoided and 5.4 kt $CO_2e$ avoided. For repair, this gave a value of 8.6 kt waste avoided and 69 kt $CO_2e$ avoided.

### 8.9.3 Innovation and policy recommendations

#### 8.9.3.1 Legislation

Right-to-repair legislation in the wind industry will require OEMs to supply parts and information to independent actors.

#### 8.9.3.2 Technology

3D printing in the repair and maintenance of wind turbines would enable the production of components on a scale and within a reduced lead time that would streamline repair operations.

QR coding or block chain technology in the wind turbine value chain would enable independent actors to easily obtain information needed to refurbish or remanufacture components to the correct standards.

#### 8.9.3.3 Collaboration

Collaboration between all parties, including universities, is required if the UK wishes to be the leader in wind energy VRP innovation.

## 8.10 ICT

The United Kingdom is the second largest ICT market in the world (ICT spending per head)[49]. VRPs that occur in this sector are reuse, repair, refurbish and remanufacture. The sector consists of business-to-business (B2B) and business to consumer (B2C) markets.

At a B2B level, the number of available VRP options is limited but organisations like Hewlett Packard Enterprise and Circular Computing are quite active. In many cases an individual servicing centre supports a whole region. The desk-based study performed found that none of these centres were in the UK.

B2C operations differ to this, with a multitude of repairers existing. This includes authorised and unauthorised repairs.

### 8.10.1 Industry insights

#### 8.10.1.1 Market analysis

A summary of the most recent market data collated in this study is presented in the table below:

*Table 36: ICT sector VRP activity*

| VRP category | Value (2020 inflation adjusted) | Year | Source and notes |
|---|---|---|---|
| **Remanufacturing, comprehensive refurbishment** | £215 m | 2015 | European Remanufacturing Network market study (9). |
| **Remanufacturing, comprehensive refurbishment** | £ 271 m | 2020 | 2015 data from above has been scaled to 2020 data using the ONS Series: GBServTO: 95 - Repair servs of computers/personal & household goods TOTAL (£m). |

[49] United Kingdom – Country Commercial Guide Information Communication Technology Link

| | | | |
|---|---|---|---|
| **Repair** | £5,928 m | 2020 | ONS Series GBServTO: 95 - Repair servs of computers/personal & household goods TOTAL (£m). |
| **Reuse** | £143 m (turnover – for furniture and electricals) | 2020 | An estimated 3.4 million electrical and furniture items were reused in 2020, with a reported saving of nearly £430 m for UK households[50] or an average of £126 per item. Assuming this saving represents 75% of the cost of purchasing new, the turnover associated with the sale of these reused items is estimated to be £143 m.. |

The ONS category found for repair services of computers/personal & household goods is likely to be broader in scope than the ICT sector category of this study and therefore likely to be an overestimate. A more disaggregated value was not found during this study, nor specific insights available from stakeholders.

As described in Section 8.4.1.1 on domestic appliances, reuse activities cover a wide range of transactions, from consumer-to-consumer sales, e.g. through on-line marketplaces like Facebook Marketplace, eBay and Gumtree, to sales via charitable and voluntary organisations. The little market data that is available is most often aggregated at the level of second-hand goods, rather than disaggregated into individual product categories. The reuse market for ICT is anticipated to be significantly larger than indicated here.

#### 8.10.1.2 Motives

This sector is highly motivated to find opportunities in circularity through promoting value retention and developing insights into modular design principles. This is driven by the need to retain critical raw materials used in many of these devices.

#### 8.10.1.3 Barriers

Finding the right resources with the skills to repair and refurbishing of ICT equipment is key. In Ireland, WEEE circular economy strategies include training programs to reskill people in this sector, for example.

Third party or unauthorised sales bring up issues around legal liability and safety. Additionally, data privacy has become a topic of discussion for discarded electronics.

#### 8.10.1.4 Prospects

Government divisions are looking at leased procurement models for ICT equipment in their drive to move towards a greener way of operating.

The current shortage of critical raw materials and the shift to a work-from-home set-up have forced organisations to look for alternative laptop procurement options. These options include refurbished or remanufactured laptops.

### 8.10.2 Environmental benefits

No additional information on the environmental impacts of remanufacturing and repair in the UK ICT sector was found in the literature or from stakeholder engagement. Therefore, to estimate the impact of remanufacturing and repair activities at a sector level we evaluated the impacts per revenue from Oakdene Hollins' and Dillon Consulting's study on Canadian VRP impacts (15) and scaled these to UK revenue. For remanufacturing this gave a value of 7 kt waste avoided and 39 kt $CO_2e$ avoided. For repair this gave a value of 156 kt waste avoided and 1,400 kt $CO_2e$ avoided.

For reuse, information from the Reuse Network was used (53) which reported the waste and emissions avoided through reuse of items corresponding to the domestic appliances, furniture and ICT sectors in

[50] Reuse Network Social impact report 2020

this study. We consider that the environmental impacts of reuse for these sectors is likely to be an underestimate as it does not account for the significant volumes of consumer-to-consumer reuse occurring.

### 8.10.3 Innovation and policy recommendations

#### 8.10.3.1 Legislation

A tax reduction on spare parts for authorised repairers would encourage consumers to choose safer repair options, as consumers often compare authorised repairer prices to online prices.

Other stakeholders felt that a tax reduction on spare parts on its own would not be sufficient to make repair economic due to the “hugely overpriced” authorised parts, with reduction or removal of taxes on labour also needed.

Standardised parts may often be preferrable in relation to design for sustainability and consumer access.

# 9 UK's strategic position

- The UK has a **strong base** from which to build based on its manufacturing capabilities and circular economy focus. However, **other nations** - notably China and the USA - are **moving fast** into this space.
- **Barriers** for VRPs are not just **technological**; there are also **behavioural** and **policy** barriers.
- **Opportunities for innovation** exist; however, while much technological innovation would support **improving efficiency** and **opening new markets**, for step changes in VRP activities, more **systemic changes**, including policy, would be needed.

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This section provides an overview of the key industry barriers and drivers to VRP identified at UK-level and across the sectors. Through a gap analysis and industry case studies, it also highlights opportunities for Innovate UK to support industry efforts in transitioning to a circular economy.

- Section 9.1 presents a SWOT analysis of the current UK's positioning in VRP activity.
- Section 9.2 presents insights into barriers and opportunities to VRP at sector-level.
- Section 9.2 provides a gap analysis to demonstrate the current programmes in this area, where increased focus is needed, and how the current system could change to support future growth in remanufacturing and other VRPs.

The presented research has been conducted using a mixed-method approach which included industry interviews and literature reviews, as specified in Section 3 of this report. Sections 9.1 and 9.2 are based on data gathered during industry interviews.

## 9.1 SWOT of UK's VRP activity

The objective of the SWOT analysis is to identify the current conditions enabling or hindering the UK-wide adoption of VRP. The following diagram provides a high-level summary of the SWOT analysis, with each element explained in more detail in the subsequent table.

*Figure 26: UK SWOT for VRP activities*

| | | | |
|---|---|---|---|
| **STRENGTHS** | *UK resources or capabilities that enable the UK-wide adoption of VRPs:*<br>• Strong engagement in standards development.<br>• Strong research activity – key universities.<br>• Well-established VRP industries in aero, auto, industrial equipment.<br>• Strong circular economy focus (NICER programme, Defra working group on circular economy for Net-Zero).<br>• Advanced manufacturing capabilities (that could be applied to VRPs). | **OPPORTUNITIES** | *Favourable situations in the environment that enable the UK-wide adoption of VRPs:*<br>• International focus on emissions reduction (policy level) – would increase awareness of VRP activities for consideration in trade policy<br>• Increasing feasibility/acceptance of carbon tax measures – would increase competitiveness of VRP activities.<br>• Increasing interest internationally e.g. Canada – VRP strategy, EU – Circular Economy Action Plan, USA – Circular Economy, China – 5-year strategy, Wales and Scotland – opportunities to collaborate.<br>• New markets, such as renewables and EVs.<br>• Leveraging existing business advisory services. |
| **WEAKNESSES** | *Limitations, faults or defects that may hinder the UK-wide adoption of VRPs:*<br>• Declining manufacturing base.<br>• Ageing manufacturing/VRP work force.<br>• Absence from public procurement.<br>• High labour costs.<br>• Weak industry-academia engagement on VRP topics.<br>• Restrictive policies on waste.<br>• Lack of visibility (industry statistics, consumer awareness).<br>• Unfavourable perceptions of VRP activities. | **THREATS** | *External barriers and challenges to the UK-wide adoption of VRPs:*<br>• Competition from low-cost imports.<br>• Development of remanufacturing hubs outside the UK.<br>• Uncertainty in trade/tariffs.<br>• Post-Brexit customs challenges. |

*Table 37: Explanation and further details for SWOT elements*

| Strengths | Explanation/further details |
|---|---|
| Strong engagement in standards development | The UK has been the only European nation to develop a cross-sectoral standard (BS 8887-2:2009) that differentiates remanufacturing from other processes (10). There are multiple technical committees at BSI working on the topic of remanufacturing standards (furniture, medical devices, automotive, etc.) and the UK has recently concluded a Joint Working Group activity with China on the same topic. This demonstrates there is an industry pull for standards in this area and a willingness to collaborate. |
| Strong research activity – key universities | A non-exhaustive list of VRP expertise in the UK includes (in alphabetical order): Cranfield University (TES); Nottingham Trent University (product life extension); University of Birmingham (remanufacturing); University of Brighton (remanufacturing); University of Creative Arts (repair); University of Exeter (Circular Economy); University of Loughborough (remanufacturing); University of Strathclyde (remanufacturing); Warwick Manufacturing Group (remanufacturing) |
| Well-established VRP industries in aero, auto, industrial equipment | With the origins of remanufacturing in the support of military assets from World War I onwards, it is unsurprising that aerospace and automotive show strength. Coupled with the fact that these are global industries under strong competition, highly regulated with safety and liabilities built in, there is an emphasis on maintaining leading-edge practices. However, the nature of modern manufacturing is one where many functions are outsourced. As a result, these sectors also display clustering effects where a ‘cloud’ of suppliers and service providers of specialist sub-systems retains much of the competence in the field. Often the headline brands are simply system assemblers. A consequence of this is that the smaller, specialist suppliers need to be nurtured to provide the genuine innovative backbone, but the aggregators are needed to provide the channel to market, especially when higher risk ‘game-changer’ developments are being considered. |
| Strong circular economy focus (NICER programme, Defra working group) | After a slow start, the UK has been a strong advocate of circular economy principles: in the private sector through the globally recognised Ellen MacArthur Foundation, and more recently through public measures to underpin the theoretical and evidence base roots of the topic through the CE-Hub based in Exeter, and the NICER programme. Materials- and process-based efficiency programmes have been a feature of Innovate UK funding since 2004, with some experimentation in business model innovation and – latterly – designing for circularity. An increased focus throughout on carbon should be a driver for embedding enabling practices such as CE more widely in academic and business thinking. The activity currently underway via the Defra working group on circular economy for Net-Zero also demonstrates the strong commitment to circular economy, in which VRPs play an important role. |
| Advanced manufacturing capabilities (that could be applied to VRPs) | UK has a track record in the development of high-value manufacturing capabilities with a particular relevance to VRPs. These techniques include: additive/subtractive techniques suited to remediation with minimum material and energy inputs; computer recognition and net-shape modelling which can be linked to CNC tooling and additive manufacturing as well as for automated part design recall; an extremely strong materials science and R&T base with effective transfer into industry; and a network of advanced manufacturing centres that can adapt to develop and pilot techniques for single companies or consortia. |

| **Weaknesses** | **Explanation/further details** |
|---|---|
| Declining manufacturing base | Although a fair fraction of this apparent decline has been attributed to the 1980's outsourcing on non-core activities from industry, there has been a genuine shift to import of manufactured goods. Cost competitiveness does play a large part in this, but the upside is that there is a concentration of high-knowledge-added manufacturing which could be nurtured to advance the VRP base and even work upstream into manufacturing via the garnering of important product knowledge which VRPs bring. |
| Ageing manufacturing/VRP work force | A strength and weakness of the 'highest' VRPs is their reliance on time-served labour which harbours diagnostic skills in particular. These skills are often acquired having graduated through manufacturing. In tandem with the above, a declining manufacturing base could result in a reduced pool of skills, which is aging and retiring. One implication of this is that – particularly in the high-value sectors – there should be a coordinated effort to ensure a pipeline of reman-ready engineers and technicians nurtured from the manufacturing base. For the bulk of VRPs, the wider dissemination and codification of supporting skills must be embedded through a practically-oriented further education system focussing on key skills. Work in 2016 for WRAP Cymru assessed the skills capacity and training provision for remanufacturing in the aerospace, automotive, electronics, and energy sectors (56). |
| Absence from public procurement | Public procurement has long been proposed as a driver for pulling through innovation and sustainable practices. Green Public Procurement is a well-establish headline activity but cannot be considered a blazing success. For a start, most 'greenness' has reverted to consideration of materials consumption and waste reduction (the easy targets) rather than products. There have been deficiencies in defining template principles and practices which can be rolled out throughout the public sector. These need to be focussed on clear metrics for success or lifetime performance expectation, for example expressed as net carbon or materials intensity. This is compounded by the permanent disjoint between capital and revenue aspects of purchase which mean that true lifecycle costing is rarely undertaken. In this respect, the Welsh Government again intends to lead the way by shifting public sector focus to products from recycling. In short, there need to be clear, targeted expectations of lifecycle value (money, carbon, other impacts) translated into actionable purchasing protocols. |
| High labour costs | It is almost axiomatic that high labour costs will act against not just VRPs but any importable competitive business, and that having high labour costs is, fundamentally, a political choice. In this context, we need to acknowledge that VRPs are inherently labour-intensive, swapping people for materials and energy. It is a fundamental tenet of capitalism that costs will be driven down to favour cheapest sources. Again, VRPs follow the same rules: although more labour intensive, they still need to drive for greater efficiencies, especially when they have emerged in 'empty' competitive spaces which then become more crowded over time. However, this shifts the focus to other sources of value. For example, automation is a response available to offsetting labour and this needs to be a focus of VRP support; new materials and techniques can reduce input costs. |
| Weak industry-academia engagement on VRP topics | Although there is a good academic community assembling for CE topics, there is a still a legacy focus on material circularity rather than product life extension. This focus is a good platform for dealing with end-of-life agents, but a poor platform for engaging with manufacturers, remanufacturers and VRP agents. One agenda of the current project has been to help start to address this issue through use of, specifically, the Exeter CE-Hub in exploration and validation workshops. However, more work needs to be done to re-orientate the evidence base community towards 'higher value' outcomes (i.e., higher value VRPs) and contributory processes and technologies. |

| | |
|---|---|
| Restrictive policies on waste | The historic focus on recycling in waste policy has led to a race to the bottom of the waste hierarchy, i.e. recycling and incineration, rather than the higher tier (VRP) activities. While the focus remains on recycling, actors will be motivated to continue the status quo and use the mature recycling infrastructure that exists in the UK. Even within the circular economy narrative there is a danger of a focus on waste management, rather than the waste avoidance that VRPs can offer. By re-framing the policy focus towards higher value and impact VRP activities, investment would be made and behaviour would change. |
| Lack of visibility (industry statistics, consumer awareness) | The need for this study is in many ways a testament to the inadequacy of national statistics related to VRPs. Lack of statistics restricts the ability to monitor trends and impacts of actions and, potentially, target communication to stakeholders such as consumers on where they can engage, make an impact and profit. It could be argued that a general overhaul of national material and product statistics is needed to modify a system which was adequate for a linear economy but is not adequate for a circular one. For example, on materials, statistics largely monitor only where 'stuff' crosses the 'line of waste' into public waste management or import/export and recycling operations. Since VRPs keep 'stuff' in use before consignment as waste, the statistics have no benefit when studying VRP effectiveness. On the monetary side, though money is well accounted for, again the categorisation of the transforming operations (SIC codes) is inadequate to differentiate the various VRP operations in play beyond 'repair' (occasionally). Further, the motivator for VRPs is strongly related to other 'value' propositions such as employment per £ generated and carbon emissions especially. Linking the various VRP monetary effects to Scope 1, 2 and 3 emissions accounts would provide a radical boost to understanding the true benefits and opportunities for intervention. It would eliminate the limitations of coarse-grained market studies which crudely hint at movements in practice and outcome. |
| Unfavourable perceptions of VRP activities | VRPs can be seen as low value, "dirty" work, and the transition to, or entry into a VRP business model can be complex and difficult to trial. Raising the profile of exemplars like Autocraft Drivetrain Solutions and Flex can show how VRPs can be high-tech, highly skilled, clean, interesting, rewarding, even creative. |
| **Opportunities** | **Explanation/further details** |
| International focus on emissions reduction (policy level)– would increase awareness of VRP activities for consideration in trade policy | The recent focus in the UK on Scope 3 emissions already provides a mechanism to focus on VRPs. It is well-established that their impacts are highly beneficial in reducing lifecycle emissions through both lower virgin material inputs and processing emissions. Making such impact declarations public internationally would have several effects: Firstly, making VRP benefits transparent, demonstrating their importance and role in decarbonisation; secondly, offering a mechanism to 'level up' the playing field by disadvantaging high-carbon products, possibly by linking to a carbon trading system; thirdly and more fundamentally, allowing international accounting and credit for net effects. One issue with VRPs is that, although they net reduce global warming potential (GWP), they locally increase retention of input resources with a greater reduction in manufacturing inputs. Where much manufacturing is offshore, these reductions are seen in the originating country, albeit with a hit to the local economy. This could motivate a response to either increase barriers to knowledge sharing or – preferably - stimulate efforts globally to decarbonise manufacture. |

| | |
|---|---|
| Increasing feasibility/ acceptance of carbon tax measures – would increase competitiveness of VRP activities | Although the energy price of carbon is already built into products, these costs do not consistently explicitly account for the externalities associated with different sources of energy, in particular a carbon-based one. A carbon tax has been mooted as a means of making GWP impacts of products and services more explicit and even internationally tradeable (or perhaps used as barriers, hurdles or enablers of targeted import/export actions). As per the opportunity above, Scope 3-type declarations are an underpinning feature of such systems as they place impact assessment on a standardised basis. |
| Increasing interest internationally | Within the last five years, the awareness of CE as a tool in sustainability has undergone a transformation. In an even shorter timescale, climate change has elevated carbon to the highest priority with an explosion of corporate interest and a rush of government commitments. However, the role of CE as a tactic in carbon reduction is recognised less widely. This study – and other research – shows a strong willingness to engage on the topic and take actions to underpin VRP practices through standards and technology development. There is also the opportunity to build on the ambition in Scotland and Wales: In Scotland, there is the “Making Things Last” strategy, along with the Scottish Institute for Remanufacturing and its industrial networks. In Wales, the “Beyond Recycling” strategy seeks to build on their achievements in recycling and elevate activity to higher-value CE activities, such as VRPs. |
| New markets, such as renewables and EVs. | Focus on climate change is motivating vast technology shifts. Renewables is a clear example, as is the drive for electric vehicles. EVs represent a radical shift in technology and indeed ownership of intellectual property. Conventionally, vehicle brands manufactured engines and drivetrains, outsourced peripherals and so owned the knowledge of the ‘core’. In EVs, the powertrain is now outsourced to a handful of specialist suppliers oriented to power-based technologies such as batteries and motor-generators (often the existing Tier 1 suppliers). This means that future VRP demands will also shift not only by technology, but also by owner of the technology. It is uncertain whether these system providers will engage in future VRPs, though most do already in electromechanical systems. Nevertheless, the signals are clear that new and enhanced competences are required to innovate, build and maintain these new technologies, with an opportunity to design VRPs into these products and business models. |
| Leveraging existing business advisory services | Business advisors in programmes such as Innovate UK Edge and Made Smarter may not typically be aware of some VRP activities (most notably remanufacturing). There is an opportunity to raise awareness of these VRP-activities to leverage the existing information channels used by business. In the case of Made Smarter there is particular synergy between Industry 4.0 and VRPs and an opportunity to connect the digital revolution with a sustainability revolution in a coherent way for SMEs to take on board. |
| **Threats** | **Explanation/further details** |
| Competition from low-cost imports | To some extent this is related to the issue of high-cost labour. However, it also concerns whether the same environmental standards and costs are being applied in offshore manufacturing companies; and whether the products are offering like-for-like functionality (such as endurance or service support). This latter is becoming less of an issue as developing nations advance their state of skills and knowledge, but the former is still relevant. Lately, because of COP26-type commitments, issues related to GWP at least will come under scrutiny, and may be made transparent by any actions motivated by the Opportunities: International piece, above. |

| | |
|---|---|
| Development of remanufacturing hubs outside the UK | Interest in the circular economy and VRPs has been accelerating over the last five years although coherent overarching responses are in the minority. The USA pioneered the concept of a hub at the Golisano Institute at Rochester; the Chinese adoped a centralised approach through the National Key Remanufacturing Laboratory. Canada aspires to create a national VRP/remanufacturing strategy but implemented in a devolved manner. In summary, components of a comprehensive approach exist in various regions. The European Remanufacturing Network study of 2015 proposed a coordinated 3-pillar approach based on research, technology and industry support, and business advisory, but this has not been translated into either virtual or actual facilities. The opportunity exists in the UK to establish a 'hub' comprising the linked capabilities of the CE-Hub, an ATI-like scanning and coordinating facility linked to BEIS/UKRI, and a network of supporting business advisory and consultancy companies translating policy and knowledge into practice. |
| Uncertainty in trade/tariffs | Uncertainty over a number of key post-Brexit trading arrangements adds another level of uncertainty to the international trading landscape for the UK. Currently, this is not a major issue because VRPs largely address local or regional demands, but it may become important if e.g. remanufacturing seeks to internationalise, or these activities natural feature more strongly in international sectors such as aerospace and automotive. |
| Post-Brexit customs challenges | This is linked to the issue above with uncertainty over treatment of core at customs. Stakeholders reported incidences of delays to core entering the UK from Europe, which has affected remanufacturing activities particularly. |

*Source: Oakdene Hollins analysis*

## 9.2 Barriers and opportunities associated with VRP activity at sector-level

This section presents overview of key barriers and opportunities to VRP at sector-level. These barriers and opportunities were identified during industry interviews as described in Section 3.

### *9.2.1 Barriers to VRP*

*Table 38: Summary of barriers to maintenance or expansion by sector and domain*

| | **Technical** | **Economic** | **Social** | **Legislative** |
|---|---|---|---|---|
| **Aerospace** | MRO only for mechanical components | | | Limitations on the recycled content allowed in aircraft components |
| **Automotive** | Lack of access to software, original specifications, and tolerances (non-OEM) | Economics and logistics of core recovery. Low-cost 'copy' parts | Increased labour costs. Lack of skills in dealing with electrical components | Obtaining core from other European countries |
| **Domestic appliances** | Non-authorised repairs | Often cheaper to replace than repair/refurbish | Predicted skills shortage in the end of the decade | |
| **ICT** | Lack of access to software, original specifications, and tolerances | Economics and logistics of core recovery | Consumer perception on purchasing new | |
| **HDOR** | Limited component availability | Sale of single life tyres | | |
| **Industrial equipment** | Limited information / original component drawings | | Skills shortage in dealing with electrical components | |
| **Furniture** | Lack of understanding of material composition (independent actors) | Procurement processes favours new products | Consumer perception on what is in style and on trend | |
| **Marine** | Older ports do not have the right technology to retrofit shipping vessels | High cost for recertification of refurbished boats | Skills shortage for retrofitting large ships | |
| **Medical devices** | Accessing software and core (independent actors) | NHS procurement process favours new products | | |
| **Rail** | Electrifying existing infrastructure | Low-cost financing options favour the purchasing of new stock | | |
| **Barriers across different sectors** | **Understanding software and material composition of components** | **Making value retention products economically competitive against low-cost imports** | **Training and upskilling programs** | **Importing of core** |

### 9.2.2 Opportunities for VRP

*Table 39: Summary of opportunities to enable sustenance or growth by sector and domain*

| | Technical | Economic | Social | Legislative |
|---|---|---|---|---|
| **Aerospace** | Digital twins and predictive maintenance<br>Material passports/ tracking | Emphasis on value retention through MRO activities<br>Mobility as a service: VRP products can reduce maintenance costs | Government and industry collaboration to identify where support is needed | Creating standards to guide innovation, Scope 3 emissions reporting |
| **Automotive** | Remanufacturing EV components, predictive maintenance on batteries | Mobility as a service: VRP products can reduce maintenance costs | Altering market conditions to encourage collaboration | |
| **Domestic appliances** | Smart devices - to promote maintenance and repair activities | Selling refurbished high-end brands | | |
| **ICT** | Modular design | Service models for laptops<br>Amending procurement processes to favour VRP | Skills needed to deal with electrical components | Possible tax incentives to promote the purchasing of value retention products |
| **HDOR** | Automated inspection process for tyres<br>3D printing for on-site repairs.<br>The 'Internet of Things' for older equipment. | Incentives to purchase retreaded tyres | | |
| **Industrial equipment** | Material passports | | | Right-to-repair policies so OEMs have to provide information to independent actors |
| **Furniture** | Introduction of a material passport/tracker<br>Modular design | Amending procurement processes to favour refurbished products | | |
| **Marine** | | | Funding virtual training to upskill people at a quicker rate | |
| **Medical devices** | | Changing NHS procurement to emphasis VRP products. | | Mandatory carbon reporting |
| **Rail** | | Export strategy for refurbished rolling stock | | Review of weight regulations to promote innovation in other material options |
| **Opportunities across different sectors** | **Mandatory material passports** | **Emphasis on value retention through service models**<br>**Procurement processes to favour value retention products** | **Upskilling the workforce to deal with electric components** | **Mandatory Scope 3 reporting** |

## 9.3 Gap analysis

Between 2015 and 2022, Innovate UK has supported 77 projects whose goals have been entirely focused on, or in support of, remanufacturing, refurbishment and reconditioning. Support was spread across 10 different funding mechanisms with the clear majority of activity undertaken as part of collaborative R&D or feasibility study projects (see the table below).

*Table 40: Summary of Innovate UK support mechanisms in remanufacturing and refurbishment projects*

| Innovate UK mechanisms | Number of projects funded |
|---|---|
| **BIS-funded programmes** | 2 |
| **Collaborative R&D** | 34 |
| **Feasibility studies** | 20 |
| **Development of prototype** | 1 |
| **Proof of concept** | 5 |
| **Proof of market** | 3 |
| **Knowledge Transfer Partnership** | 5 |
| **Small Business Research Initiative** | 3 |
| **Study** | 1 |
| **Vouchers** | 3 |

These projects can be categorised into 21 areas of focus, mostly sectoral, some on general production and manufacturing techniques and a few on business models and approaches.

*Table 41: Innovate UK projects analysed by sector or theme of application*

| Focus of work | Number of projects | Focus of work | Number of projects |
|---|---|---|---|
| **Aerospace** | 7 | **Lighting** | 2 |
| **Automotive** | 4 | **Machinery** | 3 |
| **Automotive batteries** | 9 | **Magnets** | 2 |
| **Batteries** | 2 | **Medical** | 1 |
| **Business models** | 5 | **Printing** | 3 |
| **Construction** | 2 | **Production** | 6 |
| **Décor** | 1 | **Rail** | 4 |
| **Engines** | 5 | **Textiles** | 3 |
| **Fuel Cells** | 3 | **Tools** | 1 |
| **Furniture** | 5 | **Utilities** | 6 |
| **ICT** | 3 | | |

The total amount of funding awarded to all partners on these projects was £20 million. When combined with relevant match funding, this represents a total public and private investment in VRP related innovation in the UK of over £30 million.

The lead companies on the projects themselves were spread across the UK, with the majority based in the Midlands and Southern areas, as detailed below.

*Table 42: Distribution of Innovate UK-supported projects*

| Region | Number of projects |
|---|---|
| **East Midlands** | 17 |
| **East of England** | 11 |
| **London** | 7 |
| **North-West** | 10 |
| **Scotland** | 3 |
| **South-East** | 8 |
| **South-West** | 5 |
| **Wales** | 2 |
| **West Midlands** | 11 |
| **Yorkshire and The Humber** | 3 |

If we look at the source of the funding within Innovate UK programmes across these mechanisms, they are widespread and there appears to be a lack of a clear hub around which the support has centred.

*Table 43: Numbers of projects attached to a particular support funding stream*

| Programme Title | Number of projects |
|---|---|
| Accelerating Innovation in rail | 1 |
| ATF: Moving the UK Automotive Sector to Zero Emissions | 1 |
| Building UK's leadership in aerospace technology | 1 |
| Building Whole Life Performance | 1 |
| Business-Led Innovation in Response to Global Disruption (De Minimis) | 1 |
| Catalysing Green Innovation: Strand 1, Advancing PEMD Supply Chain | 2 |
| Catalysing Green Innovation: Strand 2: Securing the Future of ZEV | 1 |
| circular economy: business models | 6 |
| December 2017 Sector Competition: Open - 13 to 24 Months | 1 |
| Energy Catalyst R3 FS | 1 |
| Energy Catalyst R4 FS | 1 |
| Energy Catalyst Round 6: Transforming Energy Access CR&D - Mid Stage | 1 |
| EUREKA Collaborative R&D: UK Sweden Aerospace 2020 | 1 |
| Faraday Batteries Innovation Batteries Phase 2 - Growth | 1 |
| Faraday Battery Challenge: Innovation Feasibility Studies Round 3 | 2 |
| Faraday Battery Challenge: Innovation R&D - Round 2 | 1 |
| Faraday Innovation Batteries Phase 2 - Growth - MM R3 | 1 |
| Flexible manufacturing | 1 |
| High Value Manufacturing | 1 |
| IDP14: Accelerating the Transition to Zero Emission Vehicles (FS) | 1 |
| IDP6 - Highly innovative strategic technologies in low carbon vehicles | 1 |

| Programme Title | Number of projects |
|---|---|
| Innovate UK Smart Grants: February 2019 (6 to 18 Months) | 1 |
| Innovate UK Smart Grants: January 2020 | 1 |
| Innovation Vouchers - Rnd 5 | 2 |
| Innovation Vouchers - Rnd 8 | 1 |
| KTP 2020/21 R2 | 1 |
| KTP Existing | 1 |
| KTP Round 3 2015 (>12 month) | 1 |
| KTP Round 6 2014 (<12 month) | 1 |
| Manufacturing Made Smarter: Digital Supply Chain | 2 |
| Materials (Fast Track) | 1 |
| Materials & Manufacturing R2 - 3-12 Month Projects | 3 |
| Materials & Manufacturing R4 - KTP | 1 |
| Materials and Manufacturing R1 - Over 12 Months or Over £100k (12-24 Month Projects) - ISCF | 1 |
| Materials and Manufacturing R1 - Under 12 Months and Under £100K | 1 |
| Medicines Manufacturing Round 2: Challenge Fund CR&D | 1 |
| New business models in high value manufacturing | 2 |
| Open Round 2 (6-18 Month Projects) | 1 |
| Prospering from the Energy Revolution - Blue Zone | 1 |
| Research and Development Competition for RAI in Extreme and Challenging Environments | 1 |
| Resilience Fund | 1 |
| Resource efficiency: New designs for a circular economy (FS) | 1 |
| Robotics & Autonomous Systems Application over £100k or Over 12 months - ISCF | 1 |
| Smart (DOP 5) | 1 |
| Smart (POC 1) | 3 |
| Smart (POM 6) | 1 |
| Smart (POC 5) | 1 |
| Smart (POC 6) | 1 |
| Smart (POM 1) | 1 |
| Smart (POM 3) | 1 |
| Sort and Segregate Nuclear Waste: Phase 1 | 1 |
| Supply chain innovation towards circular economy | 4 |
| Supply chain integration in constuction | 1 |
| Technology -Inspired innovation ADVM (FS) | 1 |
| The Sustainable Innovation Fund: Round 1 (Temporary Framework) | 2 |
| The Sustainable Innovation Fund: Round 2 (De Minimis) | 2 |
| The Sustainable Innovation Fund: SBRI Phase 1 | 2 |

Referring to the first table and the spread across mechanisms, the majority of funding was provided as match funded grants, where the participant companies contributed financially towards the overall cost of delivering the project.

### 9.3.1 Commentary

This above information suggests that remanufacturing, whilst an understood concept, is just a small part of a wide variety of Innovate UK investments. Remanufacturing is largely confined to high value markets due to the cost in delivering VRP type solutions.

Whilst there is active innovation in the UK, there is significant work happening in Europe and elsewhere: there is no guarantee that the innovations developed through these projects will be delivered in the UK.

The funding identified from Innovate UK has predominantly been focused on their traditional "valley of death" scenario, where the work has left the research base but is not usually ready for private investment. In terms of the project's Technology Readiness Levels (TRLs), this would be around 3.5-7.5: the idea has been shown to have potential but has not got to the stage of a prototype before the project work happens. It is an often difficult to secure investment for such projects, making Government support a key mechanism in keeping innovation alive.

The Research Councils, through UKRI, fund early-stage research in areas which will have a role to play in the future of VRPs, such as developing new materials or processes. This leaves a possible gap in the support landscape for mechanisms focused on the closer-to-market opportunities. Where a business can see the opportunity to bring VRP methods into its business, leveraging the innovations already happening, there are limited options unless they are then looking to innovate and significantly adapt and improve on previous activity. This could be a place for a loans style mechanism, where the focus is on the business improvement over for example technical innovation.

# 10 Enabling technologies and gaps

- VRP activities use a range of technologies to produce products at a competitive price and sufficient quality. Examples include **non-destructive testing**, **automated cleaning and testing**, and **additive manufacturing**.
- The development and application of novel technologies, currently at low TRL, could help support the development of VRP markets. Examples include **automated disassembly**, **computer vision systems**, and **3D printing**.
- **Key technology gaps** identified in the REMADE Institute's 2020 Technology Roadmap include: design for Re-X assessment frameworks; design for Re-X tools; robust non-destructive inspection/evaluation techniques; remanufacturing analysis tools and methods; and low-cost component repair technologies and restoration methods.

## 10.1 Enabling technologies

The figure below is lists enabling technologies that can support the processes underpinning development of markets for VRPs; and it maps how these technologies affect the cost, quality, efficiency and scope of VRPs. The figure distinguishes between technologies that could be applied at the design, in-use, value retention processing and resale stages of the product lifecycle.

The table which follows describes these technology areas in more detail and describes what types of technologies are or could be used to further enable VRP activities in the UK. Where technologies exist, their TRL is evaluated as either low (TRL 1-3), medium (TRL 4-7), or high (TRL >8).

*Figure 27: Enabling technology areas and their impacts*

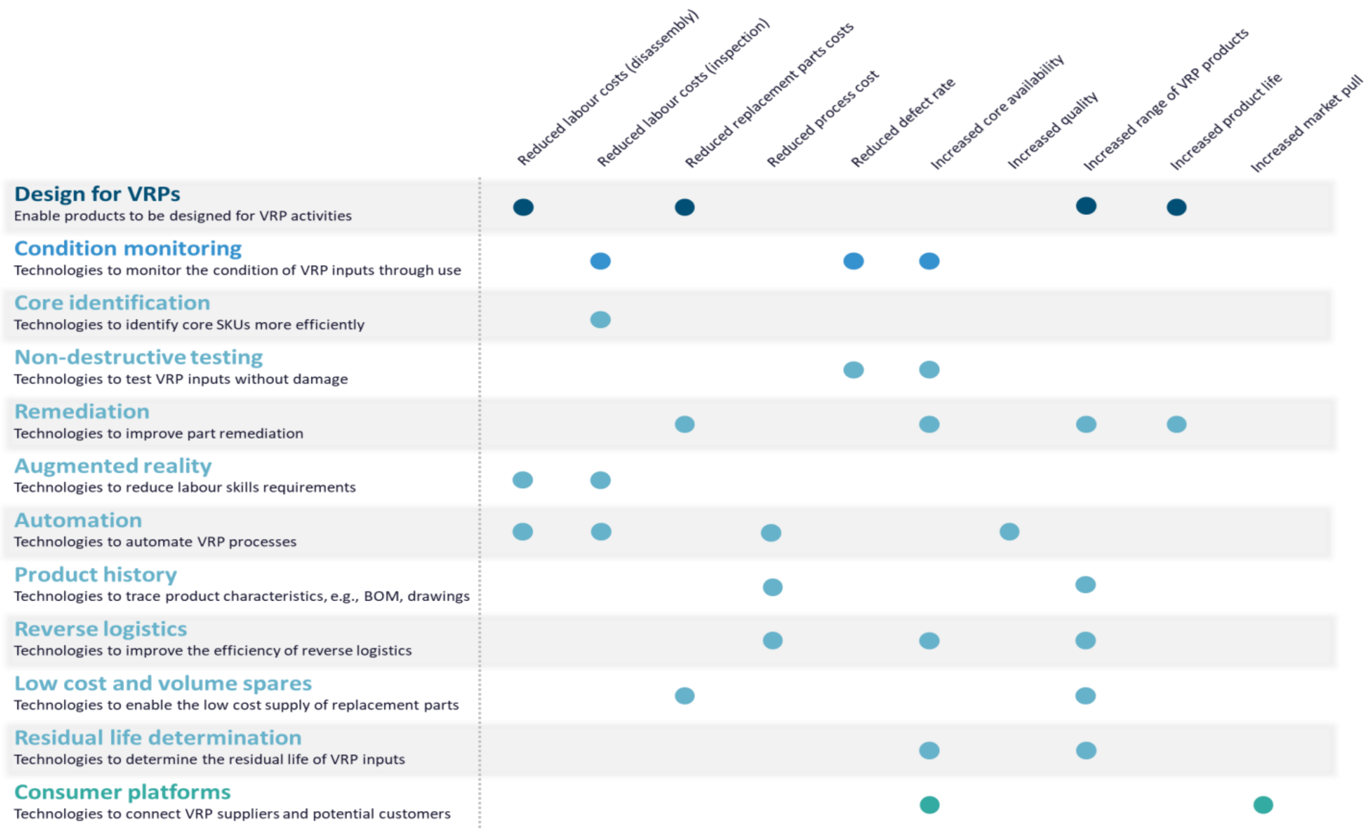


*Table 44: Enabling technology examples and technology readiness level*

| Technology area | TRL |
|---|---|
| **Design for VRPs**: These technologies would include design tools to enable product designers to design products that were easier to disassemble, modular and/or more durable. These tools may include: design guidelines, design standards, scoring frameworks for joining techniques and materials etc. The tools would need to be integrated or complementary to existing design tools/software and easy to use to ensure wide-spread uptake. | TRL: Low |
| **Condition monitoring**: These technologies would enable the condition and use history of products to be monitored through the product's life. This information could inform decisions about when a product has reached its end-of-life and would enable the VRP practitioner to have accurate information about the likely condition and remediation requirements of the incoming core. While condition monitoring is an established practice in some sectors (e.g. aerospace), technologies associated with Industry 4.0 and Digital Twins could help advance the practice and expand into new sectors. | *Industry 4.0*<br>TRL: Medium<br><br>*Digital twins*<br>TRL: Medium |
| **Core identification**: These technologies would enable a faster identification of the core stock-keeping unit (SKU). Some VRP practitioners process thousands of different SKUs with different processes, tooling, and protocols. Technologies to either label core, e.g. using QR or RFID codes (that are placed on the product during original manufacture), or identify core using computer vision identification technologies would enable more efficient core identification. The technology for using QR or RFID codes is mature but requires the engagement of OEMs. The technology for computer vision identification techniques is still at an early stage of development. | QR/RFID<br>TRL: High<br><br>Computer vision systems<br>TRL: Low |
| **Non-destructive testing**: These technologies would enable a more accurate assessment of the condition of VRP inputs. A range of non-destructive testing techniques is already deployed within the VRP sector, but further advancement would increase the range of products and materials for which VRPs could be applied. | *Existing NDT*<br>*TRL: High*<br><br>*Novel NDT*<br>*TRL: Low* |
| **Remediation**: This broad range of technologies would enable a greater fraction of VRP core components to be brought back into use, rather than being replaced. Advances in remediation techniques, for example in plastics and composites, may also allow VRPs to be applied to new products. Remediation technologies include additive manufacturing technologies (including 3D printing), which are already deployed in some sectors, and research is on-going into the remediation of composites and plastics. | *Additive manufacturing*<br>*TRL: Medium*<br><br>*Composites and plastics remediation*<br>*TRL: Low* |
| **Augmented reality**: Technologies that reduce the skills level required by the workforce to implement VRPs could help reduce costs. One VRP practitioner described how they are using virtual reality headsets to mitigate against a skills gap; however, this is not yet a widespread practice. The aerospace industry does, however, present fine examples of how widely available tablets can run part-recognition apps that overlay data onto visual shots of in-situ parts during maintenance. | *Virtual reality*<br>*TRL: Medium* |

| Technology area | TRL |
|---|---|
| **Automation**: Technologies that automate elements of VRP activities can help simultaneously reduce labour costs and improve quality. Automation has widely been adopted in some aspects of VRPs; for example, cleaning and testing processes. Significant research into automated disassembly is on-going due to its high labour costs and would have a high impact on VRPs. | *Automated disassembly TRL: Low* |
| **Product history**: Technologies that enable traceability of a product's characteristics would enable the VRP practitioner to establish VRP activities at lower cost (due to the reduced need for reverse engineering) and would improve the quality of outputs. Key characteristics of interest include the bill of materials and original product specifications. Technologies associated with traceability of product history include product passports and blockchain. | *Product passports TRL: Medium*<br>*Blockchain TRL: Medium* |
| **Reverse logistics**: Technologies that enable the greater efficiency of reverse logistics processes and planning would help reduce costs and could potentially open new markets (e.g. where reverse logistics costs are currently prohibitive). These technologies could be related to scheduling, real-time updates for processing, and processes for streamlining the payment and refund of core deposits. | *Various TRL: -* |
| **Low cost and volume spares**: A significant barrier to VRPs is the availability and cost of replacement parts. Where spares are not available either economically (e.g. a prohibitively high minimum order quantity) or are no longer available at all, VRPs may not be applicable. Technologies like 3D printing could help facilitate VRPs by providing low cost and volume spares. | *3D printing TRL: Medium* |
| **Residual life determination**: Technologies that could help determine the remaining life of products could enable more core and more product types to undergo VRPs. Where there is uncertainty over the remaining life of a product/component, e.g. due to fatigue, practitioners will most often be cautious and divert that core for recycling/disposal. Technologies in this field are estimated to mostly be at low TRL. | *Various TRL: (Low)* |
| **Consumer platforms**: Technologies that could help better connect VRP suppliers with potential customers could help expand the market for VRP products. This could include the development of new on-line platforms to promote VRP products and machine learning technologies to provide more targeted connections and promote VRP products over new. | *On-line platforms TRL: Medium*<br>*Machine learning TRL: Low* |

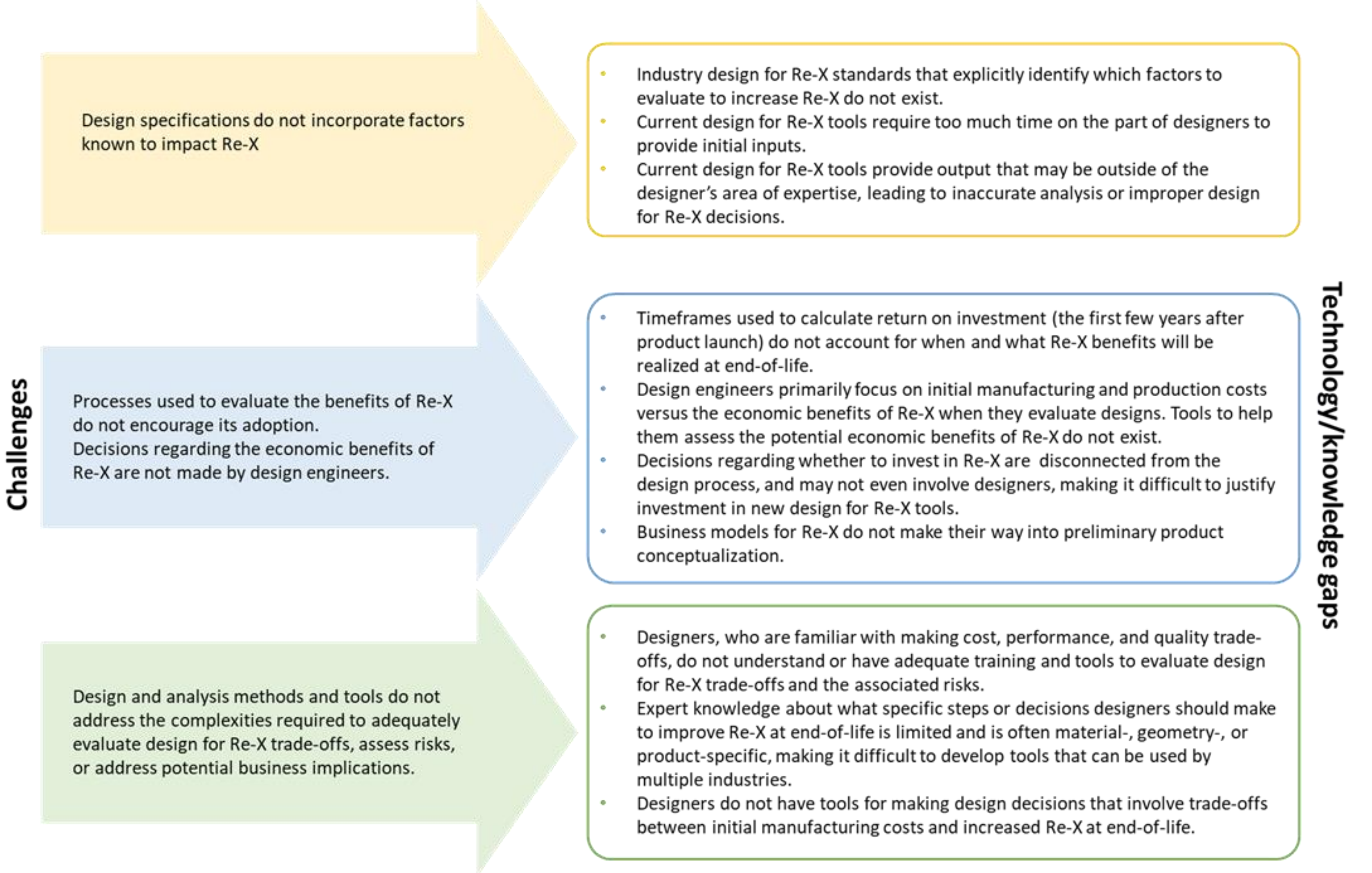
*Source: Oakdene Hollins*

## 10.2 Technology gaps

As a starting point for this analysis, we referred to the REMADE Institute Technology Roadmap 2020, which provides a comprehensive baseline from which technology gaps can be identified. The first Roadmap was developed in 2018 through a programme of stakeholder engagement, including a workshop, survey and interviews. The Roadmap was updated in 2019 and most recently in 2020.

The key technology and knowledge gaps identified in the Roadmap are presented below:

*Figure 28: Challenges and technology/knowledge gaps related to Design for Re-X*




*Source: Adapted from REMADE Institute 2020 Technology Roadmap (41) (references to secondary materials (i.e. recycling) have not been included)*

*Figure 29: Challenges and technology/knowledge gaps related to remanufacturing and end-of-life reuse*


*Source: Adapted from REMADE Institute 2020 Technology Roadmap* (57)

The suggested activities identified on the roadmap and related to the two nodes relevant to this study (Design for Re-X and Remanufacturing & End-of-Life Reuse) are presented in the tables below. Activities related solely to recycling have not been included as they are outside the scope of this study.

*Table 45: Design for Re-X research priorities*

| Design for Re-X assessment frameworks |
|---|
| Develop a Design for Circularity Framework to help designers and purchasers evaluate the trade-offs and costs associated with different end-of-life options and their impact on circularity |
| **Develop a Design for Remanufacturing Framework to help design and remanufacturing engineers evaluate the impact of design decisions on remanufacturability*** |
| Develop a Design for Product Assembly/Disassembly Framework to help design engineers and manufacturers identify ways to increase the level of automation and minimise the labour associated with product assembly/ disassembly |
| **Design for Re-X tools** |
| Establish a centralised, living (curated and maintained) design for the Re-X portal that includes industry-specific best practices, describes design for Re-X evaluation methods, and provides links to existing tools and return-on-investment details |
| **Develop a design for Re-X tools to evaluate the life cycle (energy, emissions, and materials/feedstocks) and financial impacts of design decisions at end-of-life*** |
| **Develop analysis tools to help design engineers evaluate the trade-offs between initial production cost and the revenue stream at end-of-life*** |
| **Pilot a design for Re-X tools that could be integrated with CAD systems (and required databases) to give design engineers guidance on preliminary design best practices and/or estimate the life cycle and financial impacts associated with potential Re-X design decisions*** |
| Develop analysis tools to quantify the impact of design decisions on circularity |
| Develop analysis tools to identify the highest value product form or use of the materials in a product or component at end-of-life |
| Develop analysis tools to evaluate the impact of design decisions on remanufacturability |
| Develop analysis tools to help purchasers evaluate the impact of potential purchasing decisions on circularity |
| Leverage recent developments in machine learning, deep learning and generative algorithms to accelerate development of design for Re-X tools |

** Activities identified as High Priority Activities*
*Source: REMADE Institute* (57)

*Table 46: Remanufacturing & End-of-Life Reuse research priorities*

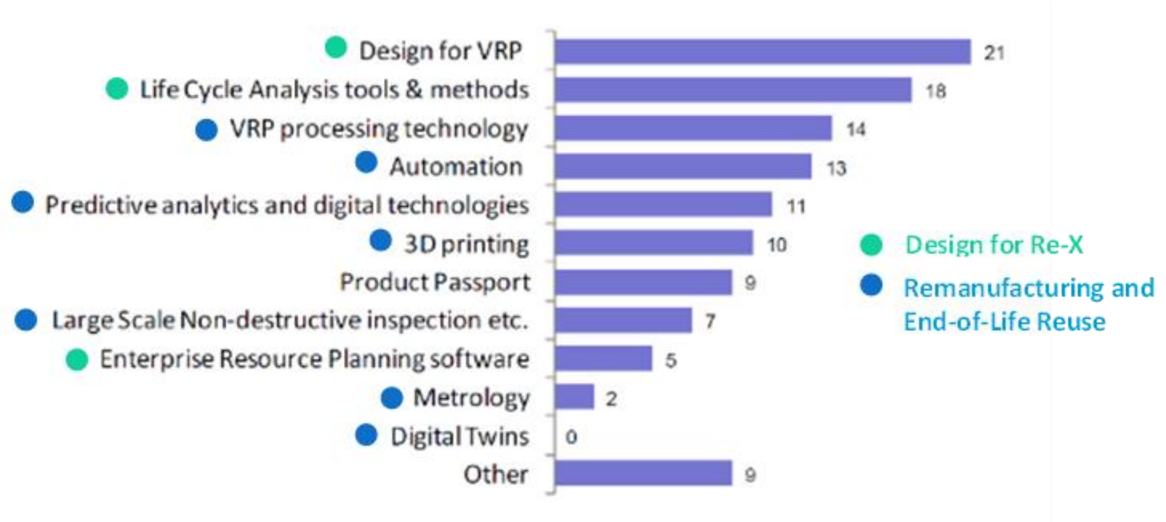
| Robust non-destructive inspection/evaluation techniques |
|---|
| **Develop technologies to identify latent faults associated with mechanical defects in printed circuit boards (PCBs)*** |
| **Explore novel non-destructive evaluation (NDE) assessment methods for identifying damage in metals*** |
| **Develop an in-process method for NDE of as-sprayed thermal coatings*** |
| **Develop automated approaches for assessing/inspecting condition of core (products returned for remanufacturing) and components (individual parts within core)*** |
| Develop low-cost inspection techniques to rapidly characterise contaminants and assess cleanliness of parts to be remanufactured |
| Develop in situ methods or embedded sensors for tracking mechanical fatigue in products |
| Develop methods to assess degradation in solid-state components |
| **Remanufacturing analysis tools and methods** |
| **Develop automated analysis methods for finding faults associated with mechanical defects in PCBs*** |
| **Develop NDE methods and analysis techniques for translating NDE data into an assessment of fatigue damage and remaining life for metals*** |

| |
|---|
| **Develop a condition assessment system for PCB reuse/remanufacturing decision support*** |
| Develop decisioning systems for rapidly determining the cleaning process to minimise process development effort and process waste |
| **Develop frameworks for assessing reuse of electrical components and chips on PCBs*** |
| **Develop low-cost component repair technologies and restoration methods to increase the component reuse yield and volume of products that can be remanufactured** |
| Develop techniques for decomposition/removal of potting material from PCBs |
| Develop improved processes and engineering procedures for repairing damage in metals |
| Develop processes for repair of damage to plastic components |
| **Integrate REMADE technologies to demonstrate proof-of-concept for consumer product remanufacturing*** |
| **Develop methods to mitigate fatigue damage in metals*** |
| **Develop methods to enable direct material reuse*** |

** Activities identified as High Priority Activities*
*Source: REMADE Institute* (57)

There is significant crossover between the technology gaps identified in the REMADE Institute Technology Roadmap and those identified by stakeholders during this research. Figure 30 shows the technology interventions identified during the survey as most important for improving VRPs in the UK and how they map to the Design for Re-X and Remanufacturing & End-of-Life Reuse themes from the REMADE Institute.

*Figure 30: Technology interventions that would improve VRPs and mapping to REMADE Institute activities*




The Institute funds research in five key 'nodes': systems analysis and integration; design for reuse, remanufacturing, recovery and recycling (Re-X); manufacturing materials optimisation; remanufacturing and end-of-life reuse; and recycling and recovery. Of these themes, Design for Re-X and Remanufacturing & End-of-Life Reuse are most relevant to this study.

The following table collates a list of projects under these two nodes that have been funded by the REMADE Institute since 2017 and gives an indication of the types of technology gaps that are being addressed, which would also be relevant in the UK.

*Table 47: REMADE-funded projects under 'Design for Re-X' and 'Remanufacturing & EoL Reuse' themes*

| **Design for Re-X** |
|---|
| Design Iteration Tool to Sustain Remanufacturability |
| Quantification of Financial and Environmental Benefits Trade-offs in Multi-Generational Product Family Development Considering Re-X Performances |
| Development of an Industrially Relevant RE-SOLAR Design Framework |
| Design for Remanufacturing |
| Data-Driven Design Decision Support for Re-X of High-Value Components in Industrial and Agricultural Equipment |
| Building Re-X (BREX): Data, Methodology, and Design Integration |
| Analysis and Design for Sustainable Circularity of Barrier Film in Sheet Moulding Composites |
| Material and Vehicle Design for High-Value Recycling of Aluminium and Steel Automotive Sheet |
| Development of a Novel Design for Remanufacturing Software Plugin for CAD |
| Design for RE-Solar |
| **Remanufacturing & End-of-Life Reuse** |
| Rapid Damage Identification to Reduce Remanufacturing Costs |
| Low Heat Repair of Cast Iron |
| Condition Assessment of Used Electronics |
| Epoxy/Silicon Potting Material Removal for Greater Recovery of Circuit Boards |
| Quantitative Non-Destructive Evaluation of Fatigue Damage Based on Multi-Sensor Fusion |
| Non-Destructive In-process Assessment of Thermal Spray Repairs |
| Remaining Life Determination |
| In-situ Non-destructive Evaluation of In-flight Particle Dynamics and Intrinsic Properties for Thermal Spray Repairs |
| High Speed Laser Cladding for Hard Surface Replacement |
| Remanufacturing of Surface-Hardened Steel Components by Ultrasonic Surface Modification |
| Development of Additive Manufacturing Material and Process Technologies to Improve the Re-Manufacturing Efficiency of Commercial Vehicle Tires |
| Development of Instruments and Techniques That Can Assess Tire Life and Increase Re-Manufacturing of Commercial Vehicle Tires |
| Hybrid Laser Processing for Metallic Surface Remanufacturing |
| Development of Hybrid Repair and Non-destructive Evaluation Technologies for Aerospace Components |
| High Speed Laser Cladding Repair Process Development |
| Improving Recycling Efficiency of Portable Electronics by Automating Battery Disassembly |
| Automation for Remanufacturing of Battery Modules |
| Fast Diagnostics to Enable EV Battery Reuse |

# 11 Intervention options

Uncovering potential interventions is the final output stage of the research process. Following the format of the previous two sections, Figure 31 shows the coverage of the previous study stages updated to include highly cited intervention issues revealed by the various exploration routes.

*Figure 31: Exploration map updated for Intervention strand*

| | Survey | Interviews | Workshop 1 | Workshop 2 | Research |
|---|---|---|---|---|---|
| Opportunities | Exploration | Exploration | Exploration | | Scene setting |
| Barriers | Exploration | Exploration | Exploration | Exploration | Collation |
| Gaps | | | | Partial | Exploration |
| Interventions | Scope 3<br>Innov’n support<br>Mat’l passports | Mat’l passports<br>Right to repair<br>Carbon taxes<br>Predictive tech | Skills<br>Standards<br>R&D investment | Behaviours<br>Measuring<br>New BMs | Collation - numerous |

There are three points to note in particular here:

1. Many interventions are not technically related and technical interventions may not be the most transformative approaches to VRP expansion. In the broader perspective, though, all these findings are relevant because of the involvement and interests of other stakeholder agencies.

2. There is a degree of commonality revealed by the different research approaches which, for readability, is not included in the diagram. Furthermore, the interventions have persisted over time, having been revealed in several other studies.

3. In respect of technical interventions or opportunities, only a few are directly related to the unique challenges of VRPs. Most could be applied equally to conventional manufacturing. Indeed, it is also the case that techniques applied and refined already in manufacturing could usefully be rolled out to VRPs. Lean Manufacturing and robotics are not widespread practices in remanufacturing, for example.

The landscape is not clear cut because respondents have not consistently differentiated Opportunity (i.e. commercial potential) from Intervention (i.e. opportunity for action). Accordingly, our detailed analysis has required some reallocation from the outputs of previous elements of the research; for example, from the summary materials of Appendix C , Appendix E and Appendix F .

The following analysis builds upon a ‘universal framework’ which Oakdene Hollins has developed and applied across international VRP scenarios. Elements will be recognisable from these studies, but have been customised to the UK for the purposes of this study.

## 11.1 Intervention framing

Although this study concerns value retention, we have not so far specified the meaning of ‘value’. The measure of ‘value’ is commonly taken to be money and, indeed, many of the metrics of this report are reported thus. However, reflecting the diversity of stakeholder interests, value may be assessed by other measures: creation of jobs, boosting of skills, defence of and repatriation of industries, reduction in environmental impacts, retention of hard-won resources are all features observed – often simultaneously – within remanufacturing.

Why is this important? Because different sectors offer greater or lesser impact in one or more of these dimensions and, accordingly, the appropriate intervention for each will vary to stimulate improvement – or preservation – of the impacts of interest. For example, the aerospace sector has huge commercial and strategic importance to the UK, but it is already well-advanced in VRPs and relatively well coordinated (e.g. through ATI) to build consensus on the direction of supporting R&D. Interventions should therefore be directed at maintaining this competitiveness, most likely through enhancing skills.

On the other hand, electronics is a sector (supply chain) that is poorly configured for VRPs and does not have a (relatively) strong UK manufacturing presence, yet has enormous potential for reduction in GWP. Interventions in VRPs might therefore be usefully directed at non-manufacturing aspects such as repair and reuse, perhaps building upstream into refurbishment and then to manufacturing as capabilities increase and as closing material loops stimulates sectoral interest in more robust supply-chain solutions.

Developing this further, interventions need a context; we have distilled the essential challenges of the key sectors from current research and previous studies. In the following figures we describe how the challenges and opportunities of the sectors translate into strategic approaches. These approaches present challenges for interventions via many routes, not just through innovation and technology. The framework (Table 48) is the first stage of this analysis: a description of five basic strategic approaches for remanufacturing (or VRP) operators.

*Table 48: Description of basic strategic approaches*

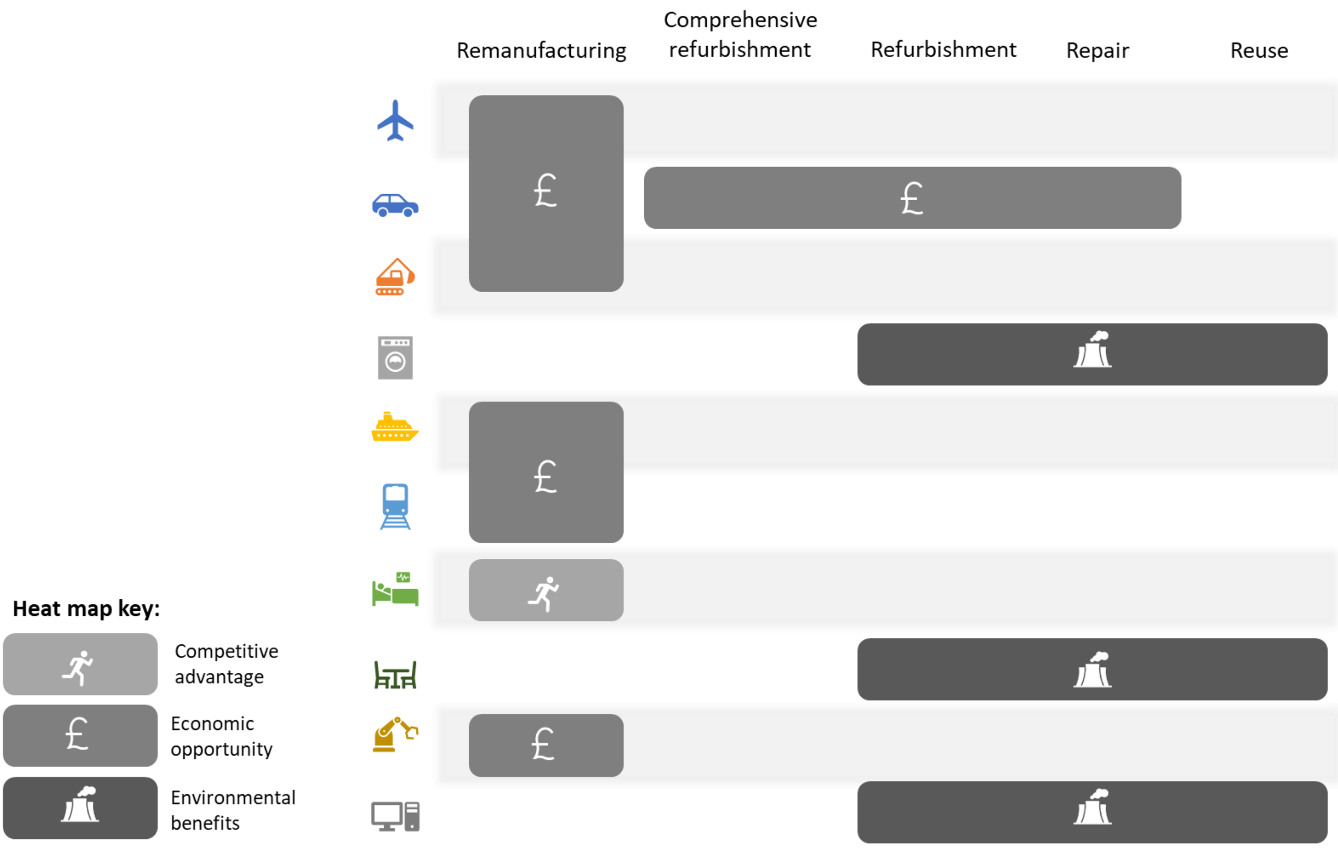
| Strategic thrust | Scope | Value proposition |
|---|---|---|
| **Grow** | The sector, or a product/VRP within it, is not at saturation, and there is room for growth.<br>E.g. electronics, home appliances, automotive, office furniture. | Sector shows capacity to boost economic impact. Support the basis of growth (possibly addressing technology, capital related, market awareness or import/export barriers). |
| **Sustain** | The sector is unlikely to grow significantly, but is beneficial, with a positive effect on the skills pool. Its decline would be a loss of capability.<br>E.g. aerospace, automotive. | Sector may be economically important. Support underpinning basis of competition (most likely technological). |
| **Transform** | The sector requires a radical change in its attitude, business models or supply chain in order to realise beneficial environmental impacts.<br>E.g. home appliances, electronics and other consumer goods. | Sector is environmentally impactful. Transform GWP and other impacts by adoption of VRPs through new business models, possibly also by redesign of products. |
| **Defend** | The sector may be threatened, particularly from foreign competition which is not subject to the same constraints. High level or international action may be needed to level the playing field.<br>E.g. tyres, home appliances. | Sector is economically or environmentally significant. Target levelling playing fields by international agreement of e.g. carbon taxes, environmental product declarations and other soft measures. |

| Strategic thrust | | Scope | Value proposition |
|---|---|---|---|
| | **Leverage** | The sector has capabilities which are cutting-edge and could be applied in less mature sectors or used to kickstart related high-value sectors such as renewables.<br>E.g. aerospace, automotive<br>Also applied in reverse to indicate required boost from R&D support or infrastructure development e.g. design for reuse, centralised collection. | Sector is likely to be both economically and environmentally significant (in its reduction measures). Engage leading operators as role models, but with support for wider adoption of practices with largely environmental benefits and possibly cost reduction. |

## 11.2 Intervention value mapping

The value propositions of *Table 25* have been combined with other study findings to identify how VRP approaches might be prioritised to realise those values. For simplicity, the values have been condensed to being of economic (GDP/market expansion, jobs), competitive (market defence, jobs) and/or environmental (GWP, virgin material reduction, critical raw material conservation) value.

*Figure 32: Map of recommended intervention priorities by sector and VRP activity*



### *Sector Commentaries: Economic Cluster*

**Aerospace**. Remanufacturing is well embedded, and awareness and activity are high. This does not mean that assistance is not required: the sector strategy acknowledges that aerospace is a high-tech, very high-value-adding component of the economy; it should be sustained by nurturing the skills base and staying internationally current with appropriate partnerships and collaborations to keep critical mass. Because it has leading practices, it can also be an exemplar for growing remanufacturing sectors and support sunrise technology sectors such as renewables.

The applicable VRP is **remanufacturing** because of the need for highest quality in support of safety and reliability.

**Automotive** is a prime target for assistance because of its potential and existential challenges (such as needing to maintain critical mass against international competition and to embrace technology shifts due to electrification of transport). Currently remanufacturing services – at best – process components arising during warranty periods because there are strong recovery networks from franchises to Tier 1 suppliers with a strong financial motive imposed by brand owners. While remanufacturing is well-embedded as a practice, considerable potential exists to reclaim the post-warranty 'grey' market. Technology (reclamation techniques, component tracking, tracing and provenance determination) and skills (Lean remanufacturing) are key components of this. Shifts to electric technology will require different set of skills and technology support. International collaboration may also play a stronger role.

VRP opportunities exist across the board for automotive; it is not as regulated from a safety perspective as aerospace and the private vehicle user is often more price-sensitive and so open to a range of life-extension options.

**HDOR** is also economically important and has the capacity to grow. The presence of Caterpillar's European remanufacturing hub within the UK is a significant feature which provides a platform of domestic competence and is an asset worth defending. Because of the similarity to automotive, the sector can benefit from common actions in skills, for example, and by use of public purchasing in fleet contracts for public vehicles.

The applicable VRP is **remanufacturing** because much of the activity is contract-driven in fleet management of relatively expensive assets where up-time is important.

**Rail** and **marine** have features which mean they should be treated similarly. At their hearts, their remanufacturing activities rely on core components derived from the automotive (or rather HDOR), electronics and machinery sectors. (Here we recognise that hulls and coachwork are routinely repaired rather than remanufactured.) There appears to be significant headroom to grow the market in these significant sectors.

The applicable VRP is **remanufacturing** since this attribute is inherited from the treatment of the supplying sectors, as noted.

**Machinery** is highly aligned with the remanufacturing heartlands of aero- and auto-manufacturing and other durable workhorse assets. Some machinery-using sectors have embraced the concept of servitised machinery. For example, it is common to buy pumps as a service in the water industry; the semi-conductor industry routinely has high-vacuum pump remanufacturing services embedded in its fabrication facilities; and there are examples of machine tool companies operating a mixed remanufacturing/redeployment/sale model. However, this model can be rolled out much more comprehensively because it is not the norm.

### *Sector Commentaries: Environmental Cluster*

**Home appliances** are a worthy but more challenging target that require a different approach. The value target is very much the environmental impact associated with the manufacture of these goods and a variety of life-extension tactics is appropriate. Ideally, appliances would be servitised: manufacturers would engage directly with consumers to lease a device which they would maintain, keep at high performance through monitoring and servicing, and manage properly at end-of-use or end-of-life. To date, there have been experiments in this area, but no large-scale uptake so sector dialogue with advocates is recommended to understand the issues.

A more practical model is the Dyson model: staying in touch with and closely supporting through parts support and cost effective at-home rejuvenation services. These companies could be encouraged and promoted, not least through public purchasing. (This applies equally to office equipment such as photocopiers).

Again, home repair for more accessible devices opens up the **repair** VRP route as is the case with ICT. Promotion of repair resources, parts, manuals etc. is within the capability of Local Authorities. We are aware that there are concerns from manufacturers over their residual liabilities and this may need industry dialogue to ensure a fair balance of legal responsibilities.

**Furniture** is a large consumer of high-volume resources and also incurs a relatively high proportion of waste during manufacture compared to other sectors. The office sector is well supplied with credible companies offering remanufacturing and manufacturing services (though expansion is possible), but the domestic market is currently wedded to a traditional linear model of make, sell, dispose. It is credible that substantial economies and environmental benefits could be made by boosting informal and semi-formal VRPs such as **reuse, repair and refurbishment**, though this might require some product redesign to enable it.

Probably the biggest environmental shifts can be achieved in consumer-facing goods. The outstanding sector in this analysis is the **ICT** subset of the **Electronics** sector. These goods embody an enormous of carbon in their manufacture and through the extraction of often critical raw materials, but they are discarded for recycling too easily with a huge loss of potential. This is unfortunate because ICT is generally very modular with elements of ‘frozen’ technology. To some extent, ICT is seen as a fashion item which is expected to be upgraded irrespective of residual age or actual performance even if it is years from failure.

There are several businesses exploiting this potential in, for example, laptop refurbishment into corporate markets, but buyers are risk-averse as they fear that technology is not future-proof. Leading edge companies are addressing this, but they need support to expand into domestic consumer markets.

This is a sector where the **full range of VRPs** can play a role: remanufacturing at the ‘top end’ for expensive performance goods, through repair and, even better, home-repair enabled through advice, parts and repair cafés. Here the public sector can play a role in all parts of the life-cycle:  through public purchasing which can pull through volumes of devices or return them into legitimate operators for remanufacture; by establishing and promoting resources for home- and community-based repair; and by ensuring end-of-use devices are securely and safely managed and directed back to remanufacturers by consumer information campaigns or dedicated collection and aggregation infrastructure.

***Sector Commentary: Competitive Basis***

Remanufacturing is established at the very top end of the **medical** sector, e.g. high-value assets such as scanners, but is less prevalent at lower value. However, there is a large economic potential associated with this as has been identified, for example, by a Danish Government study of VRP potential. As distinct from the high end, the lower value equipment is supplied by a wide network of diverse manufacturers, most of whom are not engaged with the topic or its possibilities. There is a risk that these operators will be overtaken by more agile foreign competition. Since healthcare will be an enduring feature, but subject to extreme cost pressures on health budgets, the ability to offer more cost-effective solutions will be a key.

The applicable VRP is **remanufacturing** because of the need for highly regulated, safety-assured products.

There may also be benefits in developing a 'value toolkit' for manufacturing industries, as has been developed for the construction industry[51], to better explain and communicate the different forms in which the "value" in value retention processes can be defined and help businesses make decisions.

## 11.3 Intervention classification

The VRP sector currently faces a range of barriers that can be broadly summarised as follows:

*Table 49: Barriers to the expansion of remanufacturing and other VRPs*

| Types of barriers | Examples | Description of barrier impact |
|---|---|---|
| **Regulatory and access barriers** | • Complicated regulatory definitions for remanufacturing that affect import, export, and domestic production-consumption activities.<br>• Lack of clear understanding and differentiation between remanufacturing and other value retention processes.<br>• Inputs to remanufacturing (product cores) often reflected as 'waste' under regulatory definitions. | • Affects flows of finished remanufactured products from producers to customers in domestic and/or international markets (forward-logistics). |
| **Market structure barriers** | • Intermediaries between (re)manufacturers and end-users frustrate ability to implement VRPs. | • Particularly with consumer goods, retailers have no interest in boosting the remanufacturing market as this negates new sales, despite willingness of some manufacturers to explore VRPs. |
| **Collection infrastructure barriers** | • Lack of policy requiring diversion of EoU products from entering the waste stream. | • Affects flows of EoU products and components from the customer/user back into the secondary markets and/or to the OEM to be used as inputs to |

[51] Construction Innovation Hub, Value Toolkit link

| | | |
|---|---|---|
| | • Lack of efficient and/or effective diversion and collection infrastructure.<br>• Cost-burden of reverse-logistics if left to individual organizations. | remanufacturing (reverse-logistics) |
| **Customer market barriers** | • Lack of awareness of VRP offerings and benefits.<br>• Lack of standards/certifications for remanufacturing and remanufactured products.<br>• Perceived lower-price = lower-quality of remanufactured products.<br>• High customer risk-aversion.<br>• High perceived cost of repair.<br>• Lack of support in self-repair.<br>• Consumer 'ick' factor for 'used' consumer goods. | • Creates capacity constraints for the domestic remanufacturing/repair customer market. |
| **Technological barriers** | • Increased production complexity with reverse-logistics and supply-chain considerations.<br>• Specialised labour and equipment requirements.<br>• Cost-burden of investment and R&D on individual organizations. | • Creates adoption and capacity constraints for domestic remanufacturers. |

These factors have all been cited variously by the UK sectors consulted in this study and appear little different to those seen in the rest of the world.

A number of barriers are rarely made explicit:

- The misguided assumption that a country's administration recognises VRPs and their value.
- That they are measured and regulated for desired outcomes.
- That all agents within the administrative network are equally informed on these aspects and share a strategy to support and encourage them.

## 11.4 Interventions directly related to company needs and the value propositions

Technological barriers are the main focus of this work and have been identified in Section 9.2.1. Other barriers are more generalised and appeal to other stakeholders not within the core sponsors of this work. Actions to address them have been assembled based on this work and from other similar studies as a rounder consideration of all factors involved.

These interventions address those aspects which are of immediate interest to Innovate UK, related to challenges to technical, design or business decision making, tackled singly, collaboratively or collectively.

### 11.4.1 Technology challenges addressable by existing innovation support

- D4VRP
- Automation
- Predictive techniques
- 3D printing (and one-off part generation c/w digital twins)
- NDT

### 11.4.2 Technology challenges addressable by modified VRP-oriented innovation support

- VRP-related ERP

### 11.4.3 Technology challenges addressable by international collaboration

- Material and product passports, embedding Scope 1, 2 and 3
- 'Global' digital twins

### 11.4.4 Technology challenges requiring new or upgraded skills

- D4VRP
- Industry 4.0/digital revolution – applications specific to VRPs. This could be achieved through working with the relevant strands of the Made Smarter programme and support upskilling.

### 11.4.5 Technology challenges requiring alternative mechanisms

- Use of CE-centres/CE-Hub to channel funds to address identified sector/general challenge topics, by sector
- Re-conceptualisation of product performance to make it more VRP-ready i.e. containing a max/minimisation objective. For example, vehicle performance restated as passenger.km per virgin resource input, for use as sector/challenge goals.

### 11.4.6 Business related challenges requiring development

- Methods to allow rapid assessment of VRP/business model alternatives for businesses, drawing on sufficiently robust definitions of system boundary, life-cycle data, supporting infrastructure and economics etc.
- Establishment of EPD-like standards with clear Net-Zero (or other) objectives for operations and for funding application that eliminates 'greenwashing' by applicants.
- Ability to identify and focus on 'pathfinder' sector/projects.

## 11.5 Interventions related to the general business environment for VRPs

For these interventions, we have considered the likelihood and ease of diffusion of these interventions, based upon Rogers' Theory of Diffusion using the five metrics of relative advantage, trialability, observability, compatibility, and complexity. This analysis is based on our own assessment of whether metrics are low (weak diffusion driver), medium, or high (strong diffusion driver).

### 11.5.1 Direction and control

#### 11.5.1.1 Formulate policy which incorporates VRPs into CE on an outcome basis

There are many choices of action with respect to the manufacture, use, reuse and disposal of goods, and even where they are made. Related work by, for example, WRAP and Professor Tim Cooper at Nottingham Trent University, suggests that a range of measures is needed to motivate or take advantage of productive behaviours. There are several international examples, such as China's approach summarised in Table 50, that could inform the creation of a similarly layered approach in the UK.

*Table 50: Overview of China's CE policy framework*

| Area | Micro (Enterprise) | Meso (Inter-firms) | Macro (Province, Region, State and Cities) |
|---|---|---|---|
| **Design** | Ecodesign | Environmentally friendly design | Environmentally friendly design |
| **Production** | Cleaner production | Eco-industrial park | Eco-city<br>Eco-municipality<br>Eco-province |
| **Consumption** | Green purchase and consumption | Environmentally friendly park | Renting service |
| **Waste management** | Product reuse and recycle system | Waste trade market industrial symbiosis | Urban symbiosis |

The Chinese approach recognises that there are individual winners and losers. For example, circular economy efficiencies imply a reduction in virgin materials requirement. This is a clear concern for any mining and extraction sector, and even the waste management sector. Part of the strategy should therefore address how impacts on these sectors can be mitigated. For example, a change in thinking can re-align the sector as a part of the circular economy. Waste management companies across Europe are recognizing the need to leverage their infrastructure; they are converging with logistics companies that themselves offer collection and repair services. Mineral extraction companies are exploring the idea of chemicals as a service, a practice which is already embedded by effect chemical manufacturers in the automotive and engineering sectors, where there is a motivation to reduce use and waste with benefits to all.

*Table 51: Theory of Diffusion assessment [Direction & Control 1]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | Low | High | High | Medium |

#### 11.5.1.2 Determine priorities for intervention or assistance based on impact and strategic direction

Any researcher who has spent time examining the practice of remanufacturing will quickly realise that segmentation by sector is at best a crude approach to understanding where benefits accrue and where opportunities may lie. This is because sectors embrace, typically, a host of different products, by value, size, mass, complexity, componentization, de-constructability, evolutionary trajectory, aesthetics, distribution and, not least, customer type. The products in the electronics and home appliance sectors are most recognizable in this respect, but it applies no less to aerospace and automobile: there are orders of magnitude difference between a jet engine and a fuel pump for that same engine, for example.

These enormous variations make a sectoral analysis of prevalence of one or other VRP an extremely blunt tool. Certain products will be more amenable to remanufacture, say, and others to cascaded reuse or home repair. Ultimately this comes down to issues of both design (including expected life) and trade-offs between utility and cost of passing on, repairing etc. at end of use.

Our analysis of sectors and actions to address barriers has, to some extent, taken account of the difference between B2B and B2C domains. However, we strongly recommend a much more focused approach, through engagement per sector, which unpicks issues in detail, looks for cross-cutting themes and formulates policy approaches which tackle specific market failures. In this sense we mean failures to achieve movement in an environmentally beneficial direction. This process will underwrite government actions and make them more defendable.

At this point we should make explicit that VRPs may not be an appropriate solution to some instances. For example, in the case of furniture, there is a good potential for remanufacturing and reuse of office and institutional furniture facilitated by changed business models and inherent construction features of this type of furniture. But home furniture is more problematic in these respects; it may be more beneficial (in the short term) to ensure there are at least robust collection, segregation and recycling processes in place to eliminate the negative effects of organics in landfill, rather than directing effort to encourage VRPs other than reuse for a potentially far smaller proportion of items. This underlines the need for an evidence-based approach to examine the consequences of different options.

*Table 52: Theory of Diffusion assessment [Direction & Control 2]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | High | Medium | Medium | Medium |

#### 11.5.1.3 Set up sector focus groups to better understand strengths, weaknesses, opportunities and threats and for coordination of action

To an extent, our research has uncovered sector barriers and possible actions in response. These are reported in the previous section. However, we acknowledge that a sector-based view can be simplistic since it hides a range of complexities as reported in the text. The range of products covered is one such issue, but so too is the issue of customer type. This aspect will be critical for growth in the electronics, home appliances and furniture sectors.

Options for intervention in the B2B area are generally at a national or international level to ensure a fair competitive environment which rewards desired environmental impacts and stimulates a demand for such products. Our experience shows that blanket solutions are not possible, and it is necessary to delve down to a sector-based or sub-sector-based approach.

Although sectors have their unique issues there are many issues in common, as identified in the previous section. In the interests of efficiency of action and to generate a critical mass of action, but also to be perceived as equitable, it will be wise to go into further detail regarding nature of and action on issues. Where issues are related to B2C, it is likely that systemic change (for remanufacturing) will be required in the sector, and will be emergent; other VRPs, such as repair and reuse are amenable to local action either by persons, communities or businesses and can be enacted at the municipal or regional level.

*Table 53: Theory of Diffusion assessment [Direction & Control 3]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | High | Medium | Medium | High |

### 11.5.2 Statistical, legal and skills framework conditions

This section considers aspects related to measurement, auditing, oversight of, and legal, fiscal and training policies related to VRPs. These create the ‘level playing field’ necessary for assessing the impact of other policies, and ensuring the impacts of new manufacturing and VRPs are fairly compared or motivated for their desired economic and environmental outcomes.

#### 11.5.2.1 Develop and implement CE & VRP ONS metrics to measure impact progress

Metrics are necessary to monitor progress and determine where points of effective intervention might lie. Much work has been done across the globe on proposals for CE metrics, particularly for businesses, but has typically required a large amount of data to support it. More recently, the Ellen MacArthur Foundation has promoted its own tool for self-assessment, which is easier to use and more practical, so methods are evolving.

However, at the national level, metrics are needed that offer a view on the level above this, the aggregate impacts on the nation's use of resources and energy and the wastes and other impacts associated with them; and an insight into the processes within the nation that are contributing positively or negatively to those impacts.

To some extent, gross measurement of impacts is already available via import/export/ extraction data, energy consumption and the like. More qualitative views of impacts – resource depletion, effect on biodiversity and natural capital, eco-footprint and the like are published periodically by governments and third parties. But the issue of measuring internal processes is much harder. Even if measured, how to discern the attribution to impacts, causality and repeatability (i.e. a change in X today would have the same effect tomorrow) is less well-founded.

*Table 54: Theory of Diffusion assessment [Framework Conditions 1]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| High | Low | High | Medium | Low |

#### 11.5.2.2 Enact fiscal frameworks which reward desired environmental outcomes

With metrics in place and a clear view of desired outcomes, the trickier task of determining how fiscal and taxation measures can be exploited to promote desired outcomes arises. Several approaches are in action or have been debated:

- **Reduction of VAT for reuse products.** This might be graduated depending on the extent of life left in the product, crudely reman➔repair➔reuse. For example, it might be argued for remanufactured goods that, since the value is retained, there is no added value and hence no VAT due. This is an extreme position; it would be more consistent to argue for relief on the embedded materials recovered, since they are a high-impact component at the point of first extraction, recovery and processing into products.
- **Use of tariff-based EPR schemes.** These, again, may be graduated depending on the end-of-life treatment employed, penalizing landfill (full) compared to reuse (zero). They might be implemented either by end-of-year accounting, or by a VAT-like recovery. EPR schemes are widely recognised and increasingly practised, so their use would dovetail with existing mechanisms.

The issue of correct pricing of impacts of manufacture and use is another question more widely relevant to CE. This issue is often raised by OEMs in relation to low-performing goods which may be being 'dumped' into markets and under-cutting VRP-ready goods which are costlier but more robust. Such steps need to be taken in line with foreign nations to avoid unfair economic advantage for nations that do not adopt such measures.

*Table 55: Theory of Diffusion assessment [Framework Conditions 2]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | Medium | High | Medium | Medium |

### *11.5.2.3 Enact laws which remove barriers to longevity or embed rights to repair*

A number of contributors to this work have quoted the EU's Right to Repair legislation as a possible model to follow for the UK. To some extent this tracks previous B2B-related Directives, such as the Automotive Block Exemption, which stopped vehicle manufacturers prohibiting non-OEM parts being used in-warranty with the threat of invalidating the warranty. Whether this constitutes a real barrier to expansion of VRPs in the UK is unclear, however.

Meanwhile, there are moves in France to mandate a minimum lifetime for a product. This should be considered with care as it might prove counter-productive for energy-using products. A better route might be to mandate a minimum period of spares availability to ensure support, making repair information available online with product user manuals. An interesting crossover here is the advancing technology of 3D printing which removes the barriers to 'batch of one' manufacture if the right information is available. These are strong candidates for use in community or business-led repair hubs.

Other measures being brought to bear include ecodesign legislation, notably design for disassembly and repair as well as longevity, and the publication or declaration of product repairability indices. France, for example, has implemented a suite of regulatory initiatives aimed at tackling obsolescence, starting with the National Waste Prevention Program in 2014. The Energy Transition Law of 2015 prohibits companies from building planned obsolescence into their products, and the first related lawsuit was launched in 2017 against HP for its printer cartridges. From 2015, French manufacturers were required to tell retailers how long they would make spare parts available for repair; for products purchased after 2016, product warranties were extended to two years, with the burden of proof on the producer to demonstrate a fault does not exist.

In general, ecodesign guidelines represent a soft, sector-based and business-led approach. Mandatory requirements are a harder approach. However, they will not have much impact unless they are monitored and backed up or made explicitly relevant e.g. through public purchasing criteria.

All of these should be included with careful consideration of the safety implications and manufacturer liabilities for user-repairs, an issue which achieved prominence at the 2018 G7 VRP Workshop in Montreal (58). Here, manufacturers expressed deep concern about the implications to their own liability of owners and consumers undertaking their own repairs. Furthermore, where legitimate third parties had undertaken VRPs on their goods and faults had arisen (which might include design faults) the absolute responsibility for these has not been established yet and was noted as an international action point.

*Table 56: Theory of Diffusion assessment [Framework Conditions 3]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| High | Medium | Medium | High | Medium |

### *11.5.2.4 Develop terminology, accreditation and labelling for remanufactured goods*

In the longer term, this includes the development of a definition - in keeping with international definitions - for each VRP, to ensure consistent use and application of the terminology. We identified in the earlier chapters that various terminologies and definitions are used by different sectors, but this extends across languages too.

In the immediate term, the focus should be on remanufacturing as the most clearly definitive activity. For consistency, international compatibility and to avoid a plethora of standards and labels emerging, this is an activity that needs coordination. It dovetails strongly with the international action outlined in Section 11.5.5.2 below, but draws more straightforwardly on the handful of national and international efforts to develop remanufacturing standards. It should be recognised, however, that standards are typically process-oriented, not product-oriented. It is therefore necessary to look to related schemes such as ecolabels to signal expectations of both process accreditation and performance expectations.

Major standards already in existence are the American National Standard for remanufacturing *RIC001.1-2016: Specifications for the Process of Remanufacturing* developed by the Remanufacturing Industries Council (RIC) in collaboration with a diverse consensus body made up of respected leaders from the industry, and *BSI 8887-220:2010* developed by the BSI. Both standards define and provide a benchmark for the process of remanufacturing and establish specifications that characterise the remanufacturing process and differentiate remanufacturing from other practices.

Further, both standards should be considered as generic platforms which provide the basis for the development of product-specific standards (and from there, labels via accreditation). Also, both of these standards are being considered for ‘internationalization’, the US standard by agitation for elevation to ISO (via the US Remanufacturing Council); and the British Standard (via BSI) by cooperative development with Chinese authorities with the aim of normalizing UK-China-EU practices and hence reducing barriers to trade.

An interesting practical example of standards is from the USA: the US MERA and RIC certification programs and the talk of the ‘Remanufactured in America’ brand.

*Table 57: Theory of Diffusion assessment [Framework Conditions 4]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Low | Medium | High | High | Low |

### 11.5.2.5 *Ensure research, development, skills & training resources match industry needs*

While many of the skills required by remanufacturers are the same as those of manufacturers, there are distinct competency differences. For example, in independent remanufacturers, deep product knowledge is valued. In all cases, diagnostic and problem-solving skills are required for product triage. Specific technical competences may be needed by sector, and on an evolving basis to cope with technology shifts, such as electric vehicles in automotive.

Recently, the Scottish Government instituted a study of remanufacturing skills and related gaps in the curriculum for vocational and in-work training. This did indeed confirm that they were commonalities between manufacturing and VRPs, but distinct competences existed for the latter and could be addressed by specific modules related to the ‘9 step’ remanufacturing process outlined in remanufacturing standard BS 8887-220:2010 (59). The summary skills gap and suggested training analysis is shown in Appendix G .

A related issue is that of the state of knowledge of VRPs and CE amongst business leaders. Undoubtedly the profile of environment has risen of late, but it is less certain that the thrust of, for example, MBA courses, economics and business studies has truly embedded this thinking. A strong steer for these to be core to the curriculum is suggested. There are several institutions globally that may provide a steer on the content and delivery of this knowledge.

The issue of who might tackle research into various topics related to VRPs (some raised in this work) is relevant, and a challenge shared with other areas. There is academic literature on manufacturing strategies and business models supportive of VRPs, but little has translated into actual business assistance. Notable exceptions to this are Germany and the USA, characterised by the presence of strong centres of excellence in linking academia to business: in Germany, the Fraunhofer Institutes and in the USA the Rochester Institute of Technology (RIT)/Golisano Institute. Fraunhofer Institutes are a long-established flagship which have adapted smoothly to – especially – remanufacturing, but less so to other VRPs, unless there is a clear technical need. RIT has been a 20-year climb to establish a focus for interaction between not just research and business, but also the '3rd pillar' – policy and lobbying (with great success) – via its Remanufacturing Council trade body. RIT's specialism is remanufacturing but, being the authors of the UN-IRP report, it is likely they will in time embrace a wider set of VRPs.

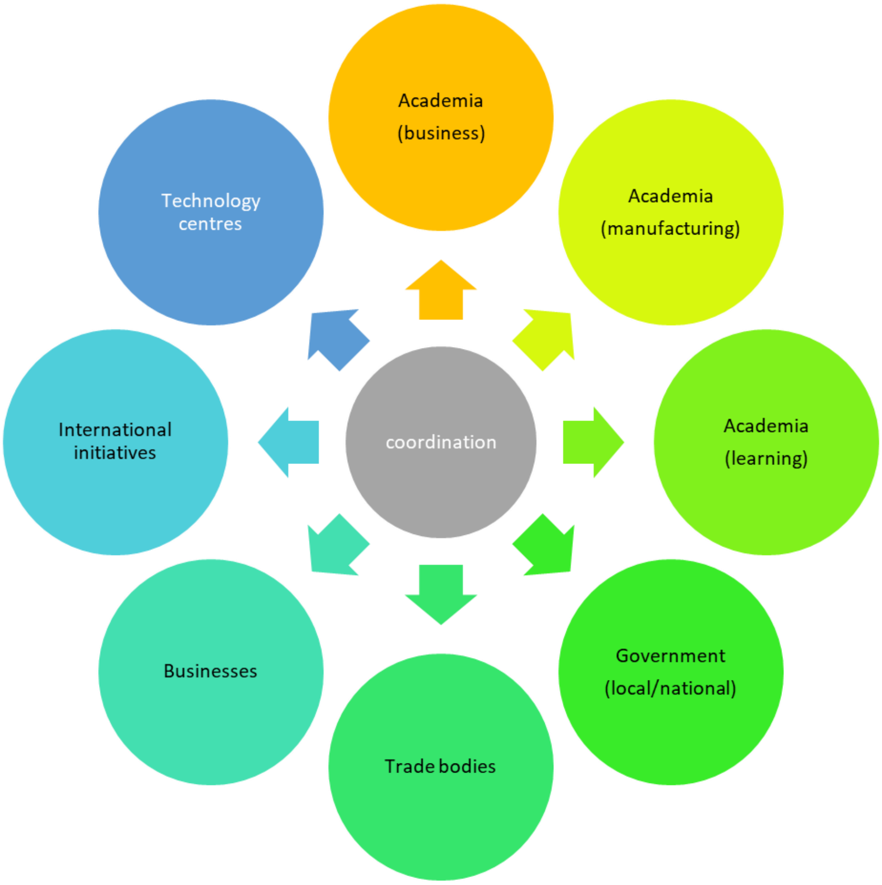
Elsewhere, there are centres of specialism – Linköping in Sweden, TU Delft in the Netherlands and Grenoble INP for system and product design, for example – but not the same degree of coordination. With a diverse manufacturing base and even more products within each sector, supporting research in this area risks becoming a haphazard collection of investigations, or a highly diffused effort which lacks critical mass. It is strongly recommended that the UK considers a centre of coordinating (but not commissioning) activity in order that:

- initiatives fit within a broad landscape which covers major hotspots with complementary activities of sufficient force to make a difference, possibly using a challenge-led approach
- there is a coherent meeting point for business, research and policy (via trade bodies and government)
- there is a well-publicised clearing house for distributing knowledge gained more widely out to sectors and businesses, to governments for improving their messaging and approaches and to integrate and influence international collaborations.

This approach is currently in its gestation in the UK. There could be an analogy with the "value network" thinking lead by Aston Advanced Services Group[52] to map value and build collaborative ecosystems across supply chains to support identification of material "leakage" and identify opportunities to close loops. The coordinating body could be private or public, academic or business focused as long as it has a good network of related governmental, business and academic interests. A 'network' of typical stakeholders in shown in Figure 33.

[52] Aston Advanced Services Group link

*Figure 33: Coordinated research eco-system*




The issue of technology development is tackled in Section 11.5.5.3.

*Table 58: Theory of Diffusion assessment [Framework Conditions 5]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| High | Low | Medium | High | Low |

### 11.5.3 Market pull and confidence building

This section should receive high priority for the action's ability to lead by example and support VRPs in a very concrete way with potentially substantial contracts.

#### 11.5.3.1 Implement public procurement based on the lifecycle impact of goods and services

This action is for operation at all levels but will require coordination to develop the principles.

Public purchasing is a substantial component of public spending either directly by agencies of the administration or via subsidiaries such as hospitals, schools and the like and thus represents a leverage point of high potential for market development of VRPs. The Welsh Government, for example, has identified this as a key action point for its next circularity drive.

Many nations advocate Green Public Purchasing, but few build VRPs, reuse and the like into their policies; some are sensitive that strict environmental criteria may be perceived as prejudicial or anti-competitive. However, there are counter-factual examples.

For example, preparing for the Olympics 2012, the Organizing Committee of the Olympic Games took an innovative approach to the purchase of the temporary facilities. Via a committee of experts, it established purchasing criteria that mandated whole-life carbon impacts and a hierarchy of VRP tactics to be demonstrated by purchasers including leasing, reuse and redeployment. This was a major contributor to the 'greenest games ever'.

Implementing a national purchasing policy which operates at all levels which concentrates on whole-life impacts and demonstrable EPR would send very strong signals to the business community. Alongside this, publicity associated with successes could also inform and motivate the public in VRP benefits. Prime initial targets are IT (including office equipment), furniture, other maintained infrastructure and vehicle/ utility vehicle fleets.

*Table 59: Theory of Diffusion assessment [Market Pull 1]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| High | High | High | Medium | Medium |

### 11.5.4 Action under local and regional authority control

This section considers actions which are predominantly under the control of Local Authorities, Unitary Authorities and the like or which involve community action. This will be the point at which policies become a reality for VRP businesses, purchasers of services and consumers.

#### 11.5.4.1 Adapt infrastructure locally to enable VRP loops especially for home products

It is hard to anticipate specifics of this action as it will be highly dependent on the local context. However, some generic actions might be in respect of what is now called waste management, whereby a more triaged approach is taken. Rather than consign all unwanted products as waste, have services which collect even in small batches – so-called mosquito fleets – in a controlled, safe and non-destructive way to return potentially re-usable productsto a hub or directly to businesses.

EPR schemes can certainly have a role but would need modified systems for the collection of consumer goods such as furniture, IT and appliances in a safe and secure manner which preserves their value. For example, recovering used goods from households to hubs would assist in triage as well as in better auditing and regulating the obligations on individual retailers or manufacturers.

*Table 60: Theory of Diffusion assessment [Regional Control 1]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | Medium | High | High | Low |

#### 11.5.4.2 Support community-led initiatives to self-help, repair clinics etc.

Repair hubs are an increasingly common feature in Northern Europe and parts of North America, so there is potential learning on successes and failures. These initiatives can augment the increasing amount of repair instructions being put on-line to assist users, such as iFixit, as well as kits of tools and simple parts. Such ventures have an added benefit of increasing community cohesion. Similarly, product share hubs allow time-share of (especially) tools which would otherwise be unproductive for much of their lives. Target public messaging and knowledge to boost VRP confidence especially in repair.

One possible messaging source was identified under public procurement above, but clearly there is much work to do to raise awareness of and confidence in VRPs. To a large extent, this will depend on solutions being in place already to avoid advertising an 'empty' proposition. For example, other actions on stimulating repair hubs, accredited services, collection systems etc. are necessary precursors. However, much information could be portal-based, pointing at other resources: spares supply sites, repair sites, reuse and recovery portals, reclaim sites etc.

Equally important are messages about safety: not going beyond confidence and competence nor infringing warranties. Here the repair café could provide a resource of confidence and advice.

*Table 61: Theory of Diffusion assessment [Regional Control 2]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | High | High | High | Medium |

### 11.5.5 International co-operative actions

This section considers actions which must be enacted by cooperation and negotiation with other countries. Because the impacts of for example, greenhouse gas emissions extend globally, common approaches and understandings are required. This is to ensure that the UK is not unreasonably disadvantaged by enacting forward-thinking policies with strong environmental benefits without reciprocating commitments by others.

#### 11.5.5.1 Ensure consistent approach to VRPs, core, imports and exports, and impact tariffs

This issue has been well tackled in the Canada-US-Mexico-Agreement, for example, which clearly forms a model for international practice. It is still common practice that, even within the EU, some border controls treat core as waste or remanufactured products as used. This will remain an area to monitor to ensure fair compliance. It may be possible to institute a reporting system that could alert International Trade officers to potential violations or non-compliances.

Though this talks of tariffs, there is of course the issue of where tariffs turn into taxes, and in particular if certain jurisdictions take a view on rebalancing prices based on carbon impacts where the impacts have not been fairly priced in. This is a trickier problem, but the necessary precursor is for the UK to determine its internal mechanism for fairly weighting the impact of new goods versus VRP goods or even recycled content goods: a substantial research project.

In a 2018 workshop conducted by the International Resource Panel and the European Commission on the promotion of Remanufacturing, Refurbishment, Repair and Direct Reuse (24), it was highlighted that policymakers must reduce the barriers for the sector by creating a 'level playing field', removing legislative barriers and facilitating greater international trade for product core.

Some specific examples of how this may be achieved included providing clarity on the distinction between products that may undergo product retention processes and those that are 'true waste', mandatory Green Public Procurement schemes (e.g. Article 19 of Italy's 2015 'Collegato Ambientale' law (25)[53]) and national educational plans to raise awareness of the circular economy.

[53] A synthesis report as a follow-up activity of the G7 Alliance on Resource Efficiency

*Table 62: Theory of Diffusion assessment [International Action 1]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | Low | High | Medium | Low |

### 11.5.5.2 Agree protocols for recognizing VRP goods and services

This item relates to the ability to verify truly remanufactured products (and by extension other VRP-treated goods). This is a slightly different issue from that of remanufacturing standards, but is inter-related. This protocol is likely to be very process-oriented. It has applicability not just in foreign trade, but domestically too, for example in purchasing.

*Table 63: Theory of Diffusion assessment [International Action 2]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | Low | High | Medium | Low |

### 11.5.5.3 Set up international collaborative R&D ventures

In key sectors, remanufacturing is a global industry. There is a critical mass of interest forming in China, the UA, Canada and Europe which is attracting substantial R&D and demonstrator finance. For smaller countries, building a critical mass of activity is difficult. Here it is especially the case that Canada should not be left behind so should attempt to collaborate in such ventures to develop its internal capability and stay current on the world stage.

As an example, the UK (Innovate UK) and Canada have a joint call for collaborative R&D in agriculture - a model which could be developed for VRPs, possibly with a permanent focus. The EU Horizon programme is also a target and with significantly more funding albeit (in our experience) much less nimble.

*Table 64: Theory of Diffusion assessment [International Action 3]*

| Relative advantage | Trialability | Observability | Compatibility | Complexity |
|---|---|---|---|---|
| Medium | High | Medium | Medium | Medium |

# 12 Recommendations

To support the UK's journey to becoming a leader in the field of value retention processes, we would make the following recommendations:

**Raise the profile of VRP activities**

The image of VRP activities must be transformed from 'dirty' and unappealing to a cutting-edge sector associated with advanced technology and playing a crucial role in sustainability:

- A high-profile centre for VRP technologies, akin to the REMADE Institute in the USA, would act as a focal point for VRP innovation, business engagement and - potentially - training.
- The profile of VRPs should continue to be promoted in the work of the NICER CE-Centres and CE-Hub, to ensure Circular Economy is not limited to recycling.
- The role of VRP activities in achieving the UK's Net-Zero targets and for businesses seeking to set Science Based Targets should be formalised through the development of carbon accounting methodologies specifically for VRPs.
- Targets need to be set for VRP activity in line with plans to reduce UK resource use.
- VRP skills development should be supported through reskilling the workforce in declining sectors (e.g. some traditional manufacturing and fossil fuel sectors) and by supporting university and college-level education. This could also be aligned with existing initiatives, such as Made Smarter, by connecting innovation and upskilling in topics like Industry 4.0 and the digital revolution, to VRPs.

**Seek out opportunities to collaborate**

Collaboration will enable faster progress from shared learning and ensure the direction of travel is aligned:

- International collaboration could support technology and innovation transfer, develop consensus on standards, and align trade policy.
- Intra-UK collaboration could achieve similar objectives as well as consensus on data needs, terminology, and priority sectors.
- Developing the most coherent strategy for UK VRP activities will require collaboration across government departments, particularly BEIS, Defra, the Treasury, and Innovate UK.

**Encourage behaviour change**

Make VRP activities and purchasing VRP products more attractive and easier than the alternatives, to help accelerate the market transition:

- More widespread requirements to report Scope 3 emissions would help demonstrate the sustainability credentials of VRPs and make using VRP products a more attractive option for entities looking to reduce their emissions footprint.
- Policy levers to make VRPs more attractive include integration into public procurement, expansion of right-to-repair initiatives, extended warranties, and modulated Extended Producer Responsibility (EPR). These options should be considered for consultation.
- Fiscal measures could improve the competitiveness of VRP products compared to alternatives, e.g. through VAT reductions and taxes on carbon emissions.
- Development of centralised data hubs and data requirements could make it easier for actors to undertake and report VRP activities and for consumers to access VRP products. This could align with planned ONS activity on material flows and include industry codes for VRP activities.

**Support VRP experimentation**

The development of new VRP business models and technologies can be risky for businesses and organisations. Support for pilots, trials and experimentation can help encourage innovation:

- New VRP business models, particularly related to shared ownership, everything-as-a-service, and community-led initiatives, may need financial, skills and innovation support to develop viable value propositions. Existing organisations like KTN and Innovate EDGE could deliver targeted VRP support in these areas.
- VRP actors, particularly non-OEM, can face limitations in knowledge, equipment, capacity and finance to develop and test new VRP technologies. Support for feasibility studies, industrial research and experimental development in VRP applications would help accelerate the uptake of technical innovations by VRP practitioners.
- Industry and academia can operate 'in silos' when it comes to fundamental research in VRP technologies. Support to foster closer links between industry and academia (for example, through the VPR technologies centre mentioned above) could better target innovation needs for key topics like design for VRPs, automated disassembly and computer vision core identification.
- Existing funding mechanisms are a robust foundation for support in VRP innovation. The continuation (and potential expansion) of funding rounds like the recently closed 'Circular Economy for Small to Medium-Sized enterprises(SMEs)' call would provide further opportunities for VRP projects. It may be valuable for funding rounds to focus on VRP activities if the proportion of funded projects with a Circular Economy scope, are predominantly focused on recycling.
- For innovation funding on topics that have cross-over between manufacturing and VRPs (e.g. blockchain, digital twins, Industry 4.0 etc.) it may be beneficial to encourage or require this research to include VRP applications and considerations as part of the scope.

**Target VRP interventions**

While some interventions will support the acceleration of VRP activities across the board, there are some key sectors and VRP activities that should be targeted:

- There is an opportunity for the UK to leverage its strengths in product design to develop expertise in design for VRP activities. This could be of particular relevance to automotive components, many of which are being re-designed for electric vehicle (EV) applications.
- The medical devices sector is actively looking at VRP options and, as yet, no remanufacturing activities occur in the UK. Government could work with the sector to encourage the choice of the UK to set up VRP operations.
- Higher-value VRP activities (in terms of economic value) are of most relevance in the aerospace, automotive, HDOR and industrial equipment sectors. The priority for realising environmental benefits lies in the lower-value VRP activities in the domestic appliances, ICT and furniture sectors.

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# Appendix A VRP terminology

We have presented in section 4 precise definitions of what constitutes each VRP scenario, but in practice the terminology used to refer to each of these activities often differs between regions and product sectors. For example, in conducting secondary research on companies undertaking VRPs in Canada, we determined that some small, independent VRP agents used the term 'remanufacturing' or 'overhaul' to describe what would be considered comprehensive refurbishment or refurbishment using the above definitions. To demonstrate this, an excerpt from HDOR producer Liebherr's report on its remanufacturing activities has been provided in *Table 65*. From this figure it's apparent that Liebherr labels two of its activities as either 'exchange components' or 'general overhaul'; but by using the definitions provided above, these product offerings could be characterised as remanufacturing and comprehensive refurbishment respectively**.**

*Table 65: Extract from Liebherr remanufacturing program pamphlet.*

| | Exchange Components | General Overhaul | Repair Components |
|---|---|---|---|
| **Components for customer** | Exchange | Customer's property | Customer's property |
| **Machine downtime** | Max. 1 day (installation and removal – with proactive ordering) | 5 days (plus transport time) | 3 days after order is placed (plus transport time)* |
| **Cost of repair** | Fixed price | Fixed price | Offer |
| **Disassembly and cleaning** | Complete | Complete | Partial |
| **Paint removal and derusting** | Complete | As required | Partial |
| **Assembly** | Complete (based on current state of technology) | Complete (based on current state of technology or original condition) | Defective parts replaced with Reman grade or new parts |
| **Inspection** | As per OEM standard | As per OEM standard | As per OEM standard |
| **Painting** | Complete | Complete | Based on customer requirement |
| **Warranty on complete component** | As per new part | As per new part | Up to 50 % of new part |

*applies to the Reman Competence Centre in Europe

*Source:* (21)

This imprecise use of terminology to describe VRP scenarios is not uncommon and can even occur within an individual product sector. Russell notes that the terms 'reconditioning', 'rebuilding' and 'remanufacturing' are all variously used to describe the same process of "returning electronic equipment to safe, reliable condition" (60). The breadth of terminology used to describe VRP activities is widened further when taking into account the multitude of global languages. Just a few of these translations can be viewed in *Table 66*, which displays the terminology used to describe VRP activity in the automotive sector across a selection of European countries.

*Table 66 Comparative remanufacturing terms in the automotive sector*

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

*Source:* (61)

Although full-service life VRPs (remanufacturing and comprehensive refurbishment) necessitate greater energy and material requirements than partial-service VRPs, these processes also generate a full, or nearly full, extension of the products service life. As a result, the energy and material intensity of full-service life VRPs must be judged relative to the improvement in the product lifespan (60).

**Alternative terminologies for VRP terms**

This research has used terms taken from and defined in the UNEP VRP Report (10). However, a number of other terms are in common use to describe one or other of the VRPs. These terms are frequently sector-specific and – confusingly – overlap in the sense that a single term may apply to one VRP in one context and another VRP in another. *Table 67* provides a non-exhaustive list of terms in use and their alternative definitions. This highlights the need for standardisation, or at least harmonisation, in this area.

*Table 67: Alternative terms used in reference to VRPs*

| Term | Definition | Reference |
|---|---|---|
| **Overhaul (=comprehensive refurbishment)** | The process of returning equipment to safe and reliable operation condition while extending the service life of the product. | RIT-RIC conference circular economy quiz https://www.rematec.com/news-articles/take-the-circular-economy-definition-quiz/ |
| **Recondition (=refurbishment)** | The potential adjustment to components bringing an item back to working order, though not necessarily to an 'as new' state. | Triple Win *The Economic, Social and Environmental Case for Remanufacturing* (62) |
| | Return a used product to a satisfactory working condition by rebuilding or repairing major components that are close to failure, even where there are no reported or apparent faults in those components. | BS 8887-2: 2009 |
| | The modification of […] a product to increase or restore its performance and/or functionality or to meet applicable technical standards or regulatory requirements, with the result of making a fully functional product to be used for a purpose that is at least the one that was originally intended. | RIT-RIC conference circular economy quiz https://www.rematec.com/news-articles/take-the-circular-economy-definition-quiz/ |
| | Notes<br>• Generally less expensive than remanufacture but more than necessary for repair.<br>• Performance after reconditioning is expected to perform its intended role but overall is likely to be inferior to that of the original model.<br>• Subsequent warranty is generally less than new or a remanufactured product. | |
| **Refurbish (=refurbishment)** | The largely aesthetic improvements of a product which may involve making it look like new, with limited improvements to functionality. | Triple Win *The Economic, Social and Environmental Case for Remanufacturing* |
| | The process of ensuring that a system continually performs its intended functions at its original level of reliability and safety. | RIT-RIC conference circular economy quiz https://www.rematec.com/news-articles/take-the-circular-economy-definition-quiz/ |
| **Repair (=repair)** | Fixing a fault but with no guarantee on the product as a whole. | Triple Win *The Economic, Social and Environmental Case for Remanufacturing* |
| | Returning a faulty or broken product or component back to a useable state. | BS 8887-2: 2009 |
| | Fixing what is broken or worn. | Lund, n.d. *The Database of Remanufacturers* (63) |

| | | |
|---|---|---|
| | The process of returning equipment to safe and reliable operation condition while extending the service life of the product. | RIT-RIC conference circular economy quiz https://www.rematec.com/news-articles/take-the-circular-economy-definition-quiz/ |
| | Notes<br>Repair may use remanufactured or reconditioned parts.<br>Minimum manufacturing effort required to address the specified fault.<br>Subsequent warranty is generally less than that of newly manufactured, reconditioned or remanufactured and may only apply to the replaced component. | |
| **Reuse (=reuse)** | The simple reuse of a product with no modifications. | Triple Win *The Economic, Social and Environmental Case for Remanufacturing* |
| | Operation by which a product or its components are put back into use for the same purpose at end of life. | BS 8887-2: 2009 |
| | The collection, inspection and testing, cleaning, and redistribution of a product back into the market under controlled conditions (e.g. a formal business undertaking). | RIT-RIC conference circular economy quiz https://www.rematec.com/news-articles/take-the-circular-economy-definition-quiz/ |
| **Recycle** | Extracting a product's raw materials to use in new products. This is a good option for products which are easily constructed and have minimal numbers of components. | Triple Win *The Economic, Social and Environmental Case for Remanufacturing* |
| | Shredding or disassembling products to recover materials value. | Lund, n.d. *The Database of Remanufacturers* |
| | Process waste materials for the original purpose or for other purposes, excluding energy recovery. | BS 8887-2: 2009 |

*Remanufacturing*

There are varied definitions of what constitutes remanufacturing, although for the purposes of this project, the definition synthesised by UNEP in their 2018 report (4) will be used.

Other definitions of remanufacturing exist, drawing upon a small pool of characteristics, emphasising some over others. In pursuit of a standardised and universal definition, these variants show a tension between defining based on process steps employed (multi-step, disassembly, testing, validation etc.) or upon the properties of the product produced (as exemplified by the life expectation and warranty). In general, ISO and other standards are designed to regulate processes and methods in the belief that this determines outcome. However, because independent and OEM remanufacturers do not operate from the same knowledge base, this may prove problematic. Therefore, a standard which guarantees a particular outcome, such as a lifetime expectation of 'x' years, offers a means of competition on an open basis and may indeed be more meaningful to a purchaser.

Remanufacturing necessitates the disassembly and the subsequent reassembly of product units. In most cases, remanufactured product units will comprise of components and modules sourced from multiple product units.

Although remanufacturing is associated with investment of higher energy, labour and finance with increased emissions compared to partial VRP scenarios, three case studies detailed in the 2018 UNEP VRP report (4) indicated that remanufacturing could reduce energy requirements relative to new production by between 57-87%, production waste by 90% and production costs by 44%.

*Comprehensive refurbishment*

The pipeline of the comprehensive refurbishment process will usually consist of collection, data wiping (for electronics) and upgrade, repair for functionality and then aesthetic touch-ups. Because of the rigorous nature of this process, the service life of the refurbished product will often be almost equal to that of the full new product service life. Comprehensive refurbishment can also result in a 44% production cost reduction relative to new production (4).

*Repair*

Unlike other VRP scenarios, repair activities take place elsewhere within the larger product system and can be considered as a separate flow. Further, most repair activities can be characterised as not requiring established infrastructure (collection, diversion or inspection), production facilities or distribution infrastructure.

Product repair requires that faulty or worn out components are removed and replaced in order to restore the product to a functional condition for the remainder of its expected lifespan. These activities are not usually accompanied by any form of warranty for the whole product unit, but generally are restricted to replaced components.

Repair activities are assumed to take place within all product sectors and for non-industrialised economies account for the great majority of VRP that are undertaken. Repair activities are also widely recognised within national accounting systems, making their tracking a somewhat easier problem than is the case for other VRPs.

# Appendix B Interview questionnaire

# Remanufacturing & other VRPs in the UK

A survey of remanufacturing and other value retention process activity

Before taking the survey, we affirm your rights to privacy and data protection under the Data Protection Act. Your responses are voluntary and may be withdrawn at any time by contacting the survey team or the Data Protection Officer at Oakdene Hollins.

If you are completing this survey with one of our interview team, they will explain these rights to you as well as giving you more background on the project. In this case, note that we have also pre-filled some responses based on our prior knowledge and research on your organisation, but please do alert us to corrections and amendments.

* Required

## Informed Consent

Your data protection and privacy is important to us. We need you to agree with the way we will handle your information and let you know your and our rights and obligations.

** I confirm that I have read and understood the Participant Information Sheet for the above study and have had any questions I had answered

** I understand my participation is voluntary and that I am free to withdraw my data, without giving a reason, by contacting the lead researcher

** I understand that all the information I provide will be held securely and treated confidentially

** I am happy for the information I provide to be used (anonymously) in formal research outputs for a Canadian government report

1. I have read and understood the nature of the survey, and the right and obligations on all parties. I agree to taking part. *

◯ I agree

◯ I don't agree. I will quit the survey.

## About this Survey

This is a short survey of around 40 questions, many of them multiple choice or tick boxes. It also contains boxes where you can enter your own text responses, so although you might expect to take around 15-20 minutes to complete, this will depend on how much extra detail you want to go into on the free text.

Very few questions are compulsory (mainly those that allow us to validate you and fulfil our data privacy obligations), but the more you can complete the better, thank you.

For clarity, we provide the following short descriptions of terms we use to classify VRPs. Broadly, these are arranged by the depth and rigor of any treatment process necessary to put them back into service:

** Remanufacturing: A standardized industrial process that takes place within industrial or factory settings, in which cores are restored to original as-new condition and performance or better. The remanufacturing process is in line with specific technical specifications, including engineering, quality, and testing standards, and typically yields fully warranted products. (Source: Abridged from Document "REDEFINING VALUE THE MANUFACTURING REVOLUTION", UNEP, 2018)

N.B. Terminology may vary by sector whilst meeting the same criteria. E.g. aerospace may use 'through life maintenance' and automotive may use 'reconditioning'

** Comprehensive Refurbishment: Refurbishment that takes place within industrial or factory settings, with a high standard and level of refurbishment. (e.g. medical, high end electronics, off-road) (UNEP definition, based on Refurbishment, next)

** Refurbishment: Modification of an object that is waste or a product to increase or restore its performance and/or functionality or to meet applicable technical standards or regulatory requirements, yielding a fully functional product to be used for a purpose that is at least the one that was originally intended. (e.g. some automotive parts, furniture)
(Source: Abridged from Document "REDEFINING VALUE THE MANUFACTURING REVOLUTION", UNEP, 2018)

** Repair: Fixing of a specified fault in an object that is a waste or a product and/or replacing defective components, in order to make the waste or product a fully functional product to be used for its originally intended purpose. (Source: Document UNEP/CHW.13/4/Add.2)

** Reuse: The using again of a product, object or substance that is not waste for the same purpose for which it was conceived without the necessity of repair or refurbishment etc.
(Source: Document UNEP/CHW.13/4/Add.2)

## Your Contact Information

2. Organisation name & primary sector (pre-fill) *

*Sectors: aerospace, automotive, heavy-duty & off-road, electronic, household appliances, furniture*

3. Your name and position in organisation (pre-fill) *

4. Your email address and phone number (pre-fill) *

5. Website address of your organisation (pre-fill)

## General Information about your Organisation

6. Where is the home country or headquarters of your organisation? (prefill)

- ◯ UK
- ◯ EU+ i.e. inc. Switzerland, Norway, Iceland, Greenland, Lichtenstein, Monaco...
- ◯ Other Europe i.e. inc. Russia, 'Eastern Europe', Turkey
- ◯ USA, Canada, Mexico
- ◯ Central America
- ◯ South America
- ◯ Asia-Pacific inc. Australia, NZ
- ◯ Africa + Middle East
- ◯ Other

7. What is the sales revenue in the UK of your organisation in GBP? *

*N.B. If you are on the boundary of a range, put yourself in the higher bracket*
*m = millions*

- ◯ Zero
- ◯ Less than £1.7m / 10 people (micro business)
- ◯ £1.7m up to £8.6m / 50 people (small business)
- ◯ £8.6m up to £43m / 250 people (medium business)
- ◯ £43m and above (large business)
- ◯ Don't know

8. What is the split of your operations in the UK? *

9. How many employees do you have in the UK?

- ◯ Zero
- ◯ Up to 9 (micro business)
- ◯ 10 to 49 (small business)
- ◯ 50 to 249 (medium business)
- ◯ 500 to 2000 (large business)
- ◯ 2000 or more (very large business)
- ◯ Don't know (we'd prefer you to guess!)

## About your VRPs and Sectors

This section asks for some basic data about what sort of VRPs you carry out and in which sectors.

10. In what sectors are you carrying out Value Retention Processes? (pre-fill) *

- ☐ Aerospace (airframes and structures)
- ☐ Aerospace (engines and turbines)
- ☐ Aerospace (sub-systems)
- ☐ Aerospace (avionics)
- ☐ Aerospace (components etc.)
- ☐ Automotive: engines + drive train
- ☐ Automotive: parts + components
- ☐ Heavy Duty and Off-Road vehicles + parts
- ☐ Domestic appliances
- ☐ Consumer electronics
- ☐ Furniture
- ☐ Marine (components, machinery, electronics, not hulls)
- ☐ Rail (rolling stock and ancillaries, not track)
- ☐ Medical
- ☐ Industrial equipment (machine tools, pumps, hoists...)
- ☐ Other

11. Which of the following VRP activities does your company engage in?

*For assistance on these definitions, please refer back to the introductory text or open a browser window to www.remancan.com/vrps (http://www.remancan.com/vrps)*

*If you have multiple products and it varies by product, please indicate in Q12 and we'll follow up with you. Continue to answer here across your product porfolio.*

- [ ] Remanufacturing (inc. Reconditioning, Overhaul)
- [ ] Comprehensive Refurbishment
- [ ] Through-life engineering
- [ ] Refurbishment
- [ ] Repair/Maintenance
- [ ] Reuse
- [ ] Other

12. If you carry out more than one VRP, please give us the approximate % splits of sales revenue

*If you could explain why you employ multiple VRPs, that would assist us. For example, "To support a variety of customer quality/performance needs" or "So I can cascade products through multiple lives."*

13. What type of VRP agent are you?

- [ ] OEM VRP agent (i.e. on your own products)
- [ ] Contract VRP agent i.e. on behalf of an OEM
- [ ] Independent VRP agent i.e. without OEM endorsement
- [ ] Other

14. How many employees do you have in the UK employed in VRP activities?

- ◯ Zero
- ◯ Less than 5
- ◯ 5 to 9
- ◯ 10 to 19
- ◯ 20 to 49
- ◯ 50 to 99
- ◯ 100 to 249
- ◯ 250 to 499
- ◯ 500 or more
- ◯ Don't know (we'd rather you guess!)

## About your VRP Sales Activities

This section is about where your VRP products are sold or exported.

15. What are the major geographical markets for your VRP products?

- ☐ UK
- ☐ EU+ – i.e. including Switzerland, Norway, Iceland, Greenland, Lichtenstein, Monaco
- ☐ Rest of Europe – i.e. including Russia, 'Eastern' Europe, Turkey
- ☐ North America, Mexico
- ☐ Central America
- ☐ South America
- ☐ Asia-Pacific, including Australia, NZ
- ☐ Africa + Middle East
- ☐ 

Other

16. What is the approximate sales revenue from all your VRP activities?

N.B. If you are on the boundary of a range e.g £8.6M, put yourself in the higher bracket i.e. £8.6M - £20M;   M = millions

- ◯ Less than £500k
- ◯ £500k up to <£1M
- ◯ £1M up to <£1.7M
- ◯ £1.7M up to <£4M
- ◯ £4M up to <£8.6M
- ◯ £8.6M up to <£20M
- ◯ £20M up to <£43M
- ◯ £43M up to <£100M
- ◯ £100M up to £250M
- ◯ £250M or more
- ◯ Don't know (we'd rather you guess!)

## About all VRP Activities

This section is about your business operations.

Please answer in respect of your MAIN VRP ACTIVITY i.e. the one you gave the highest percentage in Q11/12.

17. Briefly describe the types of products you are processing (pre-fill)

*For example, in automotive: alternators, starter motors, turbo-chargers...*

18. Whereabouts do you carry out your operations for your main VRP, Canada and abroad? (pre-fill)

- ☐ UK
- ☐ EU+ i.e. inc. Switzerland, Norway, Iceland, Greenland, Lichtenstein, Monaco...
- ☐ Rest of Europe - i.e. including Russia, 'Eastern' Europe, Turkey
- ☐ North America, Mexico
- ☐ Central America
- ☐ South America
- ☐ Asia-Pacific, inc. Australia, NZ
- ☐ Africa + Middle East
- ☐ Other

19. If you indicated UK operations above, please list regional activity splits (%)

20. If you indicated foreign operations above, please list the split of main VRP processing value between these countries (%)

*e.g. UK 65%; USA 20%; Asia-Pacific 15%*

20. If you indicated foreign operations above, please list the split of main VRP processing value between these countries (%)

    *e.g. UK 65%; USA 20%; Asia-Pacific 15%*

21. What is the approximate number of product units passing through your main VRP process annually?

22. Can you indicate the approximate gross margin on your main VRP products?

    *We'd just like an indication. Your response is confidential.*
    *Gross profit margin is calculated by subtracting the cost of goods sold from total revenue for the period and dividing that number by revenue.*

    - ◯ 0-5%
    - ◯ 5-10%
    - ◯ 10-20%
    - ◯ 20-50%
    - ◯ >50%

23. What are the employment impacts of your main VRP activity?

*Are you able to quantify job creation over and above normal manufacturing? Are there any spin-off benefits to other companies e.g. in your supply chain, or elsewhere in the economy?*

24. Have you conducted any LCA or carbon impact studies into your VRP activities?

*You may have undertaken a Life Cycle Analysis comparison to 'linear' manufacturing. If you could describe impacts on energy, CO2, plastic use/reuse, waste or another indicator that would be great. Even if you could indicate a material saving over manufacture that would assist. For example "I can reuse about 70% of my stainless-steel machined product".*

*What happens to the metals and plastics you can't conserve? Do you have a recycling policy?*

*If you have analyses or corporate statements you are able to send us, please do; that might save you time here. Our contact details are in the footer of the www.remancan.com (http://www.remancan.com) site or email dskinner@dillon.ca (mailto:dskinner@dillon.ca)*

## About your Operations in the UK

We're trying to get an idea of the scope of VRP activity, sizes of companies, where it is happening, etc. Please use the following section to give any detail you can. We've suggested some trigger questions, but feel free to use your own words.

Please continue to answer in respect of your MAIN VRP ACTIVITY i.e. the one you gave the highest percentage in Q11/12.

Consider these trigger questions:
Approximate total sector/product revenue? Major players by market share? Highest quality operators? Most innovative operators? Clusters of activity in {provinces/territories}?

25. How would you describe the main VRP sector in relation to your company?

For example "I'm a small operator, there are about 20 others like me, 5 medium size companies and 3 majors of >£20 million sales. Company Z is pushing the envelope using robotics. About half the sector is located in Wales."

## About the Market Potential in the UK

Please continue to answer in respect of your MAIN VRP ACTIVTY i.e. the one you gave the highest percentage in Q11/12.

26. How do you expect the market for your VRP products in the UK to develop in the next 5-10 years?

Answer in respect of your main VRP activity. Assume that this is the result of 'natural growth' i.e. no intervention or assistance from outside agencies.

- ◯ Strong annual growth >3%
- ◯ Moderate annual growth >1% up to 3%
- ◯ Low annual growth up to 1% p.a.
- ◯ Stagnant
- ◯ Declining
- ◯ Disappearing
- ◯ Don't know/uncertain

27. What is the potential future market size for your VRP activity in the UK up to 2030?

Please think broadly here. Consider that all barriers to expansion are removed and that only technical factors such as technological obsolescence remain. If you want to add reasons for this view, please describe. Also, if you have multiple VRP activities and they are evolving differently, we'd be interested to hear about that.

There's a question later about how VRPs might be boosted but feel free to cover that here if you'd rather.

## Engaging with Customers

28. Which of the following business models best describes how you deliver your main VRP activity?

*We appreciate you may use multiple approaches; if you'd like to qualify your answer, please use the text box in the next question.*

- ◯ Leasing
- ◯ Direct order
- ◯ Deposit/credit
- ◯ Service contract
- ◯ Other

29. Who are the major customers for your main VRP products?

*You don't need to name actual companies, just the business sectors/types.*

30. Are your VRP products or processes certified in any way?

*We'd like to know whether you've adopted standards specifically to assist with the sale of VRP products, not standards you may already have for your manufacturing operations.*

## International operations

We'd like to understand what's happening with products moving across borders as well as the nature of international competition. Numbers would be a bonus.

Please answer this question in respect of all your VRP activities.

31. Is export part of your mix? If so, what are the prospects or opportunities?

*We'd like to know how much you export, to which regions or countries and the trends.*

32. What competition do you see from imports of VRP-products?

*We'd like to hear what you know about imports of competitor products and from which countries. What countries are on the rise and what are the trends?*

33. Have you encountered any barriers to the export of your VRP-products? If so, what are they?

*They may be legislative, procurement-related, environmental, cultural etc.*

## Motives and Barriers to adopting VRPs

34. How important are the following considerations in adopting and pursuing VRPs? (pre-fill)

*This question relates to your motivation for being involved.*

| | Not important | Somewhat important | Quite important | Very important |
|---|---|---|---|---|
| Securing spare parts supply | ◯ | ◯ | ◯ | ◯ |
| Fulfilling warranties | ◯ | ◯ | ◯ | ◯ |
| To increase market share | ◯ | ◯ | ◯ | ◯ |
| Asset/brand protection | ◯ | ◯ | ◯ | ◯ |
| Customer demands | ◯ | ◯ | ◯ | ◯ |
| Legislation (federal) | ◯ | ◯ | ◯ | ◯ |
| Legislation (provincial) | ◯ | ◯ | ◯ | ◯ |
| Profitability | ◯ | ◯ | ◯ | ◯ |
| Strategic advantage | ◯ | ◯ | ◯ | ◯ |
| Securing subsidies | ◯ | ◯ | ◯ | ◯ |
| Environmental responsibility | ◯ | ◯ | ◯ | ◯ |
| Environmental benefits | ◯ | ◯ | ◯ | ◯ |
| Other (describe below) | ◯ | ◯ | ◯ | ◯ |

35. Have fluctuations in energy, materials or component prices acted as a driver for greater VRP activity?

- ◯ Definitely
- ◯ Probably
- ◯ Maybe
- ◯ No
- ◯ Not sure

36. To what extent have the following acted as barriers or issues in maintaining or expanding your business? (pre-fill)

*This question relates to your ongoing VRP activities and difficulties you encounter.*
*There is an opportunity for you to expand on your response to motivations and barriers further on.*

| | Not important | Somewhat important | Quite important | Very important |
|---|---|---|---|---|
| Availability of feedstock | ◯ | ◯ | ◯ | ◯ |
| Quality of feedstock | ◯ | ◯ | ◯ | ◯ |
| Customer recognition | ◯ | ◯ | ◯ | ◯ |
| Adequate sales channels | ◯ | ◯ | ◯ | ◯ |
| Legislation (Canadian) | ◯ | ◯ | ◯ | ◯ |
| Legislation (foreign) | ◯ | ◯ | ◯ | ◯ |
| Availability of technology/techniques | ◯ | ◯ | ◯ | ◯ |
| Adequate product knowledge | ◯ | ◯ | ◯ | ◯ |
| Access to skilled personnel | ◯ | ◯ | ◯ | ◯ |
| Labour costs | ◯ | ◯ | ◯ | ◯ |
| Pressure from foreign imports | ◯ | ◯ | ◯ | ◯ |
| Design & construction of products | ◯ | ◯ | ◯ | ◯ |
| Other (describe below) | ◯ | ◯ | ◯ | ◯ |

37. What policy measures might be useful in supporting VRP-industries?

You may have seen good/bad policies in the UK, EU or elsewhere. We'd love to hear about those.

You could make this specific to your sector or product, or a general approach, but please be clear which.

38. If you do not remanufacture, why is that?

*We're interested in what factors stop you 'moving up the value chain'.*

*Reasons could be: "product value doesn't justify it", "can't disassemble", "lack of product knowledge", "no market demand", "trade barriers" etc.*

39. Are there particular technical, manufacturing and innovation challenges or opportunities in your field?

We're interested to know how Innovate UK and BEIS might assist you in developing your products to be more suitable for VRP, extend the range of VRPs or to take advantage of technologies such as surface remediation or diagnostics.

40. Do you have further comments on motivations and barriers or other parts of the survey?

*Use this box also if you answered 'other' above, for example. You can also use it if you'd like to make additional comments on any part of the survey. For example, if you have multiple VRPs, you might like to characterise them and add commentary here.*

## Thank you!

Many thanks for you time and contribution to this work. If you consent, we'll keep you informed of progress and any reports coming out. We might also contact you for clarification on your responses, to invite you to project workshops and industry forums, or ask for feedback on possible actions government might take to assist, in line with GDPR.

41. I'm OK with you staying in touch *

◯ Yes

◯ No

# Appendix C Survey questionnaire

## National Survey for Value Retention Processes (VRP)

### 1.Introduction

As the backbone of the circular economy, Value Retention Processes (such as remanufacturing, refurbishment, repair, arranging direct reuse, and through-life engineering services) enable the retention of value of end-of-use and end-of-life products, and in some cases the creation of new value for both industry and customers, at a reduced environmental impact. Despite substantial numbers and massive environmental, social and economic benefits of VRP, the uptake of VRP is very low in industry, e.g. ratio of remanufacturing and comprehensive refurbishment to new manufacturing is only 1.9%. [ERN, 2015]. Funded by Innovate UK (governmental funding agency) and endorsed by the department for Business, Energy and Industrial Strategy (BEIS), this survey has two purposes:

- To investigate the status, barriers and opportunities of VRP for potential governmental policy intervention.
- To understand the market potential of a remanufacturing e-marketplace (REMP) that is under development to address the issues facing VRP e.g. a lack of sales channel, insufficient end-of-life products for VRP and a lack of confidence of consumers on VRP products.

This survey is composed of three parts:

Part 1: Understanding the current state of VRP in the UK in order to inform innovation needs and policy interventions.

Part 2 The need for an e-marketplace for VRP

Part 3: About your business and Wrap up

The whole survey will take approximately 18 minutes. If you need to break off at any time, please click 'Save' and you will be able to access the questionnaire later at the point where you left. Please don't click 'Save' at any other time, unless you want to exit the survey.

At the end of each page, please click the 'Next' button at the foot of the screen to go to the next page. If you need to go back to check or change an answer, please the click the 'Back' button at the foot of the screen, not the ← button in your browser.

**Definitions for VRP**

For clarity, we provide the following short descriptions of terms we use to classify VRPs. Broadly, these are arranged by the depth and rigour of any treatment process necessary to put them back into service: **

**Remanufacturing**: A standardised industrial process that takes place within industrial or factory settings, in which cores are restored to original as-new condition and performance or better. The remanufacturing process is in line with specific technical specifications, including engineering, quality, and testing standards, and typically yields fully warranted products.

**Comprehensive Refurbishment**: Refurbishment that takes place within industrial or factory settings, with a high standard and level of refurbishment. (e.g. medical, high end electronics, off-road) (UNEP definition, based on Refurbishment, next) **

**Refurbishment:** Modification of an object that is waste or a product to increase or restore its performance and/or functionality or to meet applicable technical standards or regulatory requirements, yielding a fully functional product to be used for a purpose that is at least the one that was originally intended. (e.g. some automotive parts, furniture)

**Repair:** Fixing of a specified fault in an object that is a waste or a product and/or replacing defective components, in order to make the waste or product a fully functional product to be used for its originally intended purpose. *(Source: Document UNEP/CHW.13/4/)*

**Direct Reuse:** The using again of a product, object or substance that is not waste, for the same purpose for which it was conceived without the necessity of repair or refurbishment etc.

*(Source: Document UNEP/CHW.13/4/Add.2)*

**Through-Life Engineering**

A programme of scheduled maintenance (i.e. well before end of life) designed to keep performance of goods at as-new or better levels

***(Source: Abridged from Document "REDEFINING VALUE THE MANUFACTURING REVOLUTION", UNEP, 2018)*

## Part 1- Understanding the current state of VRP in the UK in order to inform policy.

## 1.1 Your company involvement in Value Retention Processes

Q1 **Which of the following VRP activities does your company engage in?**
*PLEASE TICK ALL THAT APPLY*
- ❑ Remanufacturing
- ❑ Comprehensive refurbishment

- ❑ Refurbishment
- ❑ Through-life engineering after refurbishment
- ❑ Repair
- ❑ Direct reuse
- ❑ Services related to remanufacturing or through-life engineering
- ❑ None of the above

Q2 **What type of VRP agent are you?**

*PLEASE TICK ALL THAT APPLY*

- ❑ Original equipment manufacturers
- ❑ VRP agent contracted by OEM(s)
- ❑ Independent VRP agents
- ❑ Service provider related to VRP activities
- ❑ None of the above

Q3 **Where do you carry out your operations for your main VRP?**

*PLEASE TICK ALL THAT APPLY*

- ❑ UK
- ❑ China
- ❑ Europe
- ❑ US
- ❑ Elsewhere-please specify in the box below

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Q3a **Do you carry out any VRP-related R&D in the UK?**

- ❑ Yes
- ❑ No

Q4 **What percentage of your overall sales revenue comes from value retention processes (to the nearest 10%)?**

*PLEASE TICK ONE ANSWER ONLY*

- ❑ <10%,
- ❑ 11-19%
- ❑ 20-29%
- ❑ 30-39%
- ❑ 40-49%

- ❑ 50-59%
- ❑ 60-69%
- ❑ 70-79%
- ❑ 80-89%
- ❑ 90-99%
- ❑ 100%

Q5 **If you carry out more than one VRP, please give us the approximate % splits of sales revenue?**

______________________________________________________________________________________________
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__________________________________

Q6 **What do you estimate is the total UK market value for the VRP sectors you currently work in?**

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Q7 **What is the approximate number of product units passing through your main VRP process annually?**

______________________________________________________________________________________________
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Q8 **Please could you indicate the approximate gross margin on your main VRP products?** *We'd just like an indication. Your response is confidential, and we understand if you do not answer.*

______________________________________________________________________________________________
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## 1.2 Engaging with Customers

Q9 **Which of these activities describes your business model/approach to customers?**
*PLEASE TICK ONE ANSWER ONLY*

- ❑ Business to Business (B2B)
- ❑ Business to Consumer (B2C)
- ❑ Mix of B2B and B2C

Q10 **Which sales methods do you currently use for selling your VRP products?**

*PLEASE TICK ALL THAT APPLY*

- ❑ Own website
- ❑ E-marketplace (eBay or Amazon)
- ❑ Physical stores
- ❑ Via Original Equipment Manufacturer
- ❑ Elsewhere - please specify in the box below

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Q11a **Which business sectors are the main customers for your VRP products?**

*PLEASE TICK ALL THAT APPLY*

- ❑ Automotive
- ❑ Consumer Electronics
- ❑ Rolling Stock
- ❑ Marine
- ❑ Construction
- ❑ Machine Tools
- ❑ Electric vehicle batteries
- ❑ Office equipment
- ❑ Heavy Duty and Off-road equipment
- ❑ Renewable energy
- ❑ Aerospace
- ❑ Defence
- ❑ Other - please specify in the box below

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Q11b **What is/are the SIC code(s) for your business?**

________________________________________________________________________________________________________

____________________________________________________________

Q12 **How do you currently source your VRP operation feedstock?**

*Used products for VRP which are often referred to as "cores".*

______________________________________________________________________________
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Q13_1 **In the next few questions, we'll ask you to rank which factors are are driving your customers' buying decisions, from most important to least.**

**At each position, we've given you the opportunity to choose from several different options, but you can also answer in your own words by clicking 'Other factor' and typing in the box.**

**So first, which <u>one</u> of these factors is <u>most important</u> in driving your customers' buying decisions?**

**MOST IMPORTANT:** ***PLEASE SELECT ONE ANSWER***

- ❑ Quality of product
- ❑ Price
- ❑ Product history
- ❑ Delivery time
- ❑ Service, including after-sales support
- ❑ End of life disposal
- ❑ Online ratings
- ❑ Other factor - *please specify in the box below*

____________________________________________________________

Q13_2 **2nd MOST IMPORTANT:** ***PLEASE SELECT ONE ANSWER***

- ❑ Quality of product
- ❑ Price
- ❑ Product history
- ❑ Delivery time
- ❑ Service, including after-sales support
- ❑ End of life disposal
- ❑ Online ratings
- ❑ Other factor - *please specify in the box below*

____________________________________________________________

Q13_3. **3rd MOST IMPORTANT:** ***PLEASE SELECT ONE ANSWER***

- ❑ Quality of product
- ❑ Price
- ❑ Product history

- ❑ Delivery time
- ❑ Service, including after-sales support
- ❑ End of life disposal
- ❑ Online ratings
- ❑ Other factor - *please specify in the box below*

_______________________________________________

Q13 **4th MOST IMPORTANT:** ***PLEASE SELECT ONE ANSWER***

- ❑ Quality of product
- ❑ Price
- ❑ Product history
- ❑ Delivery time
- ❑ Service, including after-sales support
- ❑ End of life disposal
- ❑ Online ratings
- ❑ Other factor - *please specify in the box below*

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Q13 **5th MOST IMPORTANT:** ***PLEASE SELECT ONE ANSWER***

- ❑ Quality of product
- ❑ Price
- ❑ Product history
- ❑ Delivery time
- ❑ Service, including after-sales support
- ❑ End of life disposal
- ❑ Online ratings
- ❑ Other factor - *please specify in the box below*

_______________________________________________

## 1.3 General Questions

Q14 **Are your VRP products or processes certified in any way?**

- ❑ Yes
- ❑ No
- ❑ Don't know

Q15 **Which standards or legislation are relevant to you?**

_______________________________________________________________________________________________

_______________________________________________________________________________________________

Q16a **In your own words, please describe the main technical barriers that you face.**
*Examples could be: a lack of automation for VRP processes; core damage during the disassembly operations; a lack of access to OEM software; tracking and tracing of products; determining residual component life; surface remediation techniques; inspection; cleaning; (dis)assembly; processing equipment*.

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Q16b **What are the main non-technical barriers that you face? Please describe in your own words.**

*Examples could be: varying quality and quantity of feedstock for VRPs; customer awareness of VRPs; business models; supply chain integration; standards; lack of consumer confidence from consumers; shortage of skilled workforce; IP risks; competition from low cost imports; ad hoc resource planning*.

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Q17a **What is the rationale for Government intervention and why now?**

_______________________________________________________________________________________________

_______________________________________________________________________________________________

Q17b **Q17b What are the main barriers for innovation in VRP?**

_______________________________________________________________________________________________

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Q17c **Q17c What are the top three things the government can do to support the growth/ expansion/ GVA of VRP?**

*Examples are: promoting awareness of VRP benefits; increasing access to knowledge and networks in VRPs; reducing VAT on VRP products; legislation favouring eco-design; government R&D funding support for VRP; labelling (e.g. repairability labelling on products).*

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Q17d1 **We would like more detail on your answers to question 17c.**

**In the next few questions, we'll ask you to prioritise possible support mechanisms in their order of usefulness.**

**At each position, we've given you the opportunity to choose from several different options, but you can also answer in your own words by clicking 'Other support mechanism' and typing in the box.**

**TOP PRIORITY:** ***PLEASE SELECT ONE ANSWER***

- ❑ Advice or expert support for marketing/market analysis
- ❑ Advice or expert support on technology and equipment adoption
- ❑ Advice or expert support on new business models
- ❑ Finance/funding to purchase new equipment (non-digital)
- ❑ Finance/funding to purchase new industrial digital technologies
- ❑ Finance/funding to purchase or upgrade existing remanufacturing technologies
- ❑ Other support mechanism - *please specify in the box below*

________________________________________________________________________

Q17d2 **2nd PRIORITY:** ***PLEASE SELECT ONE ANSWER***

- ❑ Advice or expert support for marketing/market analysis
- ❑ Advice or expert support on technology and equipment adoption
- ❑ Advice or expert support on new business models
- ❑ Finance/funding to purchase new equipment (non-digital)
- ❑ Finance/funding to purchase new industrial digital technologies
- ❑ Finance/funding to purchase or upgrade existing remanufacturing technologies
- ❑ Other support mechanism - *please specify in the box below*

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Q17d3 **3rd PRIORITY:** ***PLEASE SELECT ONE ANSWER***

- ❑ Advice or expert support for marketing/market analysis
- ❑ Advice or expert support on technology and equipment adoption
- ❑ Advice or expert support on new business models
- ❑ Finance/funding to purchase new equipment (non-digital)
- ❑ Finance/funding to purchase new industrial digital technologies
- ❑ Finance/funding to purchase or upgrade existing remanufacturing technologies
- ❑ Other support mechanism - *please specify in the box below*

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Q17d4 **4th PRIORITY:** ***PLEASE SELECT ONE ANSWER***

- ❑ Advice or expert support for marketing/market analysis
- ❑ Advice or expert support on technology and equipment adoption
- ❑ Advice or expert support on new business models
- ❑ Finance/funding to purchase new equipment (non-digital)
- ❑ Finance/funding to purchase new industrial digital technologies
- ❑ Finance/funding to purchase or upgrade existing remanufacturing technologies
- ❑ Other support mechanism - *please specify in the box below*

___________________________________________________________________________

Q17d5 **5th PRIORITY:** ***PLEASE SELECT ONE ANSWER***

- ❑ Advice or expert support for marketing/market analysis
- ❑ Advice or expert support on technology and equipment adoption
- ❑ Advice or expert support on new business models
- ❑ Finance/funding to purchase new equipment (non-digital)
- ❑ Finance/funding to purchase new industrial digital technologies
- ❑ Finance/funding to purchase or upgrade existing remanufacturing technologies
- ❑ Other support mechanism - *please specify in the box below*

___________________________________________________________________________

Q18 **Considering your top-ranked support mechanisms, please explain how Government funding mechanisms could be designed to best support the expansion of VRP activities in your business or the wider sector.**

**If relevant, please add details of any specific capital equipment or technology needs.**

___________________________________________________________________________________________________

___________________________________________________________________________________________________

Q19 **Which of the following technology interventions would help you most to improve VRP productivity?**
*PLEASE TICK UP TO THREE OPTIONS*

- ❑ Design for VRP
- ❑ Life Cycle Analysis tools & methods
- ❑ Predictive analytics and digital technologies
- ❑ Automation
- ❑ Metrology
- ❑ Digital Twins

- ❑ Product Passport
- ❑ Large Scale Non-destructive inspection etc.
- ❑ VRP processing technology, e.g. sorting of used products, disassembly, cleaning, inspection and welding, and other
- ❑ 3D printing
- ❑ Enterprise Resource Planning software
- ❑ Other - *please specify in the box below*

______________________________________________________________________________________________
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Q20 **To help the government understand the benefits of supporting VRPs, please provide details about the environmental and other social benefits of your VRP operations, or other services you offer, like repair or reuse.**

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Q21 **What percentage of your VRP products do you export?**

- ❑ Less than 20%
- ❑ 20-50%
- ❑ More than 50%

Q22 **Have you encountered any barriers to the export of your VRP products? If so, what are they?**

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## Part 2: The need for an e-marketplace for VRP

*Remade in the UK*

Innovate UK are funding a study into the creation of a Remanufacturing Electronic Marketplace (REMP) that will facilitate both the supply of end-of-life (EOL) products for remanufacturing ("cores") and the subsequent resale of the remanufacturing products. REMP will incorporate a blockchain-enabled quality assurance (QA) mechanism in order to address the issue of poor image and lack of confidence in remanufactured products by consumers and data analytics and smart contracts.

## 2.1 Your Engagement with REMP

Q23 **Where do you see benefit in having access to improved supplies of feedstock (used products for remanufacturing, also called cores) on our online platform?**

*PLEASE TICK ALL THAT APPLY*

- ☐ Higher volumes
- ☐ More choice
- ☐ Better quality
- ☐ Supplier reviews
- ☐ Reduction in costs
- ☐ Don’t know

Q24 **REMP as an e-market will feature only VRP products which have warranties that are equal to new products. Would you be interested in showcasing your VRP products on REMP?**

*PLEASE TICK ONE ANSWER ONLY*

- ☐ Yes
- ☐ No
- ☐ Don't know

Q25 **What are the products that you would recommend we promote on the REMP platform?**

*PLEASE TICK ALL THAT APPLY*

- ☐ Automotive
- ☐ Electronics Products
- ☐ Rolling Stock
- ☐ Marine
- ☐ Construction
- ☐ Machine Tools
- ☐ Electric vehicle batteries
- ☐ Office equipment
- ☐ Heavy Duty and Office Road equipment
- ☐ Renewable energy
- ☐ Other - *please specify in the box below*

______________________________________________________________________________________________

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Q26 **What would be the added value of an *equivalent-to-new* level of warranty for your products in line with remanufacturing practice?**

*PLEASE TICK ALL THAT APPLY*

- ❑ Rise up the value chain
- ❑ Increased consumer confidence
- ❑ More sales
- ❑ Not sure - *please specify in the box below*

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## 2.2 Using blockchain to improve life-cycle accountability

Q27 **To what extent do you believe Blockchain technology implementation, to allow track and trace of feedstocks and finished products, will address the consumer confidence issues faced by the VRP industry?**

*PLEASE TICK ONE ANSWER ONLY*

- ❑ No difference
- ❑ Slightly
- ❑ Moderately
- ❑ Significantly
- ❑ Not sure

Q28 **Do you feel that using blockchain technology to support a comprehensive quality assurance policy will increase sales of VRP products?**

*PLEASE TICK ONE ANSWER ONLY*

- ❑ Yes
- ❑ No
- ❑ Not sure

## 2.3 Enterprise Resource Planning (ERP) Software

Q29 **Which enterprise resource planning software do you use?**

*PLEASE TICK ALL THAT APPLY*

- ❑ Oracle
- ❑ Microsoft
- ❑ Tier II
- ❑ SAP
- ❑ SAGE
- ❑ Other - *please specify in the box below*

______________________________________________________________________________________________

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Q30 **What problems do you envisage in integrating your ERP with our E-market place (REMP?**

*PLEASE TICK ALL THAT APPLY*

- ❑ Data transformation
- ❑ Data formats
- ❑ Non-interoperability with, e.g. other software types
- ❑ Other(s) - *please specify in the box below*

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## 2.4 Reaching Your Market

Q31 **What are the top <u>three</u> things remanufacturing stakeholders can do to increase the expansion of VRP via REMP?**

______________________________________________________________________________________________

______________________________________________________________________________________________

## Part 3: About your business

Q32 **Please provide your business contact details below:**

Your name:____________________________________________

Name of company: ____________________________________________

Your position in company:____________________________________________

Email address: ____________________________________________

Q33 **What size is your company? [based on number of employees at all sites]**
- ❑ Small (Up to 9 staff)
- ❑ Medium (10 to 49 staff)
- ❑ Large (50 to 249 staff)
- ❑ Very large (250 staf or more)

Q34 **How many employees do you have?**

____________________________________________

Q35 **What is your company turnover? [based on last full financial year]**
- ❑ Up to £2m
- ❑ More than £2m, up to £10m
- ❑ More than £10m, up to to 50m
- ❑ More than £50m

Q36 **Could the research team at the University of Brighton follow up with you on your responses to this survey if needed?**
- ❑ Yes
- ❑ No

Q37. **Would you be willing for your name and contact details to be shared with the University of Brighton, along with your responses to this survey?**

- ❑ Yes
- ❑ No

**Your data protection and privacy is important to us. We need you to agree with the way we handle your information and let you know your and our rights and obligations.**

**The data that we use to contact people to ask them to participate in research surveys is never shared with any third parties. Survey results and aggregated data, that is data collected in the survey but combined together to produce results in the form of total numbers and percentages of people expressing a particular view, will normally be provided back to our direct client, as will anonymised lists of comments made by the people that we speak to in response to our survey questions.**

**Any person whose data we hold has the right to make a Subject Access Request (SAR). We must meet such Requests without delay and within one month of receipt, apart from a possible extension of a further two months for complex and multiple requests. We cannot charge a fee for processing such requests.**

**Our direct clients will only receive any data that identifies the individuals we have spoken to for that particular survey if those individuals have given their consent for their responses to be linked to their personal details.**

**Please could you select an answer below to show whether you do or do not agree with the following statements:**

**- I understand that my participation is voluntary and that I am free to withdraw my data without giving a reason by contacting the lead researcher**

**- I understand that all the information I provide will be held securely and treated confidentially**

**- I am happy for the information I provide to be used (anonymously) in any formal research reports prepared by University of Brighton researchers working on this REMP research project**

- ❑ Yes, I agree
- ❑ No, I do not agree

**Thank you for taking part in this survey. Please now click 'Submit' below to submit your responses.**

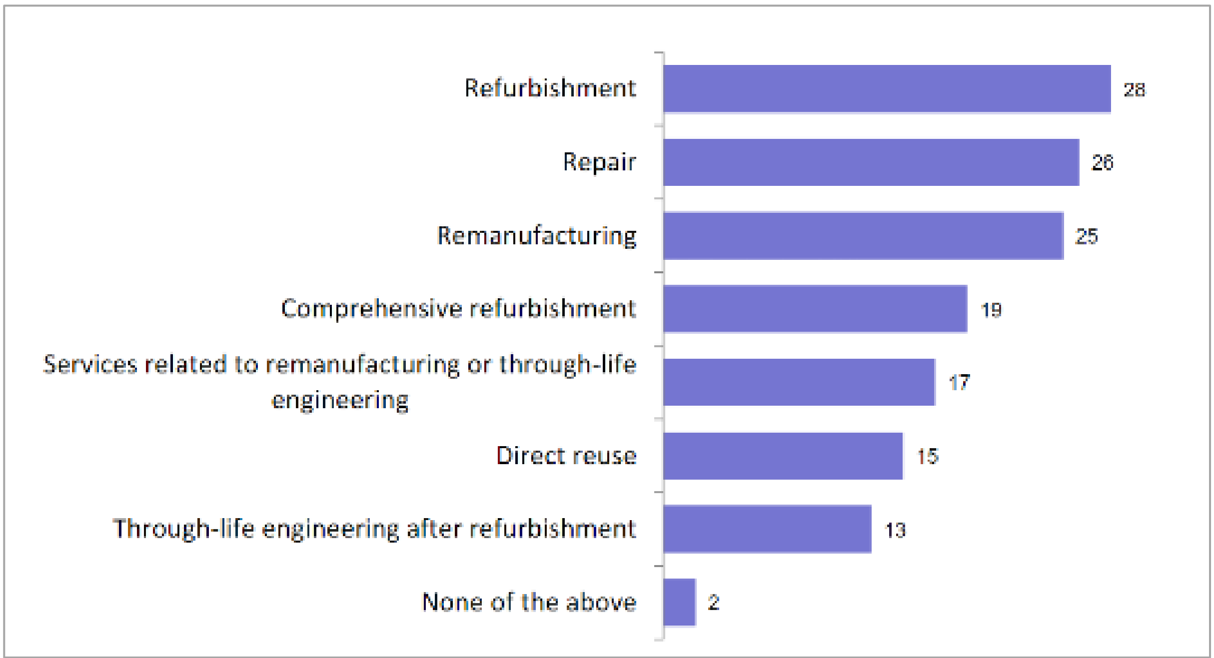
# Appendix D Survey outputs

As shown in the Appendix above, the survey consisted of two sections. Under each section, a brief summary of the survey output is provided. The overall insights were used throughout the report.

**The current state of VRP in order to inform policy**

Overall, interview participants were involved with refurbishment, repair, remanufacturing an direct reuse. Some participants were involved in more than one type of VRP activity, with the most common type of activity being remanufacturing related activities.

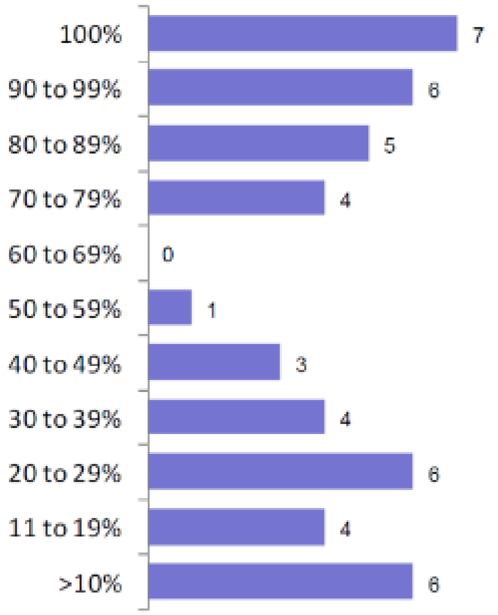
*Figure 34: Types of VRP activities that respondents were involved in*



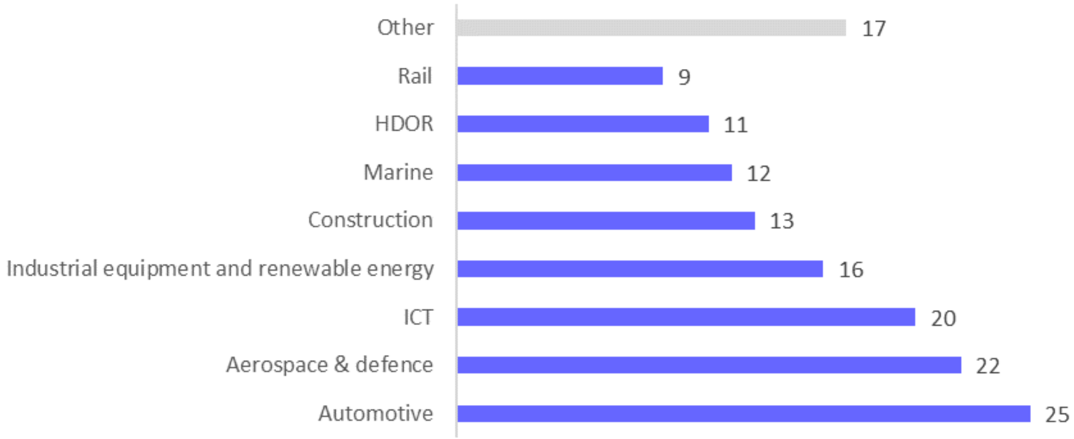

Of the 43 survey respondents, over 70% identified at independent VRP agents with operations in the UK. Most respondents carried out their VRP operation in the UK, with one in six having multiple global locations. These locations include Europe, US, China and the Middle East. Half of the respondents currently base their R&D teams in the UK.

Typically, VRP activities make up 30-40% of the respondents revenue with only 30% of them stating that VRP activities are their primary source of revenue. When asked the value of the market, respondents were very uncertain with estimates ranging from £750,000 (printer cartridge market) to £ 5 billion, with a median answer of £75 million.

*Figure 35: Percentage of revenue that VRP activities take up*




Most sectors under investigation were covered in the survey, some respondents operated in more than one sector. One sector covered in the survey, that is not covered in this report is the construction sector.




One aspect of the survey asked VRP practitioners how they obtained feedstock or core for their activities. The three most common answers for this section were customer returns, reclamations such as open markets and supplies from OEMs.

Half of the respondents operate in B2B markets, with 43% operating in both B2B and B2C markets and the rest only operating in B2C markets. The most popular method of reaching these customer groups have been company owned websites (75%), OEM channels or physical stores. The 'Elsewhere' answers mainly included word of mouth/ repeat business, direct enquiries from customers, advertising/trade shows, and some online/social media promotion.


The factors that drive consumers to choose these products over new or cheaper imports are in order of most important.

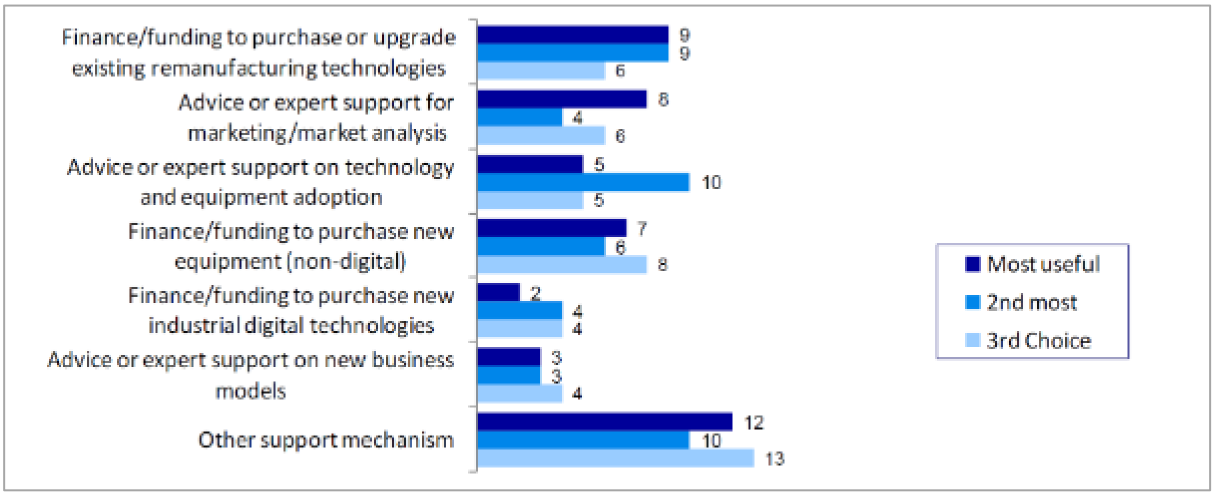
- Quality
- Price
- Aftersales services
- Delivery time
- Knowing product history
- End-of-life disposal
- Online ratings

To ensure a high quality and standard is met, about two-thirds have their products certified, with the most likely certification being ISO-related.

Barriers mentioned include lack of access to information and software from OEMs, lack of consumer awareness or confidence, skills shortage and supply chain issues/EU Exit related issues around accessing feedstock. Respondents have also noted that the largest barriers to innovation in the area are a lack of funding and support from OEMs.

The main rationales for Government intervention as suggested by VRP companies were related to reducing waste and minimising goods' carbon footprint. Leading suggestions on how government can support the growth of VRPs were reducing VAT on these kinds of products and encouraging OEMs to factor VRPs at the design stage, providing funding or grant opportunities, training and apprenticeship programs and expert support on market analysis part of the business.

*Figure 36: Useful support mechanisms from government*




From a productivity lens designing for VRPs and life cycle analysis tooling are the factors most likely to help.

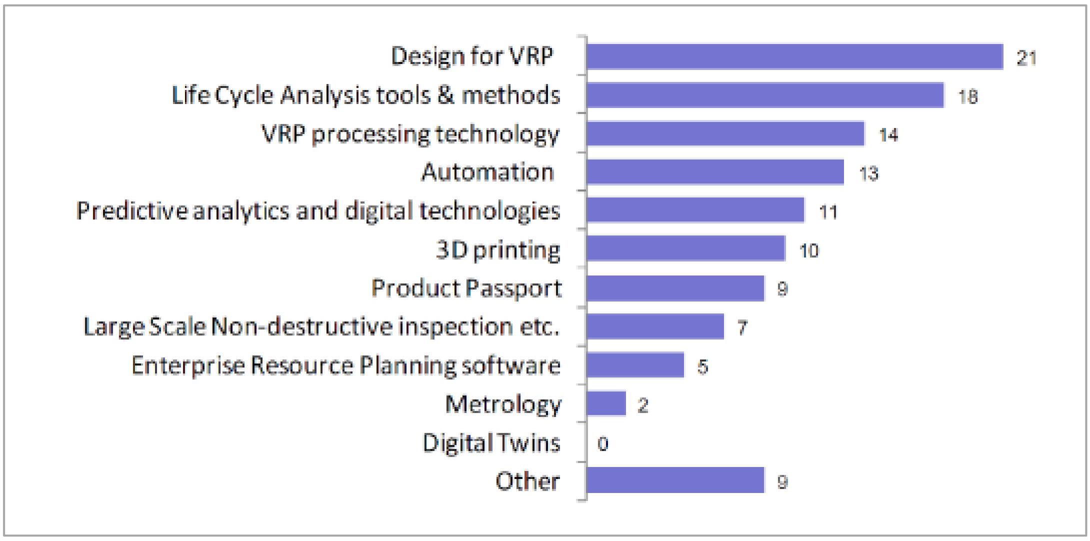


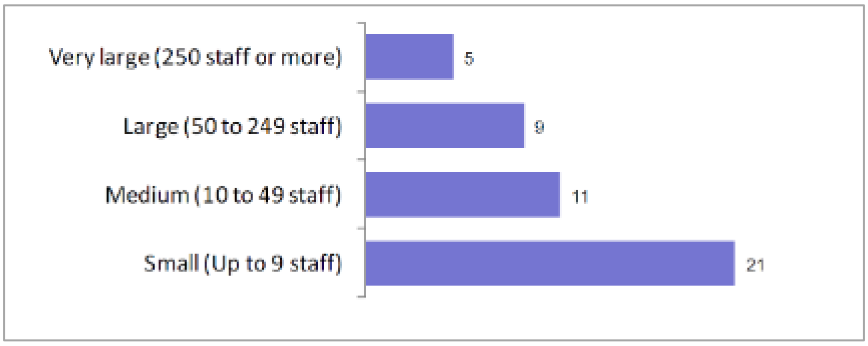

*Figure 37: Technology interventions that would improve VRPs*

Environmental benefits are currently the biggest driver behind VRPs, although some respondents have noted that there are social benefits such as job creation and that it improves resilience.

**The background of the business**

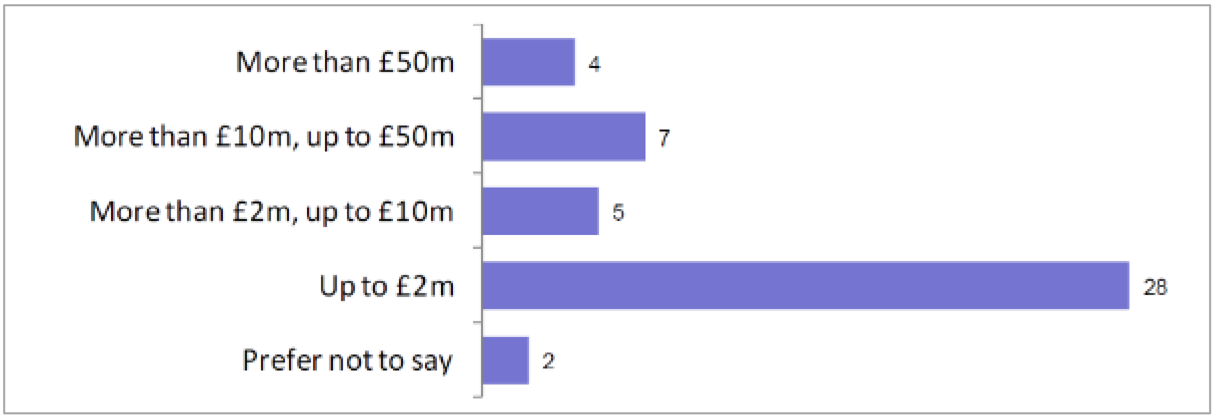
Half of the companies in the survey have fewer than 10 staff members, while only 10% employed over 250 people.

*Figure 38: Company size breakdown*




The revenue for these smaller companies are no more than £2 million, only 4 companies reported turnover above £50 million.

*Figure 39: Company turnover*



# Appendix E Workshop 1 agenda and outputs

| | | |
|---|---|---|
| **Welcome & Housekeeping**<br>**2 mins** | Ben Peace, KTN | Introduction to the workshop and agenda |
| **Intro to context behind the workshop**<br>**15 mins** | Abishek Ramesh, Innovate UK | What is value retention and why it's important? |
| **Cross government perspective**<br>**5 mins** | Stephen le Roux,<br>On behalf of BEIS & Defra | Overview of VRP importance from Government stakeholder |
| **Breakout sessions**<br>**60-90 mins** | All | Workshop using Mural to discover the ambitions for VRP and interventions to realise them |
| **Conclusions & Close**<br>**10 mins** | Facilitators, KTN | Summary of discussions |

### *Breakout room 1*

**Activity 1 - current state of VRP.** There was general agreement within the room with the pre-populated statements and overall, there was a sense that VRP fell short of expectations from attendees. Common themes were the lack of standards, lack of policy/incentives, lack of skilled workers, poor consumer understanding, no clear understanding or definition of VRP and its confusion with waste management. Some positives were encouraging examples from the automotive and office furniture sectors as well as potential for more sectors to increase uptake of VRP activities in the future.

**Activity 2 - Aspirations for 2050 and beyond.** There was greater optimism from the group looking ahead to the future. Attendees had ambitions of a global circular economy in which servitization was the dominant business model. There was a desire for greater thought into the design process enabling easier end of life management. An emphasis on cross sectoral working and a behaviour and culture shift to refuse waste and for customers to seek out VRP products over new. It was also an aspiration of the group to see clear parameters used to assess the life cycle of a product and defined metrics to measure environmental impact. None of this is possible without the supporting infrastructure to enable increased repair, recycling, remanufacturing etc.

**Activity 3 - Interventions.** After defining the present and setting aspirations for the future, the final activity asked delegates to suggest appropriate intervention mechanisms that could lay a roadmap on how to get there.

A long list of interventions was suggested but could be grouped into several key themes (suggested below with an example from each):

- Funding - any new government-run competition should have clear GHG reduction targets within the scope
- Standards - implementing a consistent and standard methodology to measure the life cycle of a product
- Skills/Training - circular/sustainable design principles taught at all university design courses
- Legislation - public contracts requiring suppliers to have a Net-Zero strategy

- Awareness/Visibility - sector specific showcase or demonstrations of VRP activities on a local level

In terms of prioritising interventions, quick wins such as showcasing successful companies embracing VRP and training/upskilling workers had potential for short term (1-3 years) impact whereas regulation change and defining standards, as well as funding competitions, were seen as slower burns to have the same level of impact.

### *Breakout room 2*

**Activity 1 - current state of VRP.** In addition to the pre-populated statements the group added commonly observed reference to issues with terminology and standards, along with more progressive observations including the need for benchmarking, intensive business support, insurance, and environmental (and possibly social) metrics across supply chains. Opportunities came to the fore in wind turbines, rail and aerospace given participants' backgrounds in these sectors – with useful specificity – e.g. Aerospace could recover 85% of aircraft.

**Activity 2 - Aspirations for 2050 and beyond.** Stated hopes included having all assets sensor-enabled; the elimination of landfill; a target (50%) for aluminium produced from scrap. A strong theme was the need for more data, accounting, and benchmarking. Another related one was the need for systems thinking to understand the impact of choices and optimise the use of VRPs.

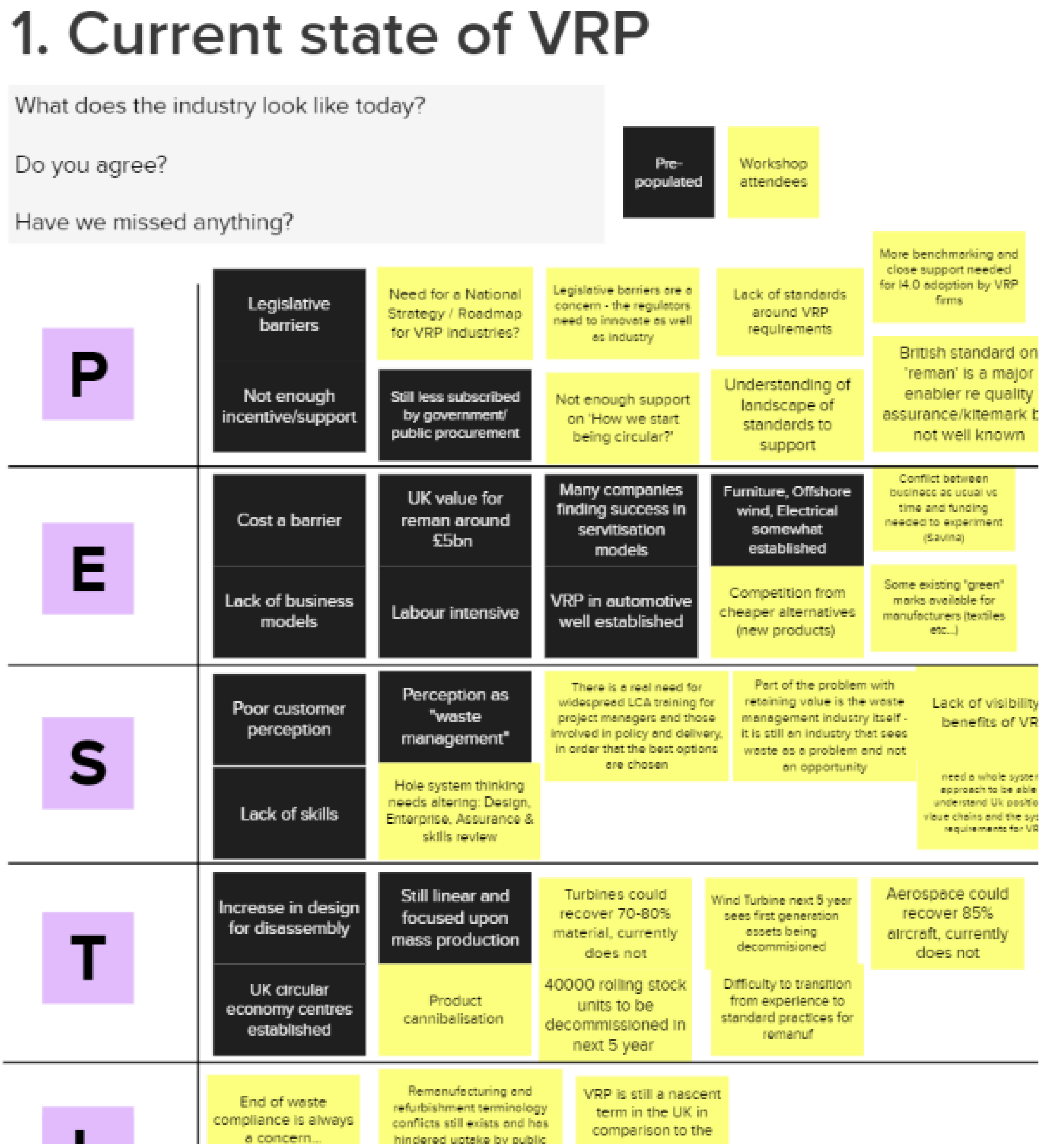
**Activity 3 - Interventions.** A rich list emerged building on activity 2, although as is so often the case it was difficult to get the group to suggest interventions at the right level of detail and informed by an understanding of the variety of levers that there are one could pull to effect change. Highlights included direct support for businesses, perhaps through hubs. Whilst some participants highlighted the need for engagement with multiple stakeholders, one powerful observation related to the need to assign ownership to a single organisation/government department, along with time-bound quantitative targets. One suggestion, given the complexity of considering the challenge, was to pick one issue, or sector, and focus on that, using successes in that as an exemplar. Procurement, labelling, and engagement across supply chains were additional themes, and one participant made a strong point about the need to forecast demand to facilitate reman.

Stephen le Roux of BEIS highlighted that whilst this kind of workshop often generates suggestions for actions, they (BEIS) need evidence if they are to put such actions into practice.

When the group moved on to prioritising the interventions, there was recognition that some actions take time.

- Particularly easy wins perhaps include sharing of frameworks like PAS280 and case studies.
- The shift to servitised models appears as high impact but will take time.
- Prioritising came out as a strong theme, perhaps starting with a specific sector or geography, or informing action based on analysis of carbon reduction potential or addressing the 'weakest link' within the drive to make our economy more circular.

Fragments of Mural outputs presented here.

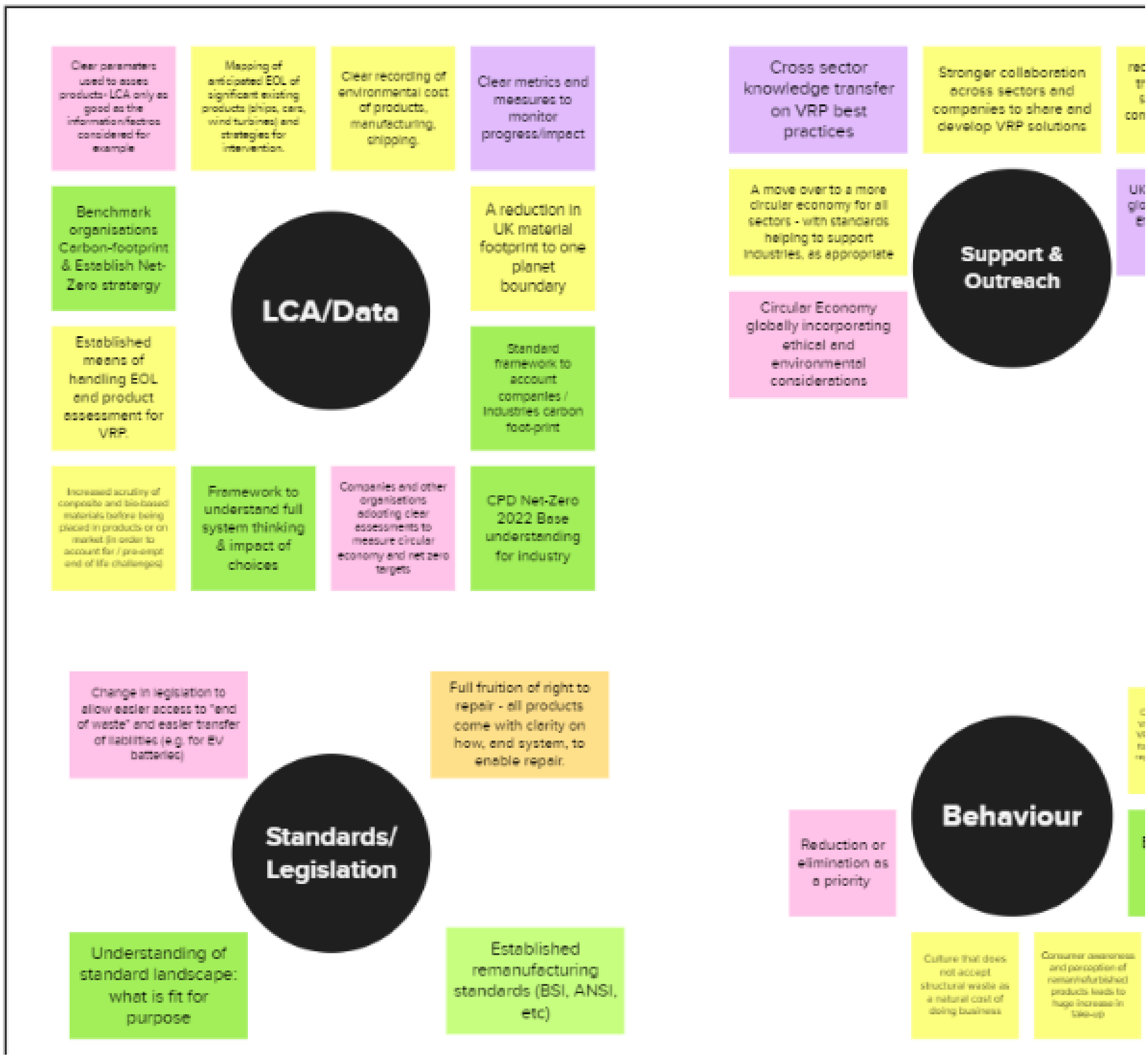


# 2. Aspirations for 2050 and beyond

What would your ambition for VRP be?

Think BIG!

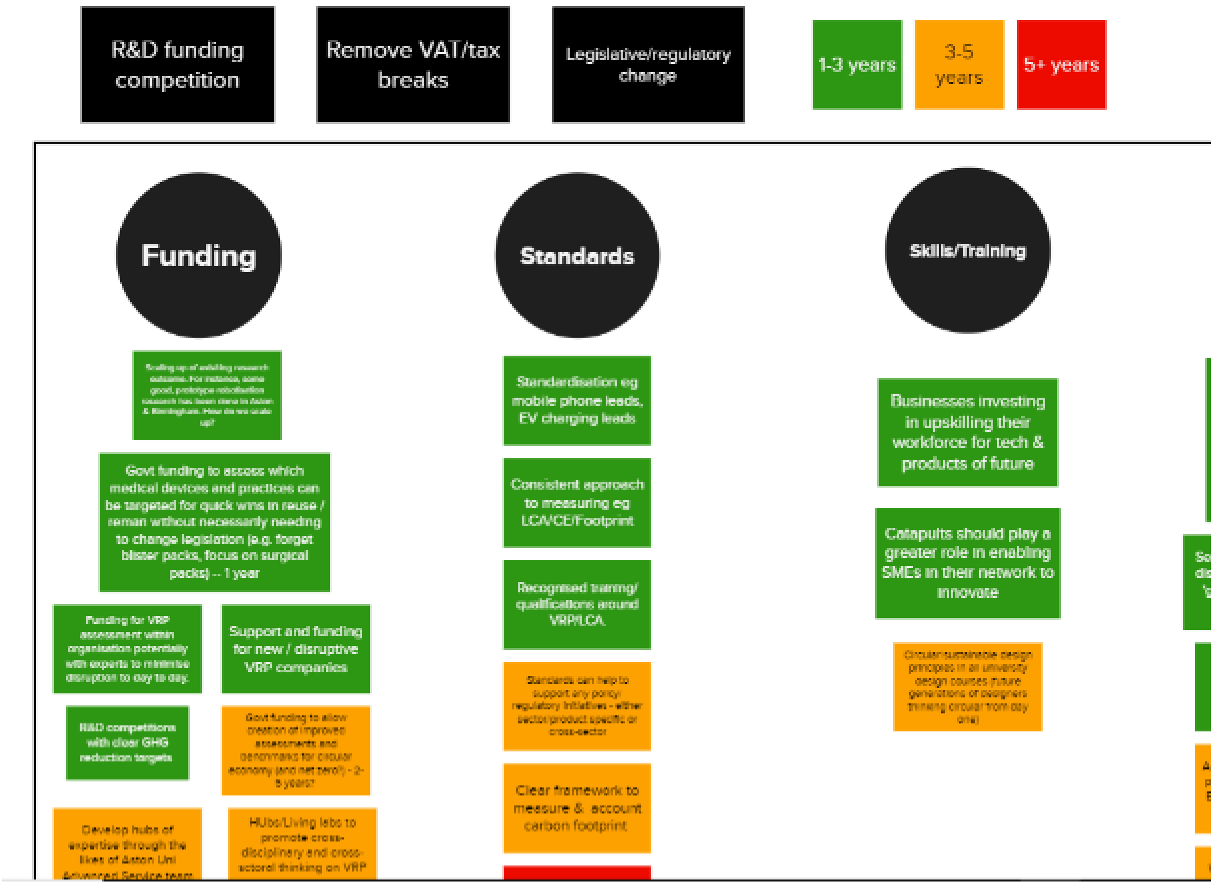
Assume no barriers to implement



# 3. Interventions

How do we get there?

Look to each aspiration and suggest a mechanism and a timeframe for implementation




Effectiveness
High
Low
Slow
Fast
Speed to implement
Public contracts require supplier to have Net-Zero strategy
Standard Frameworks: Knowing were industry start. Macro models to benchmark Co2 / GHG Emission
Standardisation eg mobile phone leads, EV charging leads
Sector specific demonstrator, focused on local content
Consumer awareness campaigns to improve understanding and perception (to lead to higher take-up)
Series of industry-Gov discussions to identify 'gaps' and agree on joint actions
Work with international like-minded countries to develop complementary VRP capabilities
Catapults should play a greater role in enabling SMEs in their network to innovate
Attract private investor community to invest in resource efficient manufacturing
Standards can help to support any policy/regulatory initiatives - either sector/product specific or cross-sector
Funding for VRP assessment within organisation potentially with experts to minimise
eBay are expanding their C2C platform activities with potential to add a carbon/reuse credit score
Regulation requiring end of life studies of new composite or bio-based materials being put on market - 5-10 years?
Develop sector specific VRP roadmaps with clear targets for GHG/waste reduction?
All materials marked with standardised identifiers to facilitate reuse.

| | Short term | | | | |
|---|---|---|---|---|---|
| **Funding** | Scaling up of exisiting research outcome. For instance, some good, prototype robotisation research has been done in Aston & Birmingham. How do we scale up? | Govt funding to assess which medical devices and practices can be targeted for quick wins in reuse / reman without necessarily needing to change legislation (e.g. forget blister packs, focus on surgical packs) -- 1 year | Funding for VRP assessment within organisation potentially with experts to minimise disruption to day to day. | Support and funding for new / disruptive VRP companies | R&D competitions with clear GHG reduction targets |
| **Standards** | Standardisation eg mobile phone leads, EV charging leads | Consistent approach to measuring eg LCA/CE/Footprint | Recognised training/qualifications around VRP/LCA. | | |
| **Skills/Training** | Businesses investing in upskilling their workforce for tech & products of future | Catapults should play a greater role in enabling SMEs in their network to innovate | | | |
| **Awareness/Visibility** | Some use case studies would be helpful to show the challenge and opportunity at a product and sectoral scale. need to build up a taxonomy of common measures and interventions that will support multiple industry. | Series of industry-Gov discussions to identify 'gaps' and agree on joint actions | Celebrate and communicate success with servitisation | Sector specific demonstrator, focused on local content | |
| **Legislation** | Public contracts require supplier to have Net-Zero strategy | Penalise single use items | | | |

| | **Medium term** | | | | | |
|---|---|---|---|---|---|---|
| **Funding** | Govt funding to allow creation of improved assessments and benchmarks for circular economy (and net zero?) - 2-5 years? | Develop hubs of expertise through the likes of Aston Uni Advanced Service team | HUbs/Living labs to promote cross-disciplinary and cross-sctoral thinking on VRP innovations | Better funding and training for the regulators - at present they do not have any real scope to assist in respect of issues such as lifecycle assessment other than at an overarching level. They also need to be less risk averse. | Greater investigation into 2nd and 3rd scope emissions (i.e. transport) rather than focus only on product. E.g. studies indicate second hand clothing market can be more emissions intensive than buying new because of massive increase in logistics cost. Putting these considerations into the assessment frameworks and standards for CE, net zero, etc | Support for more joined-up working - we've considered the work of the bioeconomy in Wales recently and concluded that there is a.) much activity and b.) not much coordination. I think we could achieve a lot more in future with far better networking. Waste producers need to be aware of reprocessors, academia, support networks, and manufacturers - I don't think this is anywhere near optimal at present, and we could improve upon this significantly. |
| **Standards** | Standards can help to support any policy/regulatory initiatives - either sector/product specific or cross-sector | Clear framework to measure & account carbon footprint | | | | |
| **Skills/Training** | Circular/sustainable design principles in all university design courses (future generations of designers thinking circular from day one) | | | | | |
| **Awareness/Visibility** | Development of material network where manufacturers can share/sell/buy "waste" or recovered products. | Advertise the VRP life of products to consumers. Educating on the value of VRP. | Develop sector specific VRP roadmaps with clear targets for GHG/waste reduction? | Work with international like-minded countries to develop complementary VRP capabilities | Attract private investor community to invest in resource efficient manufacturing | |
| **Legislation** | change in legislation to allow easier access to "end of waste" and easier transfer of liabilities (e.g. EV batteries). So far well developed in construction industry in Ireland and Nordic countires | Perhaps a compulsion or policy that encourages the use of VRP products in offices? | | | | |

| | Long term | | |
|---|---|---|---|
| **Funding** | Landfill mining - in its infancy at present, but I think should be commonplace by 2050. Further research here is needed, and we will need to work with the regulator to encourage this where appropriate. | | |
| **Standards** | All materials marked with standardised identifiers to facilitate reuse. | Establish LCA certificate with each product (eg EPD) | |
| **Skills/Training** | | | |
| **Awareness/Visibility** | Green labelling | Consumer awareness campaigns to improve understanding and perception (to lead to higher take-up) | breaking the new vs "used" mentality through clearer understanding, guidance and awareness of Validation of VRP products in cycles. |
| **Legislation** | Regulation requring end of life studies of new composite or bio-based materials being put on market - 5-10 years? | Policy interventions/changes, where appropriate, backed up by standards, where relevant, plus education and awareness-raising campaigns | |

# Appendix F Workshop 2 agenda and outputs

| | | |
|---|---|---|
| **Welcome** | Peter Hopkinson & Fiona Charnely,<br><br>CE-Hub | Welcome, Introduction to the NICER Programme and Importance of Value Creation |
| **Intro to context behind the workshop** | Abishek Ramesh,<br>Innovate UK<br><br>David Parker & Rachel Waugh,<br>Oakdene Hollins | UK Value Retention Study (funded by Innovate UK): Insights from a National and International Perspective |
| **Context to study** | Stephen le Roux,<br><br>On behalf of BEIS & Defra | Industrial Decarbonisation, Innovation and Value Retention: A Policy Perspective |
| **Industry perspective** | Richard Loretto, Amazon<br><br>James Barry, Renewable Parts<br><br>Catriona Cory, Topolytics | Creating Value from a Circular Economy: An Industrial Perspective |
| **Breakout sessions**<br><br>**60-90 mins** | All | Workshop with industry experts to discuss the following topics:<br><br>Creating value from optimising future inputs<br><br>Creating and extending value during use phase<br><br>Creating and retaining value from post use legacy products and materials |
| **Conclusions & Close**<br><br>**10 mins** | Facilitators, CE-Hib | Summary of discussions |

**Breakout room 1: Creating value from optimising future inputs.**

| |
|---|
| **Descriptor:** How do we ensure our whole systems are optimised for value retention? In this workshop we discuss extending beyond our products life to consider how our inputs and supply chains are geared towards longevity, revalorisation and optimising (or reducing) future inputs. |

*What are the opportunities for value retention processes within this industrial context / value chain?*

*What are the barriers to implementing and up-scaling value retention processes in the UK?*

*What short, medium and long-term solutions might support value retention in the UK and what type of support mechanisms would be required?*

**High level summary**

- Most common barriers to waste material reuse. Lots of opportunity out there, but the main barriers are knowing what's in the material, locale, and suitable 'matchmaking' between buyers and sellers.
- There needs to be an acceptance that a waste product won't be a perfect product. Difficult to find strategic partners that are willing to take that risk.
- Consumer behaviour does need to be more sustainable, but there also needs to be policy change and large-scale levers to encourage sustainability at an industry level

**Workshop 2: Creating and extending value during use phase**

| |
|---|
| **Descriptor:** In this workshop, we discuss the challenges and opportunities in extending value of products. How can we increase longevity and intensify product use? How can we connect and monitor condition to support predictive maintenance? |

*What are the opportunities for value retention processes within this industrial context / value chain?*

*What are the barriers to implementing and up-scaling value retention processes in the UK?*

*What short, medium and long-term solutions might support value retention in the UK and what type of support mechanisms would be required?*

**Workshop 2**

- Challenge: How to present Circularity progress to consumers in a way that doesn't alienate them. Societal understanding is key
- Challenge: Leading from understanding is societal trust. Need for a 3rd party verification for Circularity claims?
- Challenge: Need for circularity decisions based on robust science. (Small) companies having bandwidth to cover all specialisms needed to address technical and business issues inc measurement. Can there be template Circ metrics for sectors? Crowd-sourcing info, tools and techniques?
- Challenge: Business decision making and understanding trade-offs. How to shift to the view that products are part of systems; how to change corporate perspectives? Trading off commercial, physical, operations. Integrating circularity into business decisions. Modelling impact decisions and integrated view.
- Challenge: These issues are bigger than one company however large; need for macro-level view and sector level initiative.

- Challenge: How to make extended ownership of a product more attractive; component remanufacture/replacement. Consider 'skinning'; desire for mass-customisation perhaps not as big as expected, but choice is expected by consumers.
- Opps: New models of ownership, servicing and servitization necessary to redefine business success i.e. delivering effect X at cost (impact) Y in more effective way. Challenge: changing mindset of consumers

**Headlines for plenary discussion**

- Measurement, metrics and robust verification for consumer trust
- Parts remanufacture and challenge of customisation
- Different business models – expanding product as a service & rental
- Viewing at higher level 'what is the purpose' (eg. Washing over needing a shower)

***Breakout room 1***

**Optimising future inputs**

The key theme that

- Most common barriers to waste material reuse. Lots of opportunity out there, but the main barriers are knowing what's in the material, locale, and suitable 'matchmaking' between buyers and sellers.
- There needs to be an acceptance that a waste product won't be a perfect product. Difficult to find strategic partners that are willing to take that risk.
- Consumer behaviour does need to be more sustainable, but there also needs to be policy change and large-scale levers to encourage sustainability at an industry level
- Building a business case for the reuse of material
- Dealing with residual waste that is restricted by REACH

***Breakout room 2***

**Extending value during use phase**

- Challenge: How to present Circularity progress to consumers in a way that doesn't alienate them
- Challenge: Needing a 3rd party verification for Circularity claims
- (Small) companies having bandwidth to cover all specialisms needed to address technical and business issues including measurement. Can there be template Circ metrics for sectors? Crowd-sourcing info?
- Challenge: How to shift to the view that products are part of systems; how to change corporate perspectives? Trading off commercial, physical, operations.
- Challenge (Amazon): These issues are bigger than one company however large; need for sector level initiative.
- Challenge: How to make extended ownership of a product more attractive; skinning; mass-customisation.
- Opportunities: New models of ownership, servicing and servitization necessary to redefine business success i.e., delivering effect X at cost (impact) Y in more effective ways.

***Breakout room 3***

**Retaining value from post use legacy products and materials**

1. What are the opportunities for value retention processes within this industrial context/value chain?

- Resource efficiency - to enable Carbon savings & money – match high value to carbon value?
- Circular by Design – design for disassembly so that things can be reused especially in relation to the built environment – module design – learn from aviation
- Extend EPR – should be part of pre-investment business model – current approach isn't systemic enough – focus on 'endineering' – 'focus on end of life' then design something new and innovate – work backwards. Design in end-of-life decommissioning.
- Reverse logistics processing – capture, quarantine and analyse

2. What are the barriers to implementing and up-scaling value retention processes in the UK?

- Challenge is having skills to design in the first place & know how we can repurpose etc. at the end of life;
- Having the infrastructure & technology to remanufacture & the systems to capture materials and sort and expedite to relevant reuse system
- Data, Value recognition, collectively of the value inc. carbon value and capture e.g. having passports – these need to come together to drive reuse and remanufacture as a whole system

3. What short-, medium- & long-term solutions might support value retention in the UK and what type of future our mechanisms would be required?

- Potential for everything to be short, med, long – look at the 'system' and devise the right intervention, e.g. economic incentive, or regulation + funding; standards to underpin requirements
- Short & mediums solutions & mechanisms:
- Environment Bill can help to drive secondary legislation in the short term as too can economic – if adopted directly by financial services sector – need to be tweaked to get to long term stability
- Env Bill can help to drive secondary legislation in the short term as too can economic – if adopted directly by financial services sector – need to be tweaked to get to long term stability
- Skills are required e.g. engineering, remanufacturing degree courses, incentivisation around sustainability to consume in a more sensible way, increasing awareness e.g. use data to educate baseline where we are now, where can we get to in the future – measurement, skills and incentivisation – all in short and medium terms. Got to do it now!
- Long term too late – work now to create long term stability

# Appendix G Scottish remanufacturing skills gaps

| Remanufacturing step | Skill needed | Automotive | Electronics | Energy | Medical Equipment |
|---|---|---|---|---|---|
| 1. Collection of documentation | Sourcing required documentation | | | | ✓ |
| 2. Collection of core | Material selection | × | × | TI 11; p55 | × |
| | Purchasing, identifying and grading of appropriate core | TI 1; p29 | | TI 12; p56 | ✓ |
| | Salvage engineering | TI 3; p31 | × | × | × |
| | Reverse logistics | | × | × | × |
| | De-installation | × | × | × | ✓ |
| 3. Inspection (initial and/or detailed) | Cleaning | TI 2; p30 | | TI 13; p57 | ✓ |
| | Visual and/or mechanical | TI 2; p30 | | TI 13; p57 | ✓ |
| | Product analysis/diagnostics | TI 2; p30 | | TI 13; p57 | × |
| | Quality control | TI 2; p30 | | TI 13; p57 | × |
| | Safety | TI 2; p30 | | TI 13; p57 | ✓ |
| 4. Disassembly | Cleaning, technical and reverse engineering | TI 3; p31 | | TI 14; p58 | ✓ |
| | Design skills | × | × | TI 14; p58 | × |
| | IT skills | × | | × | × |
| | Safety | TI 4; p32 | | TI 15; p59 | × |
| 5. Component remediation | Cleaning techniques | | | TI 15; p59 | ✓ |
| | Repair skills - mechanical and technical | TI 5; p33 | × | TI 15; p59 | ✓ |
| | Electronic skills | × | | × | × |
| | Disinfection | × | × | × | ✓ |
| 6. Replacement | Inspecting, removing and replacing | TI 5; p33 | TI 8; p45 | | × |
| | Technical | TI 5; p33 | TI 8; p45 | | × |
| 7. Reassembly | Soldering/welding | × | TI 8; p45 | × | × |
| | Component and product reassembly | TI 5; p33 | TI 9; p46 | | ✓ |
| | Practical skills - mechanical and technical | TI 5; p33 | TI 9; p46 | | × |
| 8. Testing | Safety testing | TI 6; p34 | | | ✓ |
| | Component and product testing | TI 6; p34 | | | ✓ |
| | Quality control | TI 6; p34 | | | ✓ |
| 9. Warranty | Business models | TI 7; p35 | TI 10; p47 | | ✓ |
| | Market needs and forecasting | TI 7; p35 | TI 10; p47 | | × |

Table 5.1 Sector summary

Key:

Green – skills need adequately covered

Orange – skills need not covered adequately

Red – skills need not covered by any training provision

Grey – skill not required

✓ - skill needed

*Notes: Page numbers etc refer to sections of source report, property of Zero Waste Scotland*

# Appendix H Funding for remanufacturing from Innovate UK – KTN review

Accepting that re-manufacturing, repair, refurbishment, reconditioning and direct re use of equipment/assets is an important element in reaching sustainability goals and helping reduce costs to manufacture, we have investigated the currently known use of these methods in the UK and looked at any interventions to support. This was done across a number of sectors seen as promising,

- Materials
- Agriculture – farming and processing
- Chemicals
- Batteries
- Multi modal transport
- Electronics
- Furnishings

There were also regional examples, the South coast of England and in Scotland.

Generally there was very little application of these approaches known by contacts, the methodology is seen as costly to implement and generally reserved for high value goods and large assets.

In Materials there is a focus on re purposing and new life for larger items, an example offered was wind turbine blades. They cannot currently be safely repaired to extend life, sensors can be retro fitted, but once wear reaches a certain level they must be decommissioned. Alternative applications are then found, examples identified were to make covered bike shelters or integrated into children's play grounds as climbing structures. The focus in materials is currently on recycling, stripping component parts and materials and adding them back into the production process. Funding is available for innovation in recycling of complex and new materials.

With Agriculture the main focus is on the reconditioning and refurbishment of motors, with diesel engines having been a focus for many years. This is for the UK market but also includes players such as Britcom who are reconditioning tractors and farm machinery for direct export to Africa. Other examples of machinery refurbishment in the UK and overseas in this field are, • Chaumont, France • Bazzano, Italy • Castelvetro, Italy • Frosinone, Italy • San Eusebio, Italy • Radom, Poland • Shrewsbury, United Kingdom • Skinningrove, United Kingdom. This activity is mainly undertaken by the OEM or business built on the follow on market and self-funded through sales.

The current focus in Agri is on materials repurpose and re use such as producing plastics from plant starches.

Like Materials, the Chemistry space is focused largely on raw materials recycling and reuse, one exception possibly is the Royal Society of Chemistry activity to aimed at ReMan of paints, however this may be seen as more recycling as the aim is to create a new product. This is supported by the Society and industry.

Whilst there is significant Gov investment in new battery materials development the ReMan movement is very much in the amateur/consumer space, with minimal to no regulation and perceived as unsafe in many situations. This could signal an opportunity for regulation/standards/guidance, opening the way for business to operate safely here and be supported by Gov investment in innovation grant type activity. However, this would require first a better understanding of the physical systems and safety requirements.

Transport is one area where there is a long history of VRP, with large OEMs such as Cat operating in the space for site vehicles, this also extends to companies refurbishing turbo chargers and injectors for cars. Much of the activity in the UK is focused on cottage industry scale activity without OEM support, with buses and classic cars being converted to electric drove trains or classic engies being stripped and rebuilt as better performing.

Rolls Royce have a long-established history of aero engine maintenance, monitoring and reconditioning and this model is similar to much of the sector, self-funded and a revenue stream from the OEM into further markets.

In the Rail industry there are examples of bogeys being refurbished from franchises, diesel engines being refurbished to improve performance and lower emissions and a rising want to move to electrification, In India for example the move is motivated by many diesel engines coming towards end of life (5 years left) and electrification would repay within the 10 year predicted life and prove more cost effective.

As mentioned across Transport modes this activity is self-funded, driven in some places by a want to meet Net-Zero aspirations but in many as a way to maintain market share and being delivered by incumbent OEMs.

Electronics is a possible exception to the large machinery HVM trend as devices can be small and high volume, however the bring their own problems. Firstly, there is often an issue of system life cycle which tends to be in the 3-5 year scale due to nature of current materials and the Operating System surpassing the capability of the hardware. It is seen as often more efficient to extract the raw materials and use for new products. With the RSA nd Innovate UKs Great Recpvery there was a move to promote better product design to consider things like design for fit-form-and-function, to encourage and better facilitate replacement of obsolete parts e.g new valves for audio amplifiers and the ability to repair and remanufacture rather than just materials recovery. Often the current preferred route for higher end electronics is OEM/Retailer offering refurbishment which involves cleaning of parts, delete and re install software, repair of screens etc and sell with a similar warranty to new. There is also a large consumer led secondhand market in the UK with high street vendors such as CeX and Cash Converters offering refurbished items below new cost, but with warranty, having undertaken any reconditioning work in house.

A non technology driven space where ReMan is happening currently is in furnishings, this has happened in independent studios all over the Country for centuries, more recently brands have started to adopt this. Most notable is Ikea, and an established but less known producer Rype Office who have previously received KTN support and Innovate UK funding for their sustainable design work.

Zero Waste Scotland supports the principles of ReMan and produced a report on opportunities and barriers to adoption, much of this seems to remain and has been born out by what has been identified in this activity looking at what is available and what is missing.

On the South coast there are two programmes looking to bring ReMan and repurposing into the Marine sector to work towards lowering emissions. First is through either adapting engines to run on biofuels or replacing ICE with electric drives. Being considered at various scales of commercial vehicle from marine servicing to mass transport. Secondly a programme has emerged to re-invigorate decommissioned marine vessels to meet overseas market needs, like the Britcom example in Agriculture. This activity appears to be largely operator and customer/purchaser funded and whilst it fits with local agendas on lowering emissions and is supported, it is not financially buoyed by the region.

Opportunities?

Can we encourage more ReMan thinking over recycling, where economically and environmentally viable, in new industry segments? How would this new drive be funded, could a grant offering from agencies like Innovate UK, or the Design Council allow innovative thought to deliver similar to the thinking behind The Great Recovery?

There does not appear to be any National specific financial support for ReMan at present, entities like the High Value Manufacturing Catapult, Zero Waste Scotland and Innovate UKs Made Smarter programme support the principals and have released targeted interactions where applications could be made for support.

Other avenues have existed through EPSRC, (part or UK Research and Innovation along with Innovate UK), looking at increasing productivity in manufacturing through new process innovation, which could have included ReMan.

In respect to current programmes Innovate UKs Smart grant and A4I programmes offer opportunities to look at process innovation and improving current products respectively. Neither are live currently but may be available later in 2022. One support mechanism that is live is the KTP programme, whoch allows business to access cutting edge academic knoedge and embed it in their business to deliver a specific goal. The programme funded the following work, both of which are ReMan examples,

The Turbo Guy, they ReMan Turbo Chargers for cars, to be at least same standard as OEM.

Carwood Motor Units, they ReMan fuel injectors and that was a significant contribution to their profits as a sales line.

Possibly a missing part of this low adoption outside of cost, is low visibility of a mainstream drive towards ReMan, with recycling having grasped the main focus, which again comes back to it often being economically more viable due to scale and deliverables. Possibly new collaborations with the Design Council and parts of UK Research and Innovation could inspire new conversations, without needing explicit new funding. However past experience with programmes such as Design Foundations shows that one of the most effective ways to change thinking and practices is to de risk the new approach through provision of funding for elements not part of the core business, which in this case is most likely the design thinking first and then the engineering to understand if it can be achieved.

Whilst there is very limited direct funding for ReMan currently, there is support for areas which are part of ReMan, such as  - Design and Business Models/ finance/ reverse supply chain, and there are the supporting technologies such as - Additive Manufacture, predictive modelling, AI, sensors, materials, which have their own funding streams through Research Councils and Innovate UK.

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*Value-driven consulting*

*Science-led research*

From its offices in Aylesbury and Brussels, Oakdene Hollins provides research and consulting services to clients under three main themes:

- circular economy
- Sustainable Products
- Innovative Technologies & Materials

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