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International Resource Panel

REDEFINING VALUE

THE MANUFACTURING REVOLUTION

Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy

Summary for Business Leaders

Acknowledgements

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Produced by the International Resource Panel

This document highlights key findings from the full report and should be read in conjunction with it. References to research and reviews on which this report is based are listed in the full report.

The full report can be downloaded at: http://www.resourcepanel.org/reports/re-defining-value-manufacturing-revolution

Additional copies can be ordered via email: resourcepanel@unep.org

Preface

Circular Economy is at the forefront of current global discussions. This is due to the concerning pace by which natural resources are being used, and the consequent risk of scarcity of some resources, but also because of the environmental, social and economic benefits of a shift in the economy. Transformation from a linear economy, where products, once used, are discarded, to a circular one, where products and materials continue in the system for as long as possible, will contribute to a more sustainable future.

This report from the International Resource Panel, entitled *Redefining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy,* highlights processes that contribute to the Circular Economy shift by retaining the value of the products within the system, through the extension of their useful life.

The report calls for a revolution in the way of producing and consuming. A revolution where we move away from resource-intensive production and consumption models, towards low carbon, efficient processes, and where innovation will be the motor of change. This manufacturing revolution is essential for achieving the Sustainable Development Goals, specifically Goal 12 – Sustainable Consumption and Production – as well as the Paris Agreement, given the contributions of such processes to climate goals.

The report applies the value-retention processes to a series of products within three industrial sectors, so as to quantify the benefits relative to the original manufactured product. In this manner, the material requirement, the energy used, the waste, but also the costs and the generation of jobs are measured through first hand data from selected industries.

It also highlights the different barriers faced in the implementation of the processes, including regulatory, market, technology and infrastructure barriers, and how they can be overcome by a collaborative approach and by changing the mind-set of policy makers, industries and consumers.

We wish to thank the lead author Nabil Nasr and the rest of the team, for this very valuable contribution to advancing towards a Circular Economy and hope that it can influence the pace we are all making towards this transition.

Janez Potočnik
Co-Chair,
International Resource Panel

Izabella Teixeira
Co-Chair,
International Resource Panel

Foreword

If we want to change the world we live in, we will need to make big changes to the way we do things. Whether it's the way we build houses, produce electricity, or dispose of the waste, we need to re-think every aspect of what we do to make sure we are doing the best that we can with what we have.

For more equitable, sustainable development, we will need also to re-think the global economy, and how we value the resources supplied by nature. The traditional manufacturing model, where we make, use, and then dispose of a product is both wasteful and polluting. If we re-think this, and move towards a more circular model, where a product is used and then re-used, we retain the value of the materials and resources used to make that product.

Understanding the environmental and economic benefits of a circular economy, this report highlights important ways in which we can retain the value of products within the system by extending their life. And there are many examples of success. At repair cafes in 29 different countries all over the world, people come together to extend the life of their products through repair. The ***REVISE-Network*** in Flanders, uses a labelling system to guarantee the quality of electrical and electronic equipment which are sold by reuse shops. A social enterprise Fairphone designs products that last – both in their original design and in designing their repair to be as easy as possible.

It is clear that we need to scale up such initiatives that retain the value of products to preserve the planets resources, reduce greenhouse gas emissions and contribute to climate goals. I believe this report will inspire policymakers and the private sector to adopt a circular economy approach to production, thereby guiding us to a more sustainable world for all.

Erik Solheim
Under-Secretary General
of the United Nations and
Executive Director, UN Environment

Key Insights for Business Leaders

- Remanufacturing and comprehensive refurbishment (Full Service Life Value-Retention Processes (VRPs)) are intensive, standardized industrial processes that provide an opportunity to add value and utility to a product's service life.
- Repair, refurbishment, and arranging direct reuse (Partial Service Life VRPs) are maintenance processes that typically occur outside of industrial facilities and provide an opportunity to extend the product's useful life.
- Relative to original equipment manufacturer (OEM) New production, value-retention processes (VRPs) require less new material and energy inputs and generate less production waste and emissions per-unit. These reductions can lead to reduced marginal costs for producers who adopt VRPs. Report findings suggest that at the product-level, remanufacturing and comprehensive refurbishment can contribute to GHG emissions reduction by between 79 per cent and 99 per cent in appropriate sectors. Similarly, the opportunity for material savings via VRPs is significant: Compared to traditional OEM New production, remanufacturing can reduce new material requirement by between 80per cent and 98 per cent; comprehensive refurbishing saved slightly more materials on average, between 82 per cent and 99 per cent. Repair saved between 94 per cent and 99 per cent; and arranging direct reuse largely does not require any inputs of new materials. Cost advantages of VRPs range, conservatively, between 15 per cent and 80 per cent of the cost of an OEM New version of the product
- VRPs rely on high-quality, durable products and components as inputs: there will always be a need for original manufacturing activity alongside VRPs and other circular economy practices.

- Adopting VRPs for appropriate products and product-lines can empower companies to reduce the environmental footprint of their products and their operations. This can enable improved ability to meet climate change commitments and other sustainability goals, as well as achieve compliance with increasing sustainability and circular economy regulations in markets around the world.
- When vertically-integrated into a company's operations, customer-service supported VRPs provide an opportunity to extend and strengthen valuable customer relationships, and tap into new, diverse market segments. Companies can often leverage existing production, logistics, service systems, and distribution infrastructure in the implementation of VRPs.
- Innovative business models, including product-service systems (PSS), product-as-service, sharing economy, and warranty-driven reverse-logistics, can provide cost-effective opportunities for companies to pursue VRPs and enhance the value of their offering.
- An optimized VRP strategy requires that companies adopt new product design processes and priorities. Products must be designed to be durable, upgradable, able to be refurbished or remanufactured and repairable, and these design objectives need to be incorporated early in product planning and business case development stages.
- A strong business case for adopting VRPs is often impaired by the presence of government policies that restrict the import, distribution, and/or sale of VRP products and inputs (e.g. cores[1]), as well as the lack of required technology, product information, and skilled labor.
- A significant customer market barrier stems from a common perception that VRP products are of lower-quality than traditional OEM New offerings. To increase customer market demand, there is a need to reconcile any gap between perceived and actual VRP product quality.
- VRPs may not be appropriate for all products or organizations. When considering adoption of VRPs companies should also evaluate: the nature of the product and components (e.g. durability, material composition); the use-phase energy requirement and energy efficiency of the product; the residual value of the product at its end-of-use (EOU); and the marginal cost of the VRP relative to the market value of the VRP product.

1- A core is a previously sold, worn or non-functional product or module, intended for the remanufacturing process. During reverse logistics, a core is protected, handled and identified for remanufacturing to avoid damage and to preserve its value. A core is usually not waste or scrap, and it is not intended to be reused for other purposes before comprehensive refurbishment or remanufacturing takes place.

Summary of Recommendations for Business Leaders

The adoption of value-retention processes (VRPs) is an important strategy for companies interested in taking a leadership position on sustainability and circular economy and interested in the economic and environmental benefits that can be achieved. The following recommendations highlight the key priorities that Business Leaders must incorporate as part of their strategy:

1. **Adopt** an expanded systems-perspective that considers the product within the broader system in which it exists, and across its life cycle: production, use, and end-of-use (EOU), or end-of-life (EOL).

2. **Evaluate** existing product lines to identify opportunities to adopt VRPs within the product-system, directly (e.g. offering VRP products) and/or indirectly (e.g. enabling VRPs through third-party arrangements).

3. **Modify** product design priorities to incorporate principles essential to VRPs and circular economy: value creation (e.g. design for quality); value protection and preservation (e.g. design for durability); and cost-effective and easy value recovery (e.g. design for disassembly). Design for VRPs must be incorporated from the beginning of the product development process.

4. **Utilize** – wherever possible – existing production, distribution, and collection infrastructure and networks to facilitate the closing of product and material loops within the supply chain. This can support the implementation of VRPs and enable the transition to circular economy.

5. **Contribute** to the development, ratification, and enforcement of VRP standards that guide industry practice.

6. **Provide** transparent and credible information to customers about VRPs and the quality of VRP products to objectively inform customer perceptions of risk and value relative to the traditional OEM New offering.

7. **Engage** policy-makers in collaborative discussion and initiative focused on communicating and alleviating VRP production-capacity and other technological barriers to VRPs.

8. **Partner** with other industry members to provide active education and awareness initiatives to the customer market about VRPs, VPR products, and the economic and environmental benefits of VRPs.

9. **Collaborate** with other industry members and policy-makers to clearly identify and communicate the key barriers that inhibit the business case for VRPs in all operating jurisdictions.

10. **Coordinate** with internal company stakeholders to facilitate the intra-firm sharing of essential VRP resources across national borders, including necessary technology transfer, resources, product information, and training.

11. **Partner** with research institutes to support and enable enhanced R&D focused on product design, process design, infrastructure design, and other opportunities to adopt and optimize VRPs.

Content


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1 Introduction & Overview

There is a growing sense of urgency and interest in the role that industry must play within national sustainability and circular economy objectives. Government pursuit of the circular economy as a framework for sustainable economic growth and human prosperity is increasing, as demonstrated by the European Commission's Circular Economy Package (Bourguignon 2016), The Netherlands' Government-wide Programme for a Circular Economy (Government of the Netherlands 2016), China's 13th Five-Year Plan (Koleski 2017). The United Nation's 2030 Agenda for Sustainable Development specifies Sustainable Development Goal (SDG) #12 as ensuring sustainable consumption and production patterns, by promoting resource and energy efficiency, reduced environmental degradation, and the building of collaborative relationships between stakeholders throughout the consumption-production system (United Nations General Assembly 2015).

Interest in the need for sustainable production is not limited to policy-makers: Industry members around the world are increasingly aware of the business risks posed by uncertainty in materials markets, operating costs, supply chain security, and consumer market attitudes and priorities. It is becoming increasingly clear to many industry leaders that a business-as-usual strategy not only threatens current operations, but also the potential to grow and expand into new markets.

Some initiatives such as the Ellen MacArthur Foundation's Circular Economy 100 (CE 100) are increasingly bringing together leading companies, researchers, and policy-makers together to facilitate and collaborate on optimal strategies for accelerating the transition to a circular economy (Ellen MacArthur Foundation 2018); however, there is a clear need and opportunity for increased, decisive, and bold action by industry members.

Figure 1: Definition of value-retention processes

	Value-Retention Process	Definition
Full Service Life VRPs (Occur within Factory Operations)	OEM NEW[2] (MANUFACTURING)	The value-added to production of merchandise for use or sale, from using labor and machines, tools, chemical and biological processing, or formulation. Manufacturing processes are the steps through which raw materials are transformed into a final product. The manufacturing process begins with the product design, and materials specification from which the product is made. These materials are then modified through manufacturing processes to become the required part.
	REMANUFACTURING	A standardized industrial process[3] that takes place within industrial or factory settings, in which cores[1] 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.
	COMPREHENSIVE REFURBISHMENT*	Refurbishment that takes place within industrial or factory settings, with a high standard and level of refurbishment.
Partial Service Life VRPs (Occur within Non-Factory Operations)	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). (From Document UNEP/CHW.13/4/Add.2)
	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.[5] (From Document UNEP/CHW.13/4/Add.2)
	REFURBISHMENT	Modification of an object that is waste[4] 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.[5] (From Document UNEP/CHW.13/4/Add.2)

* This only exists for certain sectors and products.

2- Original Equipment Manufacturer (OEM) New: Refers to traditional linear manufacturing production process activities that rely on 100% new material inputs, and which are performed by the original equipment manufacturer.

3- An industrial process is an established process, which is fully documented, and capable to fulfill the requirements established by the remanufacturer.

4- The term 'waste' in this sense may be misinterpreted: In the context of this study, the term 'waste' is aligned with definitions and terminology of the Basel Convention and does not reflect or infer that 'waste' materials or products do not have value. It is important to note that refurbishment, comprehensive refurbishment, and remanufacturing processes may not be performed on waste, in accordance with the EU Waste Framework Directive, and US legislation.

5- This definition is in accordance with Document UNEP/CHW.13/4/Add.2, the revised Glossary of Terms adopted at COP 13 in May 2017.

Fortunately, the economic concept of value-retention is also well aligned with the objectives of circular economy, resource efficiency, resource productivity, and even climate change mitigation. Value-retention processes (VRPs) – *remanufacturing, refurbishment, repair and arranging direct reuse* – enable the retention of value, and in some cases the creation of new value for both the producer and customer, at a reduced environmental impact (See Figure 1)

As part of a circular economy toolbox, the expanded adoption of VRPs can offer countries an opportunity to decouple industrial production activities from negative environmental impacts. For industry members, the expanded adoption of VRPs can offer companies an opportunity to mitigate operations and supply chain risk, to access new customer markets, and to show strong leadership in the area of sustainability and circular economy.

This report quantifies for the first time how VRPs:

1. Decrease the overall product cost
2. Reduce new material input requirements
3. Reduce embodied energy and embodied emissions
4. Reduce energy needs in the production process and related emissions
5. Cut production waste
6. Can create jobs while additional labour costs are more than off-set

These benefits have been assessed through nine case studies, three for each of the following sectors: Industrial Printer sector, Vehicle Part sector, and Heavy-Duty and Off-Road (HDOR) Equipment (See Figure 2). These insights were then considered and assessed in the context of diverse sample industrial economies around the world (Brazil, China, Germany, and United States of America) to better understand how varied systemic conditions and barriers to VRPs may affect the realization of these benefits.


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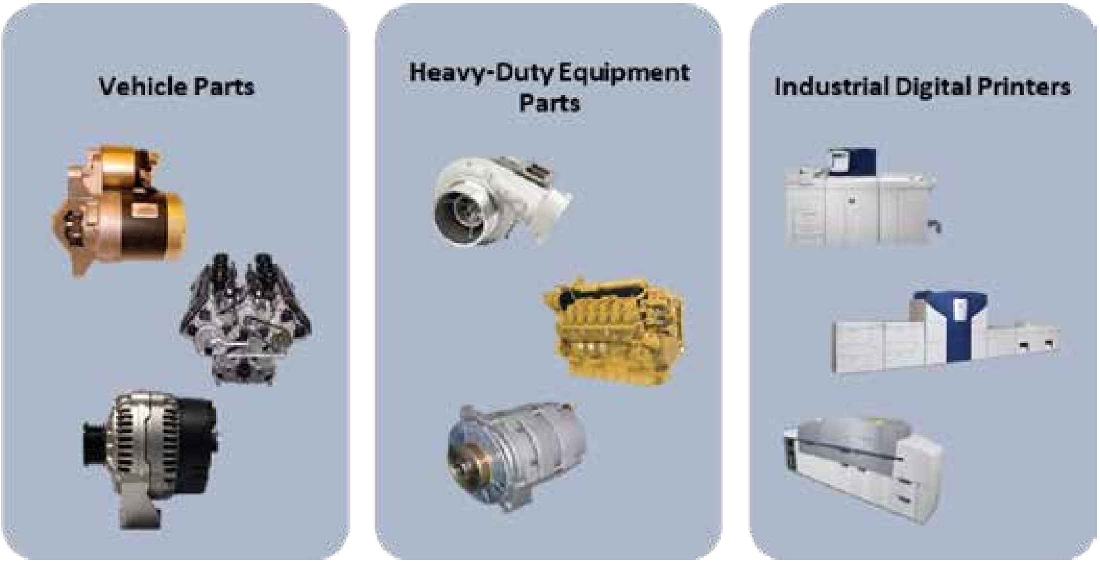
Figure 2: Case study products and sectors



1.1. The Untapped Potential of Retaining Value in the Circular Economy

Industrial supply chains today leave large value pools untapped as they are not set up to retain the most value out of products after their first use.

- Recycling is currently the most widely adopted process to retain value at the end of a product's life, for example at 40 per cent for municipal solid waste (include appliances) in Europe. However, recycling retains little value. In Europe, only 5 per cent of material initial value is recovered through the waste management and recycling sector (OECD 2015, Ellen MacArthur Foundation 2016).
- Closer loops of circular economy - namely remanufacturing, refurbishment, repair and reuse (here denominated Value Retention Processes, VRPs) – generate substantially higher economic, environmental and social value.
- Yet, VRPs are currently deployed at very low rates; for example, remanufacturing accounts

for only ~2 per cent of US and EU production (U.S. International Trade Commission 2012, European Remanufacturing Network 2015). The main root cause for this low adoption rate is an absent systems-view by many manufacturers that have limited knowledge about the possibilities in the value chain, for example for reverse-logistics or interaction with the customer. VRP adoption can further be complicated by regulatory barriers, a lack of customer awareness, limited technological capacity, or inadequate collection infrastructure– barriers that can be overcome through business model innovation, collaboration and engaging policy makers.

1.2. Quantifying the Business Opportunity of Value-Retention Processes (VRPs)

Based on detailed case studies analysing digital printers, vehicle parts and Heavy-Duty and Off-Road (HDOR) equipment in the US, this report found that manufacturing companies, by moving from linear to circular business models based on VRPs, could achieve 15 per cent - 44 per cent cost savings for close/equivalent-to-new quality products, and up to 95 per cent for repaired products. VRPs further reduce harmful environmental impacts of production, such as CO2 emissions and production waste.

- Remanufacturing, which can produce the same or better quality relative to a product made from virgin materials, saves 23 per cent of the cost in the case of the analysed HDOR engine, 18 per cent in the case of the production printing press, and 15 per cent for the vehicle engine. Comprehensive refurbishment produces almost new quality and saves up to 44 per cent of the product cost.
- Repair and reuse, which restore part of the original service life length, save 80 per cent - 95 per cent of costs for industrial printers, 50 per cent - 80 per cent for vehicle parts and up to 95 per cent for HDOR equipment.
- Savings mainly come from avoided new materials and process energy costs. In some cases, significant job opportunities are created while still saving costs. Cost estimates are based on the commercial product cost for the customer; hence, savings and profitability can be even higher for the producer.
- Remanufacturing, across the case studies, reduces environmental footprints of products substantially compared to a linear economy: 79 per cent - 99 per cent of embodied material energy and emissions are avoided, 57 per cent

- 87per cent of process energy and emissions, as well as 90 per cent of production waste.

- The other VRPs (refurbishment, repair, reuse) can offer significant reduction of environmental impacts per production cycle, however, they retain less value. Detailed environmental impact reduction for all VRPs are presented in Section 2.1.1.
- Manufacturers must choose the appropriate VRP considering the viability and utility of the product, its market and the benefits or savings to be maximised.
- VRPs are viable in around ~35 per cent of the manufacturing sector across the sample economies today, with product and process innovations opening new opportunities.

This cost advantage to the producer, typically in the range of a 30 per cent - 80 per cent reduction versus the OEM New product, generates additional economic opportunities in several ways: first, with lower operating costs there are fewer cost barriers to entry into the marketplace for potential VRP producers, and this can support and enable faster scale-up within domestic industry; and second, lower operating costs enable VRP producers to pass the cost advantage along to their customers. Lower-priced VRP product options in the market can enable new segments of customers to participate where budget constraints may previously have prevented such engagement (Atasu, Sarvary, and Van Wassenhove 2008, Debo, Toktay, and Wassenhove 2006, Debo, Toktay, and Van Wassenhove 2005, Hamzaoui-Essoussi and Linton 2014, Hazen et al. 2012).

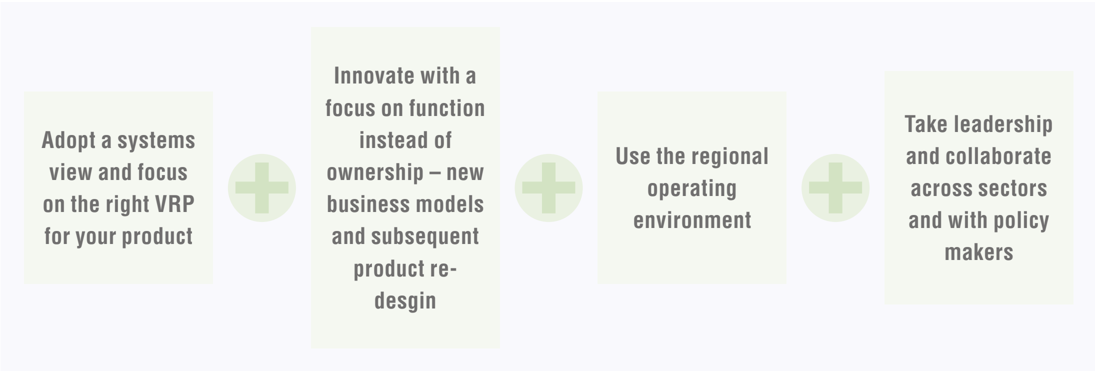
Export opportunities for VRP goods are significant for many economies. For the United States, with remanufacturing industries accounting for approximately 11.7 billion USD in 2011, and especially for foreign markets that require lower price points, and/or that have accessibility challenges within their domestic markets. (U.S. International Trade Commission 2012)

1.3. How to Capture the Opportunity of VRPs

Companies can unlock the substantial benefits of VRPs through a combination of product redesign, developing performance-based business models, scaling up reverse-logistics, and collaborating across sectors and along value chains. A systems perspective supported by strategic data use will be essential in all approaches, which includes strategically considering context specific endowments and barriers.

- Product redesign with a focus on durability, upgradability and reparability is a first step toward harnessing the benefits of VRPs – as well as upgrading service warranties and other customer interaction.
- Innovating the business model more profoundly to sell a performance instead of ownership can boost the profits from VRPs as well as customer satisfaction. Some examples of these models include the provision of lighting and flooring as a service; and the "pay per sheet" model used in the printer industry, all of which can lead to higher profits than the sale of the physical unit- as savings from VRPs stay directly with the producer.
- Producers are best placed to build up circular models and infrastructure starting from existing regional infrastructures, formal or informal. Collaborative approaches to (shared) collection and reverse-logistics infrastructure are likely to be the most feasible. The key success factors in capturing the benefits from circular production models are summarized in Figure 3.
- In addition to regional context, global cooperation is important. Global industry initiatives to set transnational standards require a multi-stakeholder 'collective' approach, with institutional features and procedures to help establish the legitimacy and buy-in for the effort (Ponte 2014).
- In addition to regional context, global cooperation is important. Global industry initiatives to set transnational standards require a multi-stakeholder 'collective' approach, with institutional features and procedures to help establish the legitimacy and buy-in for the effort (Ponte 2014).

Figure 3: Success factors for capturing the benefits of VRPs



1.4. Overcoming the Barriers to Scaling Circular Production Models

Collaboration across companies and engaging policy makers is also key to tackle systemic barriers such as constraining regulation, unaware customers, lack of infrastructure and lack in technological capacity. This report analyses these barriers across four sample economies: US, Germany, Brazil and China. Industry leadership will be essential to guide and urge policy makers to tackle systemic barriers, having in mind their relative local weight:

- Companies in the US and Germany encounter lower barriers to scaling VRPs overall compared to those in Brazil and China. However, in the US, education and research could be optimized, as well as clusters and networks supporting VRPs.
- In Germany, industry and policy can improve information and communications technology infrastructure, as well as regulatory conditions, that, for example currently obstruct the trade of VRP industrial printers.
- In Brazil, regulatory barriers are significant, for example obstructing trade in component parts necessary for VRPs. Technological barriers, such as a lack of ICT infrastructure, are high too. In China, these technological barriers are lower but still need to be improved; regulatory factors are most constraining.
- Regulatory barriers in China and Brazil prevent the movement of inputs to VRP processes (e.g. cores), as well as the movement of finished VRP products, into and within these economies.
- In all sample economies customer interest in and awareness of VRPs needs to be increased, specifically regarding the quality of remanufacturing. Industry standardization initiatives, in collaboration with policy, have shown to be effective in tackling this barrier and have the potential to be upscaled.

2

Key Insights & Strategic Recommendations

2.1. Companies can Benefit from the Adoption of VRPs

2.1.1. Benefits of VRPs

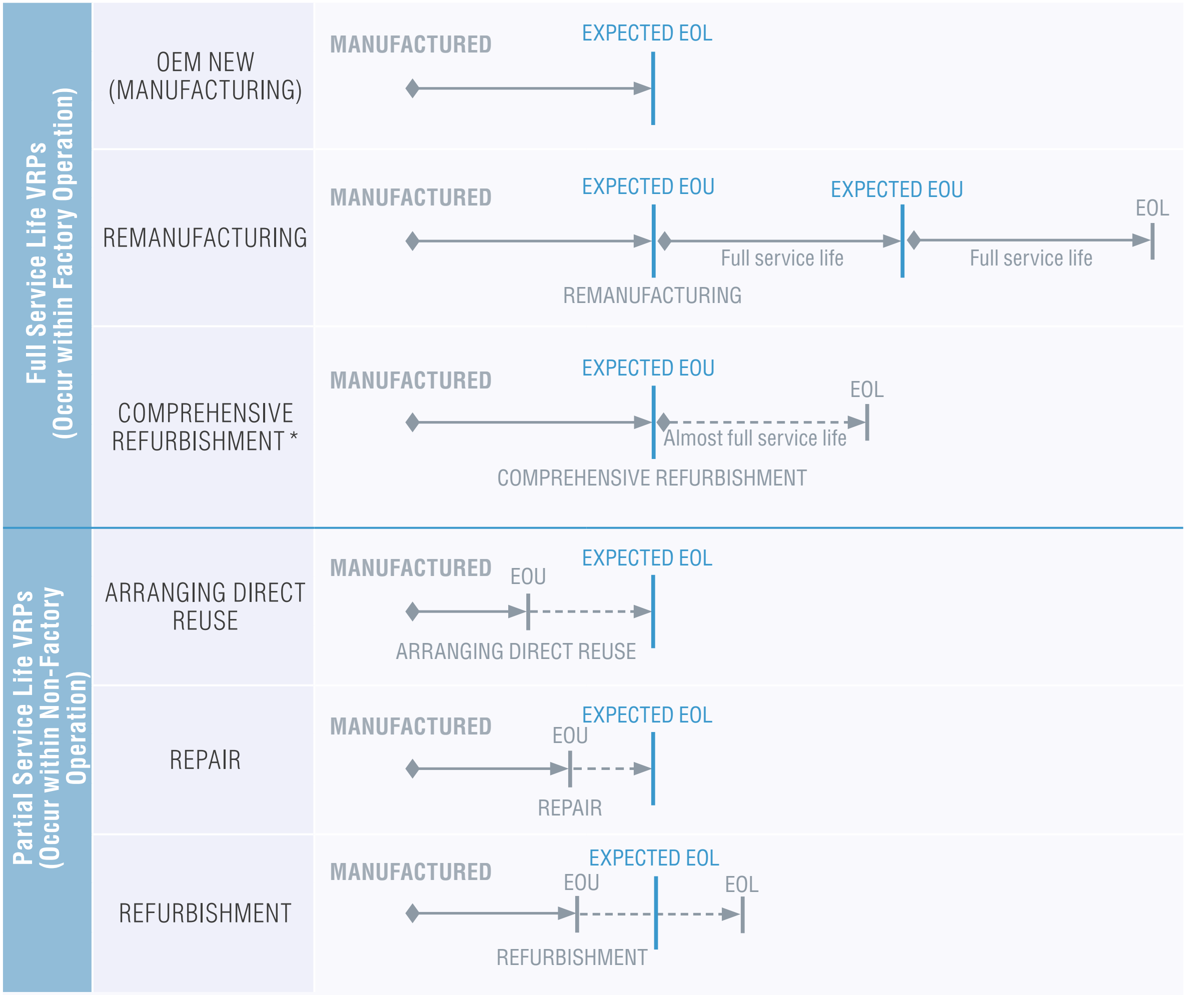
Value-retention processes (VRPs), as the term suggests, retain value in the system by adding value and utility to a product (remanufacturing and comprehensive refurbishment) and/or extending the useful life of a product (arranging direct reuse, repair, and refurbishment) beyond its expected end-of-use (EOU) (See Figure 4). Additional clarification regarding the distinction between full service life VRPs and partial service life VRPs is included in the full report.

By retaining the functional form of product cores, via VRPs, the resource value invested in the original production of those cores is retained within the system. In addition, the requirement for new materials, energy, and the inherent wastes associated with upstream production activities can be offset. As a result, in addition to avoiding significant upstream environmental and economic impacts associated with OEM New produced parts and components, there is the potential for significant production cost savings for VRP producers.

The **environmental and economic** impacts of VRPs differ by product, material, and market as a result of complexity within the system.

In evaluating the benefits of VRPs, it is important to be aware that the benefits here are shown per production cycle. Remanufacturing and comprehensive refurbishment may require greater process energy, produce more process emissions and more waste as they require more intensive industrial processes than repair or direct reuse. However, remanufacturing and comprehensive refurbishment also add and retain relatively greater value in the system in terms of materials and functional form and can create greater utility for the end customer.

Figure 4: Summary of value-retention process differentiation within the context of EOU and EOL



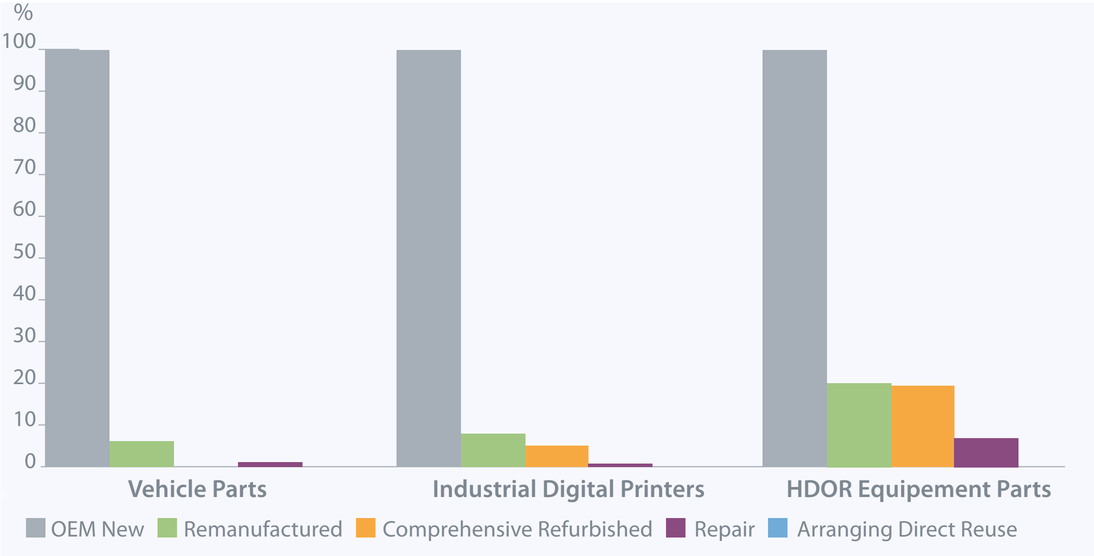
* This only exists for certain sectors and products.

2.1.1.1. VRPs Reduce New Material Input Requirements

VRP processes reduce the average new material demand, therefore, creates an opportunity to avoid requirement for new materials. Resource constraints can present a meaningful risk to business growth, and the reduced requirement for new material inputs – as enabled via VRPs – offers industry members an opportunity for improved resource efficiency and sustainability within the supply chain.

The individual case studies showed remanufacturing reduced the new materials requirement by between 80 per cent and 98 per cent. Comprehensive Refurbishment saved, slightly more materials, between 82 per cent and 99 per cent. Repair saved an even higher share of between 94 per cent and 99 per cent. Direct reuse does not require any inputs of new materials. For detailed relative new material requirements of VRPs relative to OEM New production per sector, refer to Figure 5.

Figure 5: Weighted average new materials requirement of VRPs relative to traditional OEM New production[6]



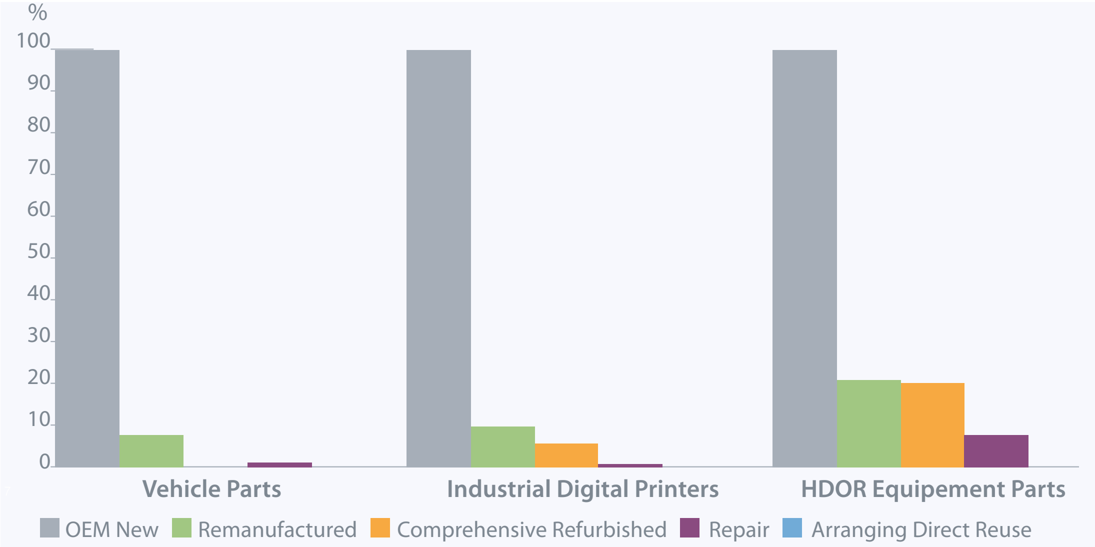
6- Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

2.1.1.2. VRPs Reduce Embodied Material Energy and Embodied Material Emissions

Embodied material energy and emissions refer to the energy and emissions associated with the extraction and processing of raw materials prior to production. With reduced new material inputs, the embodied material energy and emissions of a product also decrease; the magnitude depending on the type of materials that are retained.

Remanufacturing, across the individual case studies, avoided 79 per cent - 99 per cent of embodied material energy and emissions of the product compared to OEM New. Refurbishment saved 80 per cent - 99 per cent, repair 93 per cent - 99 per cent, and direct reuse does not produce any additional embodied emissions. Overall, refurbishment led to the slightly larger savings compared to remanufacturing; the part-service life VRPs (repair and direct reuse) avoided most emissions. Savings were substantial across all VRPs. For detailed relative embodied material energy and embodied material emissions of VRPs relative to OEM New production, refer to Figure 6.

Figure 6: Weighted average embodied material energy and emissions impacts of VRPs relative to traditional OEM New production[7]

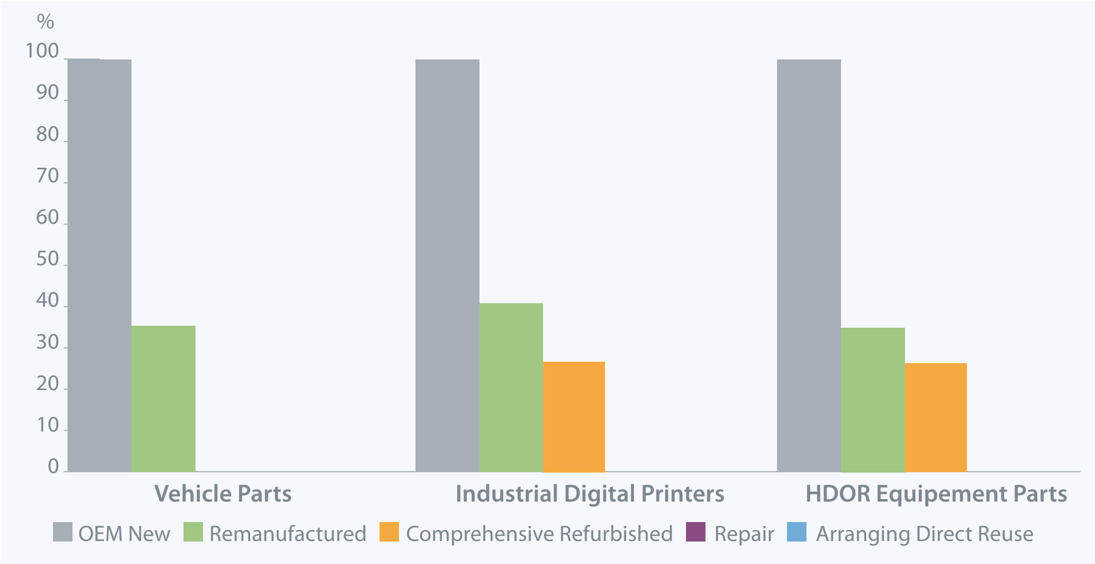


7- Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

2.1.1.3 VRPs Reduce Energy Needs in The Production Process and Reduce Related Emissions

Across the case studies, remanufacturing avoided process energy use and related emissions of 57 per cent – 87 per cent relative to the linear process. The average savings for refurbishment were slightly larger, ranging between 69 per cent and 85 per cent. Process energy and process emissions associated with repair and direct reuse are minimal. For detailed relative process energy and process emissions of VRPs, relative to OEM New production per sector, refer to Figure 7.

Figure 7: Weighted average process energy and emissions impacts of VRPs relative to traditional OEM New production[8]



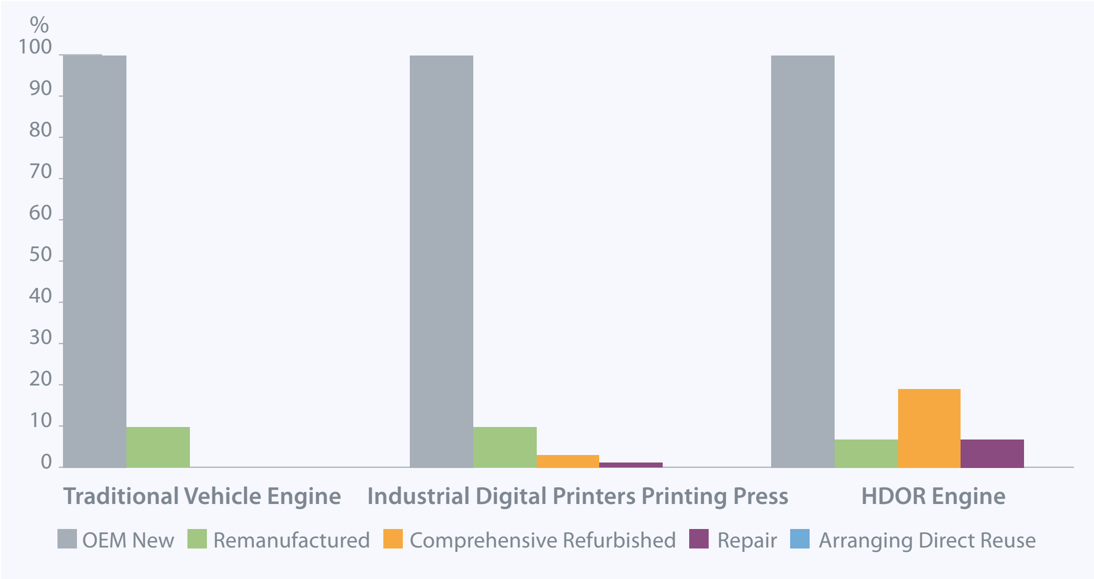
8- Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

This is extremely important for the contributions of VRPs to efforts on Climate change.

2.1.1.4. VRPs Cut Production Waste

The decrease in production waste is inversely correlated to the increase in VRP production. Part-service life VRPs avoided most waste in comparison to the linear reference product. Repair reduced production waste by 95 per cent – 99 per cent and direct reuse does not cause production waste. Remanufacturing led to a cut of about 90 per cent in production waste across the sectors, comprehensive refurbishment reduced about 80 per cent to 95 per cent of production waste. For detailed savings per sector, refer to Figure 8.

Figure 8: Production waste impacts of VRPs relative to traditional OEM New production[9]



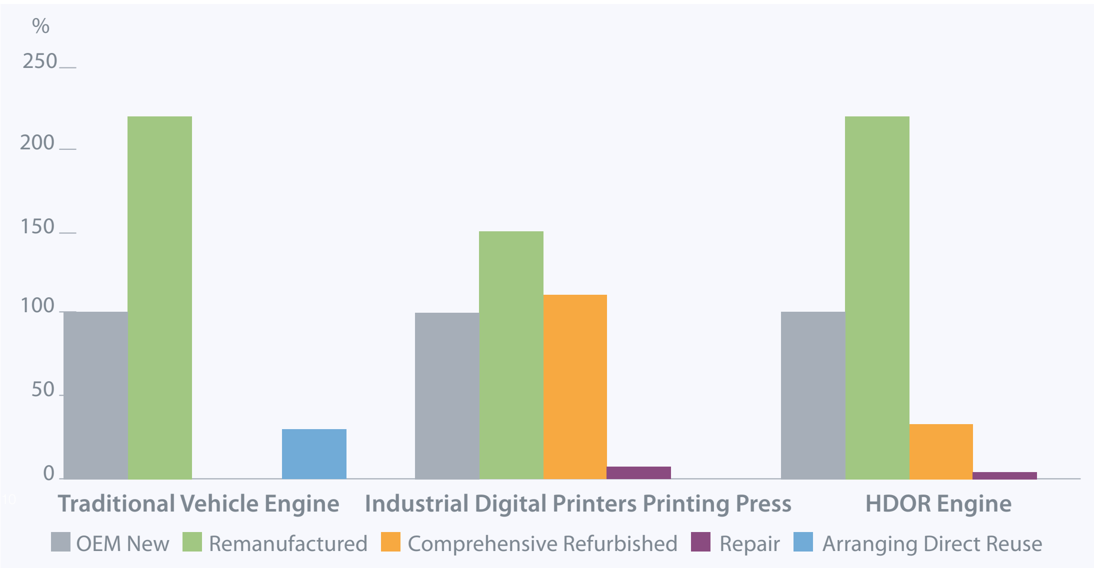
9- Once case study product per sector analyzed: Traditional cast iron vehicle engine (for Vehicle Parts); Industrial Digital Printing Press #2 (for Industrial Digital Printers); and HDOR engine (for HDOR Equipment Parts). Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

2.1.1.5. VRPs Can Create Jobs and Offset Labor Costs

The requirement for potentially more manual VRP production processes, and a necessary level of labor force skills, highlights the employment opportunity inherent in VRPs.

Employment opportunity, in the context of OEM New and VRP production, was evaluated in terms of the labor-hours required to complete each production process. Full service life VRPs including remanufacturing and comprehensive refurbishment offer significantly higher opportunity to increase employment levels, because in most cases they require additional process steps, including evaluation, cleaning, and additional quality testing. These additional process activities for full service life VRPs increase the total labor-hours required (relative to the OEM New process), thereby creating additional direct and secondary economic benefits within an economy. Thus, as the production share of remanufacturing and refurbishment are increased, a corresponding increase in full-time employment opportunities is possible.

Figure 9: Skilled labor requirement for VRPs relative to traditional OEM New production[10]



10- Once case study product per sector analyzed: Traditional cast iron vehicle engine (for Vehicle Parts); Industrial Digital Printing Press #2 (for Industrial Digital Printers); and HDOR engine (for HDOR Equipment Parts). Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

Specifically, remanufacturing and sometimes refurbishment have larger requirements for skilled labour than a linear production of the product (refer to Figure 9). Remanufacturing increased skilled labour hours by up to 120 per cent in comparison to the linear production. Repair required less labour than the linear reference product, showing a decrease of 70 per cent to 99 per cent.

In the case of increased labour requirements, within the context of broader operating costs, the potential increases to labour costs are more than offset by the material and energy savings.

As the part-service life VRPs prolong a product's service life to a limited extent, they can be seen as complementary to the new production or remanufacturing of products. Overall, VRPs can therefore increase high skilled job opportunities in an economy while saving costs in the company.

2.1.1.6. VRPs can reduce related production cost

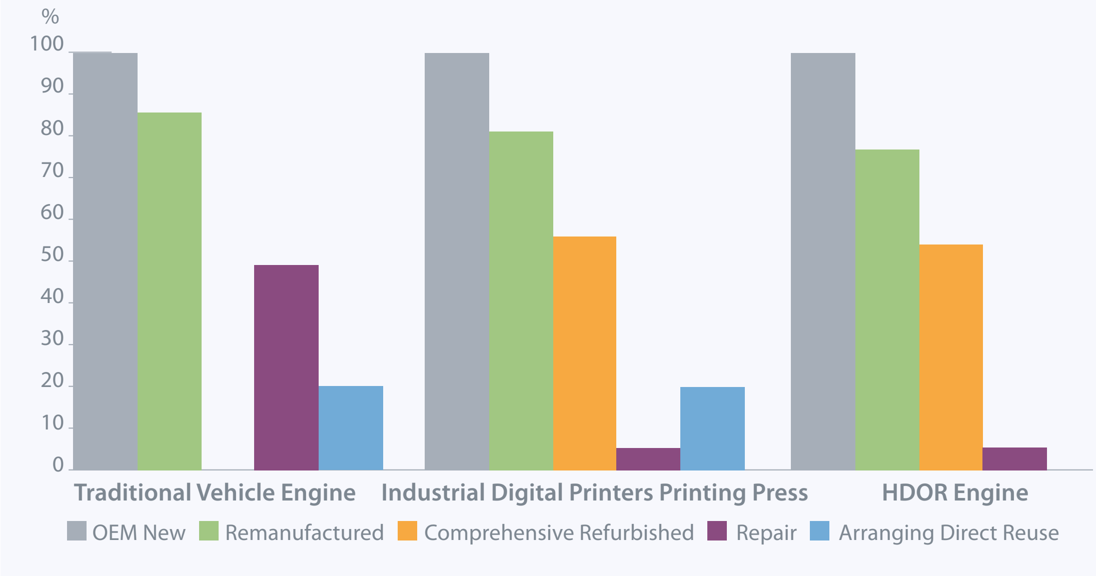
Cost advantages of VRPs range, conservatively, between 15 per cent and 80 per cent of the cost of an OEM New version of the product, with the lowest cost option enabled via repair for partial service life VRPs, and comprehensive refurbishment for full service life VRPs. Once again, while every VRP offers a cost advantage (reduction) in comparison to the OEM New option, the preferred VRP option may depend on the priorities and economic situation of the customer or user. In key sectors, the VRPs remanufacturing and comprehensive refurbishment can lead to up to 44 per cent cost reduction, whilst repair and reuse lead to up to 95 per cent.

In addition, the decrease in the volume of production waste and recyclables is first and foremost an economic opportunity associated with increased adoption of VRPs: not only do high quantities of production waste indicate that there is value within the system that is currently being lost (e.g. not being utilized at its highest potential) through design, technological and/or other forms of process inefficiency; but there are also operating costs associated with that waste production that must be borne by the producer, including storage, hauling and tipping fees.

2.1.1.7. VRPs Enable New Segments of Customers to Participate in The Market

While VRPs present alternative product options to the customer market, VRPs ultimately rely on the continued presence of OEM New products in the market. As such, VRP products are not intended as replacements for OEM New products, and if differentiated and positioned appropriately, VRP products may serve to enable growth opportunities for the entire product segment by targeting and engaging new, previously untapped, market segments that

Figure 10: Cost of VRP products relative to traditional OEM New products[11]



11- Once case study product per sector analyzed: Traditional cast iron vehicle engine (for Vehicle Parts); Industrial Digital Printing Press #2 (for Industrial Digital Printers); and HDOR engine (for HDOR Equipment Parts). Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

The presence of lower-priced VRP product options in the market, compared to the new manufactured product, can enable new segments of customers to participate where budget constraints may previously have prevented such engagement (Atasu, Sarvary, and Van Wassenhove 2008, Debo, Toktay, and Wassenhove 2006, Debo, Toktay, and Van Wassenhove 2005, Hamzaoui-Essoussi and Linton 2014, Hazen et al. 2012).

2.1.1.8. VRPs Open Export Opportunities for VRP Goods

While some economies have regulatory and access barriers in place that affect the import and trade of VRP products, export opportunities for VRP products are significant for many economies. For the United States, with remanufacturing industries accounting for approximately 11.7 billion USD in 2011, and especially for foreign markets that require lower price points, and/or that have accessibility challenges within their domestic markets (U.S. International Trade Commission 2012).

It is important to note that where regulatory and access barriers exist (e.g. regulations prohibiting engagement in VRP activities or restricting the movement of cores and VRP inputs) all other aspects of the circular VRP system will constrained. Most importantly, where regulatory and access barriers exist, producers may be unable to develop the strong business case that is ultimately required to facilitate VRP adoption in an economy.

The use of VRPs reduces new material input requirement, and the embodied value inherent in the already-functional form ensures that VRPs can offset a significant share of costs otherwise required for OEM New production. This generates additional economic opportunities in several ways:

- Lower operating costs reduce cost barriers to entry into the marketplace for potential VRP producers, supporting and enabling faster scale-up within domestic industry; and
- Lower operating costs enable VRP producers to pass the cost advantage along to their customers, which can enable new segments of customers to participate where budget constraints may previously have prevented such engagement.

Box: Environmental and Economic benefits associated to value retention processes

- VRPs reduce new material input requirements
- VRPs reduce embodied material energy and embodied material emissions
- VRPs optimize energy needs in the production process and reduce related emissions
- VRPs cut production waste
- VRPs can create jobs
- VRPs can reduce related production cost
- VRPs can enable new segments of customers to participate in the market
- VRPs open export opportunities for VRP goods

2.2. Appropriate Use of VRPs

The benefits of VRPs are not 'equal', and industry decision-makers must also consider which VRP(s) are most appropriate for a given strategic objective (e.g. capital investment requirements versus environmental footprint reduction), given the relative 'trade-offs' between the environmental and economic impact that can exist (See Figure 11). These trade-off insights are supported by the findings from each of the case study sectors assessed (See Figures 5 through 10).

Figure 11: Relative environmental impact and economic benefit trade-offs of full serice life versus partial service life VRPs

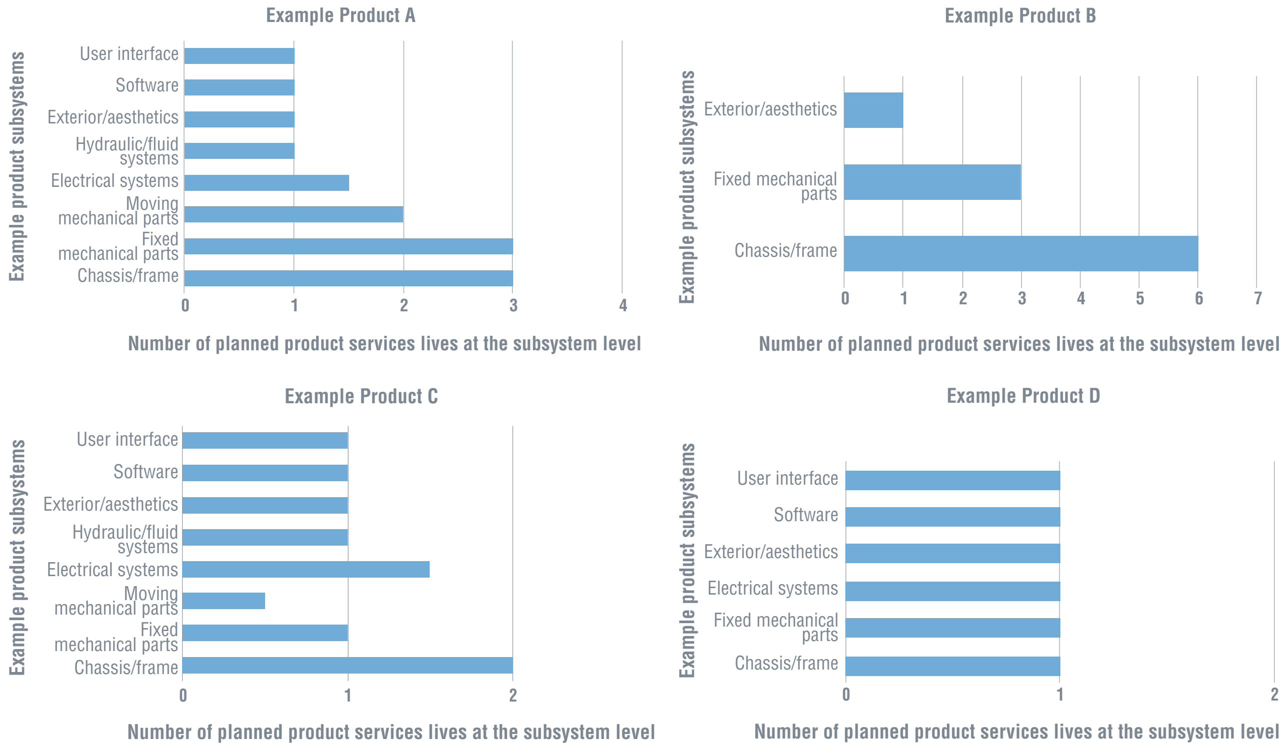
	Full Service Life VRPs (Remanufacturing & Comprehensive Refurbishment)	**Partial Service Life VRPs** (Arranging Direct Reuse, Repair & Refurbishment)
Environmental	• Higher energy requirement relative to partial service life VRPs; • Higher emissions generation relative to partial service life VRPs	• Lower energy requirement relative to full service life VRPs; • Lower emissions generation relative to full service life VRPs.
Economic	• Higher employment opportunity relative to partial service life VRPs; • Higher product value-retention relative to partial service life VRPs; • Higher cost to produce relative to partial service life VRPs.	• Lower employment opportunity relative to full service life VRPs; • Lower product value-retention relative to full service life VRPs; • Lower cost to product relative to full service life VRPs..

VRPs may not always be the optimal circular economy strategy for a firm to pursue, and the appropriateness of VRPs must be assessed on a product-by-product basis. Important product-level considerations for VRPs include:

- The nature of product and sub-system components, which dictate wear-and-tear and durability;
- The use-phase energy requirement and energy efficiency of the product, which dictate life-cycle energy requirement;
- The residual/remaining value that can be captured if VRPs were in-place; and
- The material composition of the product, which dictates the technical complexity of VRPs.

This concept is clarified further in Figure 12. Example products A (e.g. medical imaging equipment), C (e.g. industrial digital printer), and D (e.g. mobile phone) reflect products with more complex sub-systems; Example product B (e.g. office furniture) reflects products with relatively simpler sub-systems.

Figure 12: **Planned service lives of product sub-systems for example products (A, B, C, and D)**



Some key questions that industry members should consider and address when evaluating whether to pursue VRPs within their current operations include:

- Whether some product sub-systems may have the potential for multiple service lives (e.g. durability)?
- Whether retaining the sub-systems and/or parts via VRPs will constitute meaningful economic and environmental benefits, such as avoided new material requirement?
- Whether the retained value enabled by the VRP product (e.g. cost-savings, waste avoidance) exceeds the investment that would be required to complete the VRP, including recovery and reverse-logistics?

Inherent in these insights is the fact that if products are only designed to complete a single service life, opportunities for circular economy are limited.

There are many VRP-appropriate products that were not included in the study, and there are also many products that are not suited for VRPs. Within VRP-appropriate manufacturing sectors there remains significant opportunity and untapped potential to increase the level of VRP activity occurring within VRP-appropriate manufacturing sectors in the sample economies.

Although current VRP adoption remains low, with remanufacturing accounting for ~2 per cent of production in US and the EU (U.S. International Trade Commission 2012, European Remanufacturing Network 2015), it is estimated that as much as 41 per cent of the aggregated manufacturing GDP for these sample economies are potentially VRP-appropriate. This suggests significant opportunity for industry members to investigate and pursue VRPs within or parallel to their current operations and product lines.

Although current VRP adoption remains low, with remanufacturing accounting for ~2% of production in US and the EU (U.S. International Trade Commission 2012, European Remanufacturing Network 2015), it is estimated that as much as 41% of the aggregated manufacturing GDP for these sample economies are potentially VRP-appropriate. This suggests significant opportunity for industry members to investigate and pursue VRPs within or parallel to their current operations and product lines.

2.2.1. Strategic Opportunity for Growth for VRPs Alongside OEM New Products

VRPs are very important for circular economy, however, they need not necessarily be competitors to OEM New products. As emphasized throughout the assessment report, VRPs rely on continued OEM New production and design innovation. The sustainable design of OEM New products can help to facilitate continued reduction of environmental impacts during the first service life of products; when these better-designed products incorporate circular economy and VRP design principles will enable continued potential for economic and environmental benefits.

In many markets, the availability of VRP product options creates targeted and differentiated opportunities to approach new markets and new market segments:

- Lower-cost, high-quality VRP products may appeal to large-quantity consumers who must manage tight budgets, such as institutions, government agencies, and centralized corporate procurement functions;
- Lower-cost VRP product options may appeal to customers previously unable to participate in markets where only higher-cost OEM New options were available;
- Environmentally-preferable VRP product options may appeal to customers who incorporate environmentally and/or socially-conscious values into their purchase decisions;
- VRP offerings can also complement OEM New sales through innovative business and service models; such as the case of a product-as-service option where customers can choose to pay for the provision of the service, not ownership of the product.

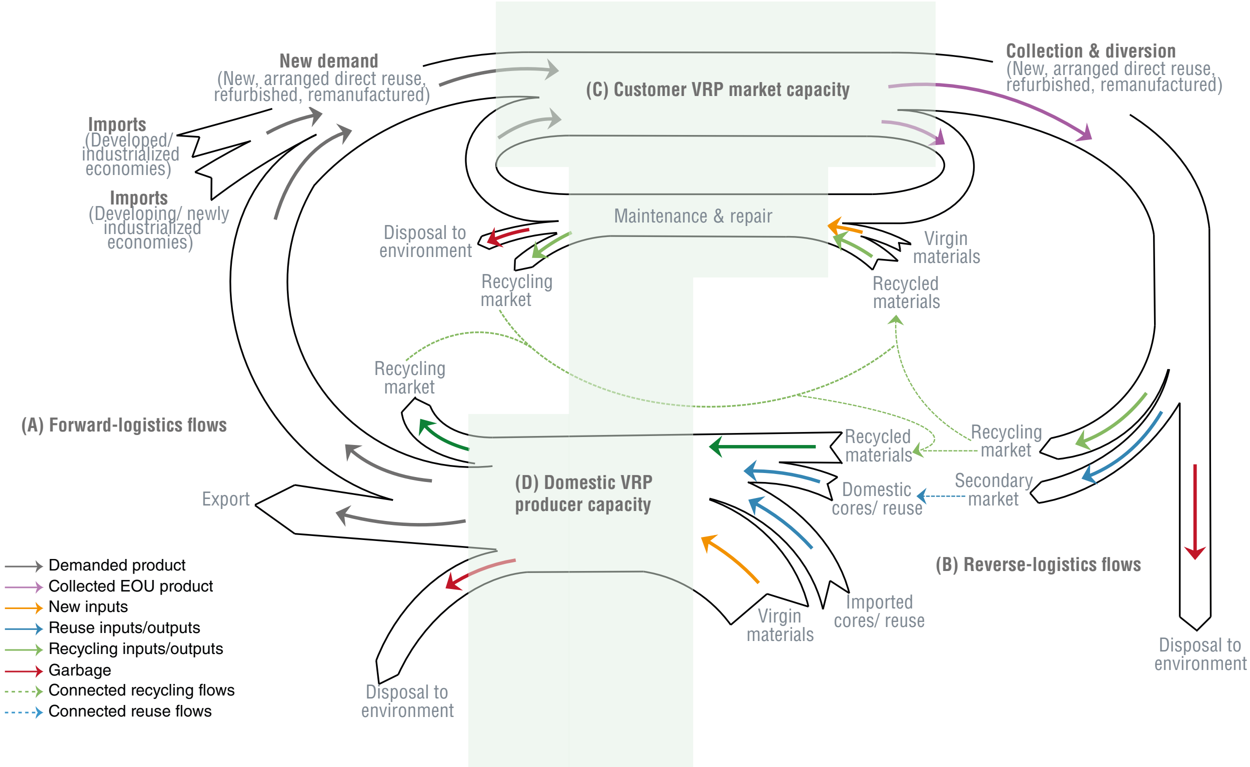
2.3. Strategy Must be Shaped by an Expanded Systems-Perspective

2.3.1. Circular Economy Requires A New Way of Seeing the Business System

A 'systems-view' is essential for circular economy and expanded system boundaries are needed. The product can no longer be viewed in isolation, but instead must be considered, evaluated, and designed for the broader system in which it exists throughout the course of its life cycle: Production, Use, and End-of-Use (EOU) or End-of-Life (EOL).

The expanded systems perspective highlights the complex interactions of stakeholders, perspectives, interests, and activities inherent to VRPs that must be engaged for successful circular economy transition (See Figure 13).

Figure 13: Descriptive Circular Economy System Model for VRPs



The circular economy objective of retaining value via product and materials recovery and life-extension requires industry members to consider the larger system: Looking upstream, to consider the source and impacts of the production system; and looking downstream, to consider how to create value-retention and recovery channels via customer engagement and reverse logistics.

Circular system design does not need to be developed from scratch; in fact, designers and industry decision-makers will very rarely have a clean slate from which to start. Instead, attention must be paid to existing diversion and collection infrastructure and programs, as well as existing forward-logistics technologies and best practices that might be leveraged and/or provide a conceptual starting point. Innovative, effective, and efficient business models that complement and facilitate the adoption of VRPs and VRP products is essential.

Advances in shared-economy principles, as well as collaboration and partnership with third-party entities can help to more equitably distribute capital and knowledge requirements, and to facilitate the sharing of reverse-logistics expertise. There is potential for shared infrastructure and services, with appropriate coordination; in addition, inter-sector and inter-industry partnerships can help to facilitate necessary technology and knowledge transfer needed for effective circular, value-retaining systems.

2.3.2. Design for the Expanded System

Currently, product design specifications are ultimately responsible for ~75 per cent of a product's manufacturing costs, and ~80 per cent of the environmental and social impacts of a product: without an emphasis on overcoming waste and retaining value within production- and product-systems, the pursuit of circular economy can only be incremental at-best.

The transition to circular economy relies on a new approach to product and system design, founded on three requirements: 1) The ability to create value; 2) The ability to protect and preserve value; and 3) The ability to easily and cost-effectively recover value. In addition, requirements for VRPs and VRP products must be built-into product specifications and included in planning and business case development stages long before product designers are involved in the process.

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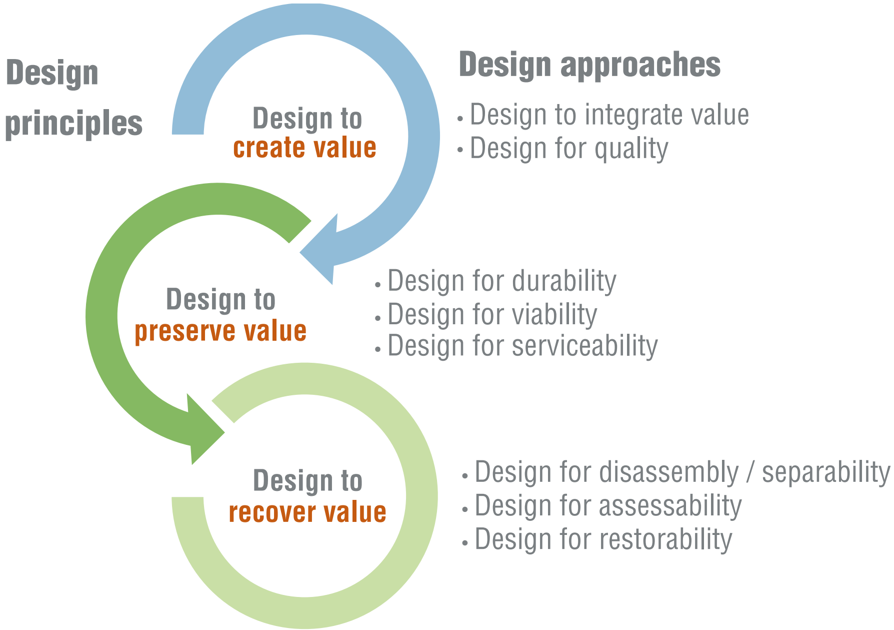
Figure 14: Product development incorporates both VRP design principles and approaches



These three system requirements allude to essential circularity objectives that cut across product-, process-, facility-, and system-perspectives. These may include designing the product for long life, and/or keeping the product in the system (retaining value) for longer – in both cases, slowing the flows of materials into and out of the economic system, and reducing the materials that ultimately escape from the system. There are different design approaches that can be employed in pursuit of these objectives, organized below according to circularity priorities and principles (See Figure 14).

For the circular economy to thrive, industry members must focus on design practices that create, preserve, and enable the recovery of value. In addition, the provision of service warranties to customers helps to facilitate the closing of product life-cycle loops and the retention of value within product- and material-systems.

2.4. An Innovative and Collaborative Approach Works Best

2.4.1. A Stronger Business Case for VRPs Via Business Model Innovation

Innovative business models can complement design approaches by integrating the essential systems-perspective that seeks to reduce the loss of value to the system. In many cases, simple interventions may include improved and/or optimized product design and delivery, enhanced service contracts, and/or third-party operated reverse-logistics systems to facilitate VRPs at the product's EOU/EOL.

In other cases, creative business model approaches can take circular economy efforts further, facilitating the retention of product ownership by the producer. Inherent in this ownership is the opportunity to track the product throughout the distribution system, to actively intervene for maintenance or service purposes at different stages of the product's service life, and to take-back the product from the user once it has reached a predetermined EOU or EOL.

A particular business model approach that offers variations appropriate and effective within a circular VRP system are Product Service Systems (PSSs), focused on creating consumer utility and value. PSSs are shown to create opportunity for improved resource efficiency with varied effectiveness. Results-focused PSS models that are structured on the provision of activity management (e.g. pay-per-service) have been identified as particularly effective at resource efficiency and circular economy potential: by design, results-oriented PSSs enable a built-in customer incentive for keeping costs low, with associated reduction in material use and negative environmental impacts.

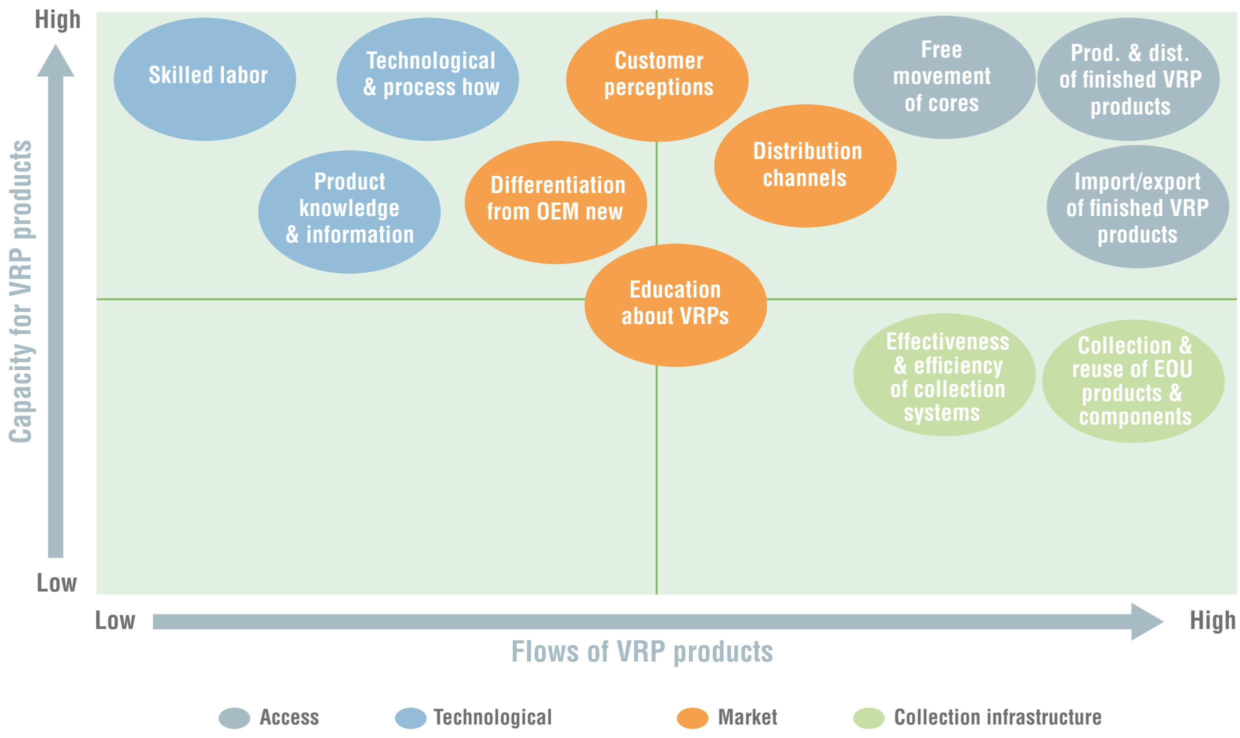
An example of results-focused PSS is the service provided by an industrial printer, for which the user pays a fee for every printed sheet rather than paying to own or lease the printer. This approach, by design, helps the customer to associate product use and degradation from use with a real unit-cost, and thus encourages the minimization of the total costs of ownership and contributes to extended product service life (Baker 2006, Lifset 2000).

2.4.2. Successful VRP Expansion Requires a United Front

The circular economy and its interconnected, diverse, and complex set of networks and systems cannot be facilitated by policy and regulatory leadership alone. The achievement of circular economy will depend on the bold and decisive leadership of industry decision-makers to collaborate with and guide government policy approaches, to develop voluntary standards, and to coordinate and engage with diverse and global stakeholders.

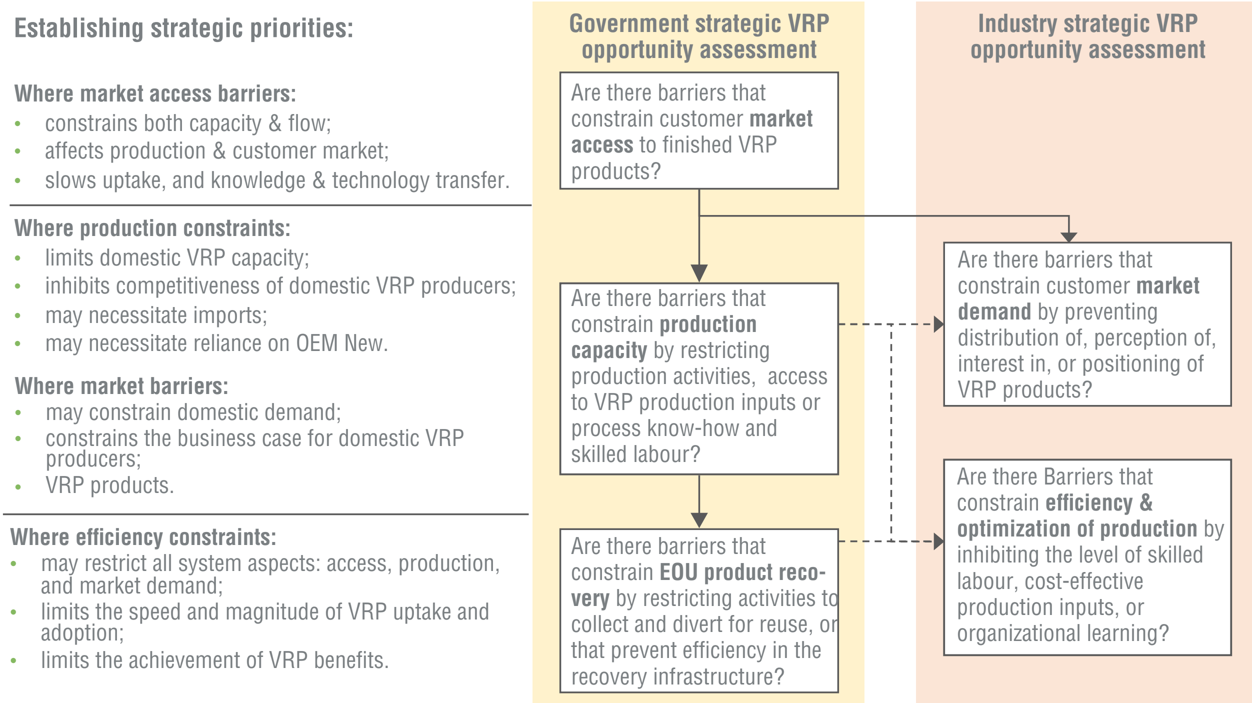
Specific actions can help to alleviate barriers and constraints within the circular system, across issues of access and regulation (black), technological capacity (blue), customer markets (orange), and collection infrastructure (green) (See Figure 15).

Figure 15: Differentiated barrier alleviation strategies for different economic objectives



In particular, industry members have an important role to play alongside policy-makers to help identify and alleviate customer market and technological capacity barriers that currently inhibit the adoption of VRPs and other circular economy practices (See Figure 16).

Figure 16: Role of industry decision-makers and policy-makers in assessment of VRP barriers and strategic priorities



Important strategies for individual and collaborative industry approaches must include:

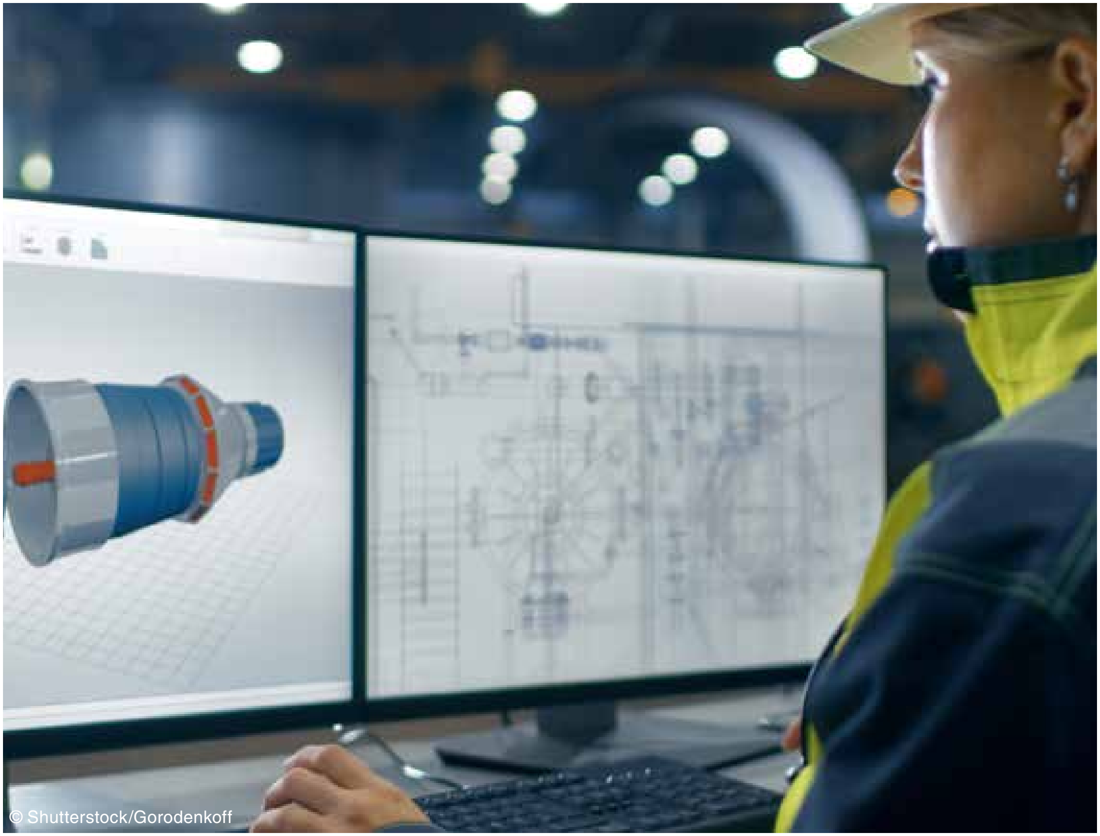
- Engaging in active education and awareness initiatives to inform the customer market about VRPs, VRP products, and the economic and environmental benefits that are enabled by these offerings;
- Increasing the transparency and credibility of quality and process information related to VRPs in order to inform the customer's assessment (perception) of the value and risk associated with VRP products;
- Engaging with and educating policy-makers regarding the technological barriers currently facing VRP producers, and working to develop realistic and reasonable policy-supported approaches to alleviating these technological and production-capacity barriers;
- Particularly in the case of VRP producers that operate across industrialized and non-industrialized economies around the world, collaborating with other industry members across national borders to facilitate necessary technology transfer, shared resource pools and infrastructure, labor and training needs, and the integration of diverse global markets.

In many cases, governments may delegate responsibility for environmental and social issues to industry by requiring them to develop voluntary standards. For example, in the US, experienced VRP industry members successfully coordinated efforts to establish the Specifications for the Process of Remanufacturing (ANSI RIC001.1-2016) as an American National Standard in February 2017 (Remanufacturing Industries Council 2017). Another standard for medical imaging devices defines best practices for the refurbishment of medical imaging equipment (IEC PAS 63077-2016-11). Although limited to the US market, this achievement offers a means of addressing issues of competition, trade (e.g. policy definitions), and best practice standards affecting market growth, performance, and opportunity.

Industry members must work with policy-makers to enforce fair competition in VRP product markets: in the absence of market awareness, information, and standardization, firms practicing high VRP standards are often unable to compete against those achieving lower standards.

Individually or through alliances, industry members have a unique opportunity to facilitate circular economy transformation in both industrialized (developed) and non-industrialized (developing) economies by adopting multi-stakeholder approaches that engage and reflect broader "collective" interests, including the needs of customers, distributors, producers, third-party service providers, consumers, communities, institutions, and policy-makers.

The elevation of the entire industry, via collaborative and reflective voluntary industry standards, offers an opportunity for industry members to not only legitimize and codify the value of circular economy and VRP practices, but also the opportunity to equitably level the playing field in a sustainable manner.



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3 Conclusions

There is often a perception that the pursuit of sustainability must come at an economic cost. However, this assessment reveals that circular economy, via VRPs, can offer an opportunity to achieve significant value-retention and environmental impact reduction, while also creating economic and growth opportunities for industry members.

A top priority for industry decision-makers must be the adoption of a broad systems-perspective into business model and product design, and the prioritization of value-creation, value-preservation, and value-recovery as key objectives within the product-service system.

Finally, there is an essential need for enhanced coordination and alignment between industry decision-makers and policy-makers. Developing enhanced business models, extended circular consumption-production systems, voluntary standards, and engaging and educating the customer marketplace are essential functions for industry decision-makers. However, these efforts must be integrated with the efforts of policy-makers to protect economic and environmental interests, and to facilitate the transition to more resource-efficient circular economies at national, regional, and global scales.

From this assessment, eleven industry priorities are recommended to facilitate the adoption of VRPs and the transition to circular economy:

1. **Adopt** an expanded systems-perspective that considers the product within the broader system in which it exists, and across its life cycle: production, use, and end-of-use (EOU) or end-of-life (EOL).

2. **Evaluate** existing product lines to identify opportunities to adopt VRPs within the product-system, directly (e.g. offering VRP products) and/or indirectly (e.g. enabling VRPs through third-party arrangements.
3. **Modify** product design priorities to incorporate principles essential to VRPs and circular economy: value creation (e.g. design for quality); value protection and preservation (e.g. design for durability); and cost-effective and easy value recovery (e.g. design for disassembly). Design for VRPs must start at the beginning in the product development process.
4. **Utilize** existing production, distribution, and collection infrastructure and networks – wherever possible – to facilitate the closing of product and material loops within the supply chain. This can support the implementation of VRPs and enable the transition to circular economy.
5. **Contribute** to the development, ratification, and enforcement of VRP standards that guide industry practice.
6. **Provide** transparent and credible information to customers about VRPs and the quality of VRP products to objectively inform customer perceptions of risk and value relative to the traditional OEM New offering.
7. **Engage** policy-makers in collaborative discussion and initiative focused on communicating and alleviating VRP production-capacity and other technological barriers to VRPs.
8. **Partner** with other industry members to provide active education and awareness initiatives to the customer market about VRPs, VPR products, and the economic and environmental benefits of VRPs.
9. **Collaborate** with other industry members and policy-makers to clearly identify and communicate the key barriers that inhibit the business case for VRPs in all operating jurisdictions.
10. **Coordinate** with internal company stakeholders to facilitate the intra-firm sharing of essential VRP resources across national borders, including necessary technology transfer, resources, product information, and training.
11. **Partner** with research institutes to support and enable enhanced R&D focused on product design, process design, infrastructure design, and other opportunities to adopt and optimize VRPs.

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UN environment

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Environment Programme

There is growing international interest in the concept of circular economy as a framework for pursuing sustainable economic growth and human prosperity.

A key aspect of circular economy, well-aligned with current objectives of resource efficiency and resource productivity, is the concept of value-retention within economic production-consumption systems. Value-retention processes, such as *remanufacturing, refurbishment, repair and arranging direct reuse*, enable, to varying degrees, the retention of value, and in some cases the creation of new value for both the producer and customer, at a reduced environmental impact.

This report connects the potential for resource efficiency, via circular economy and the processes that retain product value within the systems, with a policy-relevant lens. The report is one of the first reports to quantify the current-state and potential impacts associated with the inclusion of value-retention processes within industrial economic systems. In order to do that the assessment applies the different value-retention processes to a series of products within three industrial sectors and quantifies benefits in relation to the original manufactured product, such as the material requirement, the energy used, the waste as well as the costs and the generation of jobs.

The report also highlights the systemic barriers that may inhibit progressive scale-up including regulatory, market, technology and infrastructure barriers, and how they could be overcome.

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