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International Resource Panel

REDEFINING VALUE

THE MANUFACTURING REVOLUTION

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

Summary for Policy Makers

Acknowledgements

Lead Author: N.Z. Nasr; **Authors:** Prof. N.Z. Nasr (Rochester Institute of Technology, US), J.D. Russell (Rochester Institute of Technology, US).

Contributors: C. Kreiss (Rochester Institute of Technology, US), B. Hilton (Rochester Institute of Technology, US), S. Hellweg (ETH Zurich, Switzerland), S. Bringe zu (University of Kassel, Germany), and N. von Gries (Wuppertal Institute, Germany).
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Summary for Policy Makers

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

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 Policy Makers

- Value-Retention Processes (VRPs) (namely remanufacturing, (comprehensive) refurbishment, repair and direct reuse) and recycling are complementary processes that, if pursued strategically, can enable faster achievement of circular economy. While most actors in the manufacturing supply chain are currently focused on recycling their products, the adoption of VRPs can lead to the retention of substantially greater value in the system: VRPs enable the retention of the inherent value of the product, whereas recycling retains just the value of the material or resource that is recycled.

- VRPs create net-positive outcomes for circular economy by enabling product-level efficiency gains in material and energy use, and in emissions and waste generation. 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 Original Equipment Manufacturer (OEM) New production, remanufacturing can reduce new material requirement by between 80 per cent and 98 per cent; comprehensive refurbishing saved slightly more materials, between 82 per cent and 99 per cent. Repair saved an even higher share, between 94 per cent and 99 per cent; and arranging direct reuse does not require any inputs of new materials.

- Where pursued strategically and systematically, expanded adoption of VRPs in a country's production activities can enable increased production activity without the associated increased negative environmental impacts.

- Remanufacturing and comprehensive refurbishment (Full Service Life VRPs) are intensive, standardized industrial processes that provide an opportunity to add value and utility to a product's service life. These processes enable 'as-new' (remanufacturing) and 'high-quality' (comprehensive refurbishment) products, at significantly lower environmental impact and lower cost to the producer, and potentially the customer.
- Repair, refurbishment, and arranging direct reuse (Partial Service Life VRPs) are formal and informal maintenance processes that provide an opportunity to extend the product's useful life at significantly lower environmental impact and lower cost to the producer, and potentially the customer.
- The intensive nature of remanufacturing and comprehensive refurbishment means that growth of these VRP activities creates new demand and opportunity for skilled labor. Remanufacturing and sometimes refurbishment have larger requirements for skilled labour than a linear production of the product. Remanufacturing increased skilled labour hours by up to 120 per cent. Repair required less labour than the linear reference product, showing a decrease of 70 per cent to 99 per cent.
- Barriers to VRPs that inhibit the generation of demand (e.g. policies that restrict the import, distribution, and/or sale of VRP products) prevent the strong business case that industry members require to engage in VRP production.
- There is opportunity for VRPs to be adopted in appropriate industries and markets: currently Remanufacturing accounts for only ~2 per cent of USA production, and only ~1.9 per cent of EU production (U.S. International Trade Commission 2012, European Remanufacturing Network 2015). Overcoming regulatory, infrastructure, technological and market barriers will allow opening new markets while generating environmental and social value.
- Policy makers are called on to alleviate some of these barriers. Barriers to VRPs that restrict VRP producer's technological capacity (e.g. policies that restrict access to VRP inputs such as cores[1], and skilled labor shortages) restrict domestic production capacity and limit the potential to achieve reduced environmental impacts.

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.

- It is important that policy interventions target both radical (system-level) and incremental (process-level) innovation, via integrated technology, innovation, and environmental policy approaches.
- All economies can benefit – environmentally, socially and economically – from implementing VRPs and optimizing their role within their circular economy strategy. VRP expansion strategies in industrialized countries must leverage mature manufacturing industries and well-established production, logistics and collection infrastructures. In these countries, policy approaches should focus on encouraging value-add Full Service Life VRPs and should engage industry members and consumers in the alleviation of barriers, which are primarily market-based and technological in nature.
- VRP expansion strategies in non-industrialized countries should focus on the formalization of existing VRP economies and systems. In these countries, policy initiatives should focus on the alleviation of access and regulatory barriers. 'Closing-the-loop' must be a short-term policy priority, focused on establishing efficient collection programmes and infrastructure. Longer-term policy priorities must focus on expanding VRP production capacity via knowledge and technology transfer, and training programmes to increase skilled labor supply

Summary of Policy Recommendations

The increased adoption of value-retention processes (VRPs) can enable substantial environmental benefits and economic opportunities for countries pursuing a transition to circular economy. The following recommendations highlight the key priorities that policy-makers from every country should incorporate into a broader circular economy strategy:

1. **Eliminate** regulatory barriers that impede and/or prohibit the movement of finished VRP products within and between countries.
2. **Eliminate** regulatory barriers that interfere with the movement of cores[1] within and between countries and ensure that cores are as far as possible considered as 'non-waste'. This effort must be balanced with equally important measures to prevent dumping (e.g. e-waste) that may occur under the guise of VRPs.
3. **Accept** and align VRP definitions across different countries, particularly within trade policies, trade agreements, and between trade partners.
4. **Adopt** the definitions of each class of VRP (See Figure 1) and ensure alignment of these definitions within related national waste hierarchy, waste management, and other diversion policy language.
5. **Expand** existing 3R's approaches to integrate VRPs alongside traditional recycling policies, and position VRPs as gateway activities to improved recycling.

6. **Engage** with stakeholders (producers, distributors, sellers, customers, collectors, policy-makers, political leaders, research and education institutions, etc.) to communicate and ensure clear understanding of these VRP definitions and the opportunities inherent to expanded adoption of VRPs.
7. **Establish** clear standards and guidelines for each class of VRP, which are accepted by industry and government, and which can be used to effectively differentiate VRPs and VRP products from traditionally manufactured options.
8. **Establish** review and compliance mechanisms for defined VRP standards and definitions to prevent misuse of VRP product labeling in the market.
9. **Enforce** VRP standards and guidelines with domestic VRP producers to ensure that practice in the market reflects accepted definitions and expectations.
10. **Align** the regulatory treatment of validated remanufactured products with the treatment of OEM New products in both domestic and trade policies. Validated remanufactured products meet or exceed the quality and performance specifications of OEM New products and should thus be treated equally.
11. **Lead-by-example** by adopting VRP-friendly public procurement practices and policies to facilitate awareness, adoption, and stimulation of domestic demand for VRP products.
12. **Invest** in accelerated VRP adoption and capacity by providing funding to VRP producers for R&D, capital acquisitions and workforce training.
13. **Implement** customer market education and awareness campaigns to encourage the acceptance of VRP products and to strengthen the business-case for VRP producers.
14. **Encourage** participation in circular economy and VRPs by investing in accessible and efficient end-of-use (EOU) product collection programs and infrastructure and restricting options for EOU products to be disposed into the environment (e.g. landfill bans).

Content


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PEOPLE
CUSTOMER
MODELING

Introduction

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

The 2030 Agenda for Sustainable Development outlines an action plan, accompanied by 17 Sustainable Development Goals (SDGs), to guide countries and stakeholders in the pursuit of sustainable development that balances economic, social, and environmental systems (United Nations General Assembly 2015). In particular, SDG 12 is focused on ensuring sustainable consumption and production patterns by promoting resource and energy efficiency, reducing environmental degradation, and building collaborative relationships between stakeholders throughout the consumption-production system (United Nations General Assembly 2015).

The concept of value-retention is well aligned with the objectives of circular economy, resource efficiency, resource productivity, and even climate change. 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).

Figure 1: **Definition of value-retention processes**

	Value-Retention Process	Definition
Full Service Life VRPs (Occur within Factory Operation)	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 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 Operation)	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[4] (From Document UNEP/CHW.13/4/Add.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[4] (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 per cent new material inputs, and which are performed by the original equipment manufacturer.

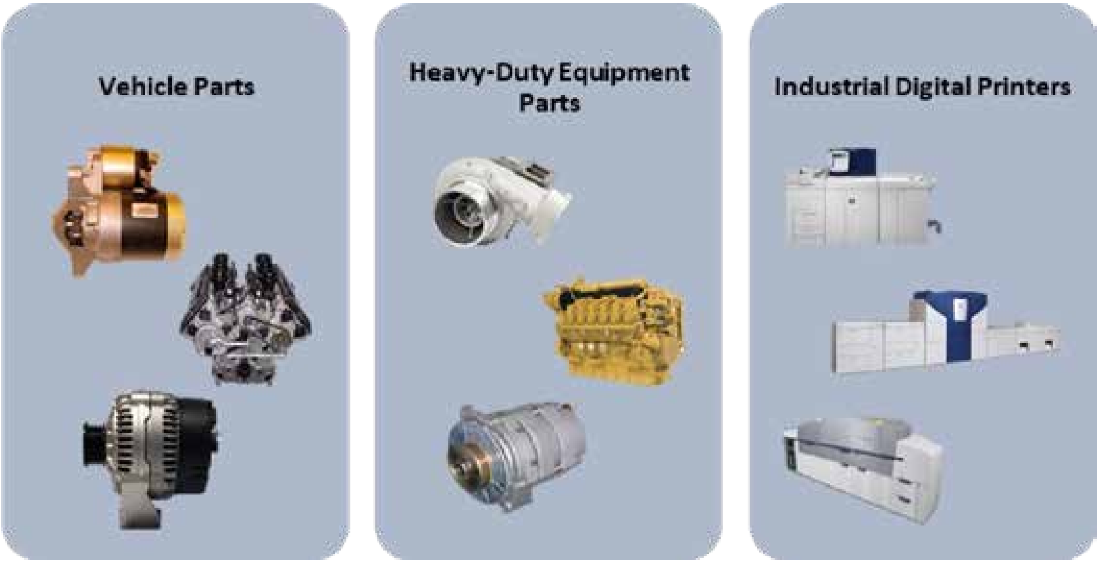
3- An industrial process is an established process, which is fully documented, and capable to fulfill the requirements established by the remanufacturer.

4- 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.

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.

This summary highlights key policy-related findings from the International Resource Panel's report entitled "Redefining Value – The Manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy " (IRP 2018). A complex methodology was used for the study: Three representative products were selected from each of three industrial sectors known to engage in VRPs (Industrial digital printers, vehicle parts, and heavy-duty and off-road equipment) for a total of nine case study products, assessed at the material- and product-levels across new manufacturing processes and each identified VRP (See Figure 2: Case study products and sectors).

Figure 2: Case study products and sectors



For each, select environmental and economic impact metrics were assessed: new material input requirement, production waste generation, embodied material energy requirement, process energy requirement, embodied material emissions generation, process emissions generation, production cost implications, and labor opportunity. 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 at the aggregate economy level.

1 Environmental and Economic Benefits of Value Retention Processes

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)[5] (See Figure 3).

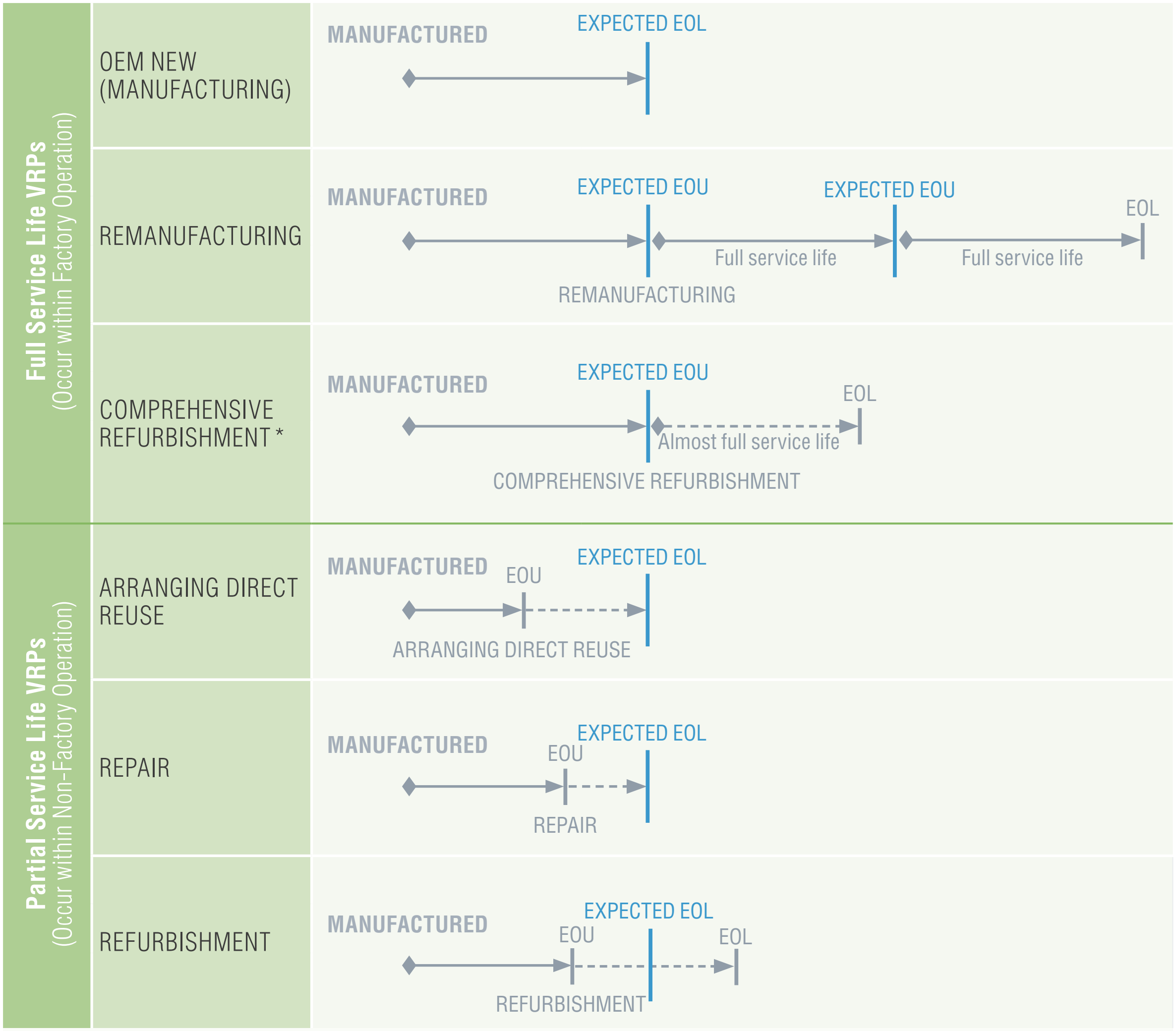
When compared to traditional OEM New production processes, the adoption of any VRP will result in incremental environmental and economic benefits (See Figure 4 through Figure 9). As such, the expanded adoption of VRPs to offset OEM New production must be a priority for policy-makers.

5- End-of-Use (EOU): Refers to the point in the product or object's service life at which the product may not be needed by the current owner/user, or able to function or perform as required, and for which there are other options available to keep the product and/or its components within the market, via value-retention processes (VRPs). It is important to note that EOU may occur without any product issue at all and includes various forms of obsolescence.

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 at lower marginal impact
- VRPs open export opportunities for VRP goods

Figure 3: Summary of value-retention process differentiation within the context of EOU[5] and EOL[6]



* This only exists for certain sectors and products.

6- End-of-Life (EOL): Refers to the point in the product or object's service life at which the product or object is no longer able to function or perform as required, and for which there are no other options for the product but to be recycled or disposed into the environment.

1.1. Environmental benefits

The environmental impacts of VRPs differ by product, material, and market as a result of complexity within the system. It is recognized that all VRPs require material and energy resources for essential activities including EOU core collection, transportation, storage, production processes (including washing and cleaning), and testing. In evaluating the environmental benefits of VRPs it is important to be aware that the benefits presented reflect a single production cycle, and do not include EOL/EOU collection and transportation impacts[7].

The magnitude and nature of these impact reduction and impact avoidance ranges, can be attributed to two key factors: (1) the product type; and (2) the nature of the VRP being employed. In absolute terms, VRPs enable reduction in environmental impacts from 60 per cent to 99 per cent of the original manufactured product (single process 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.

7- EOU/EOL collection and transportation activities are required for both traditional OEM New production and VRPs of the case study products evaluated. As such, these were assumed to be equivalent for the purposes of this study, and therefore excluded from the comparative analysis.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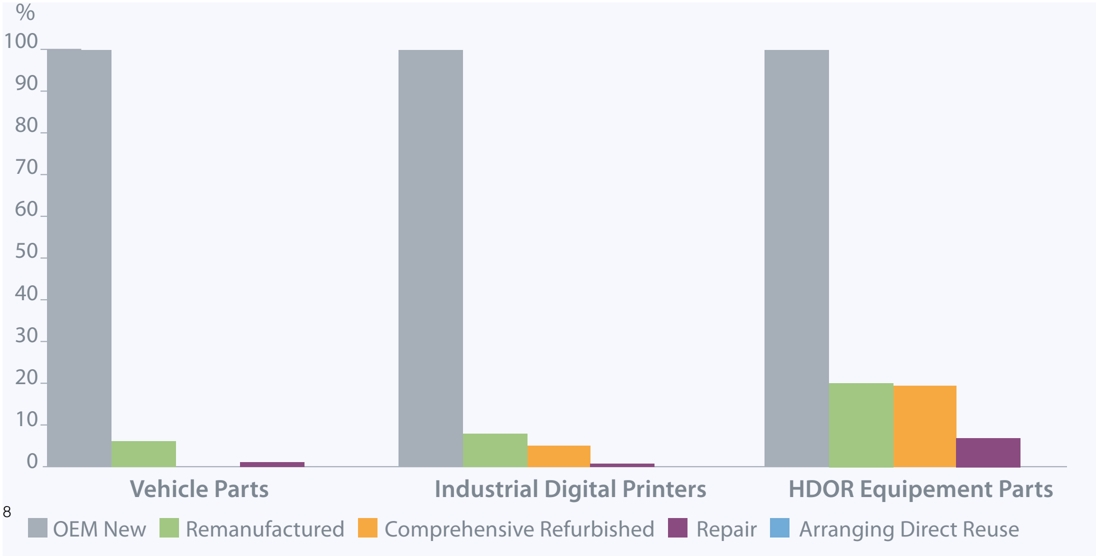
1.1.1. VRPs reduce new material input requirements

VRP processes reduce the average new material demand, therefore, creates an opportunity to avoid requirement for new materials.

The individual case studies showed that 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; and 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 4.

Figure 4: Weighted average new materials requirement of VRPs relative to traditional OEM New production[8]



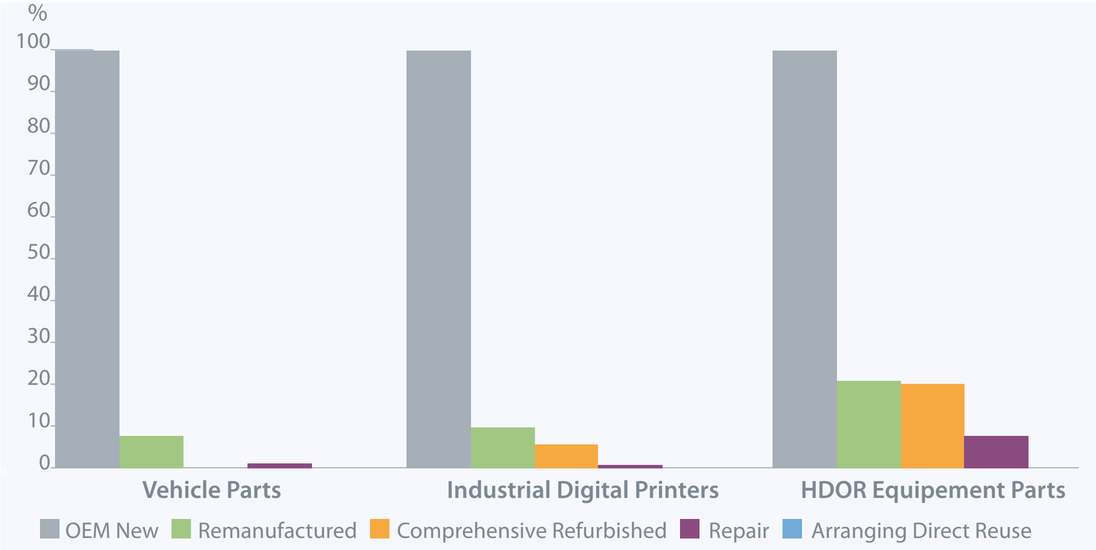
8- Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

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 per sector, refer to Figure 5.

Figure 5: Weighted average embodied material energy and emissions impacts of VRPs relative to traditional OEM New production[9]

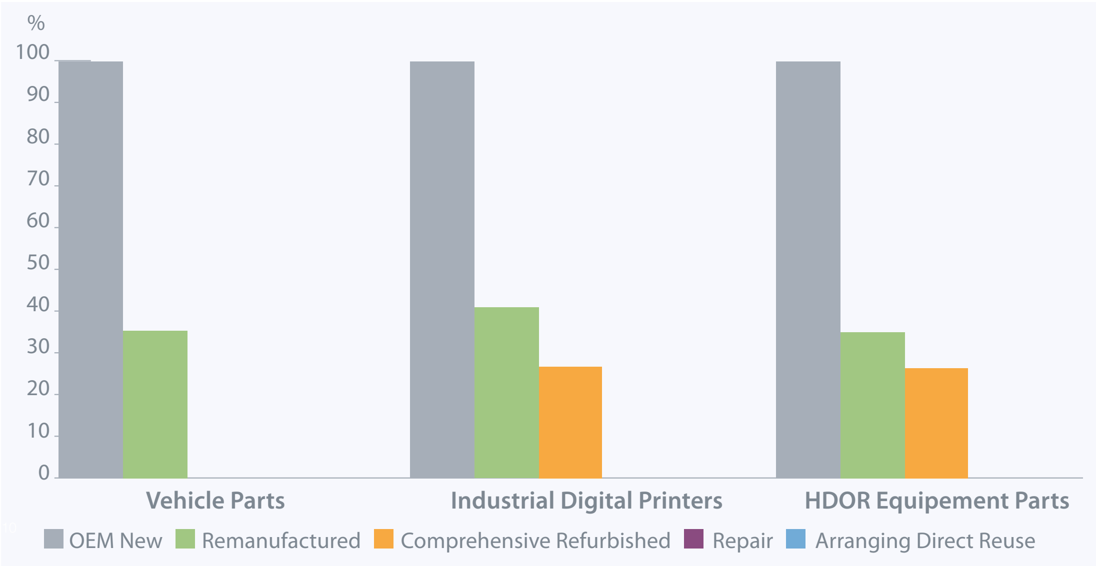


9- Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

1.1.3. VRPs optimize energy needs in the production process and reduce related emissions

Across the individual case studies, remanufacturing avoided process energy use and related emissions of 57 per cent – 87 per cent relative to the linear process. The savings for refurbishment were slightly larger, ranging between 69 per cent and 85 per cent across the case study products. Repair and direct reuse did not cause any process emissions as they take place outside of the factory production process. For detailed relative process energy and process emissions of VRPs relative to OEM New production per sector, refer to Figure 6.

Figure 6: Weighted average process energy and emissions impacts of VRPs relative to traditional OEM New production[10]



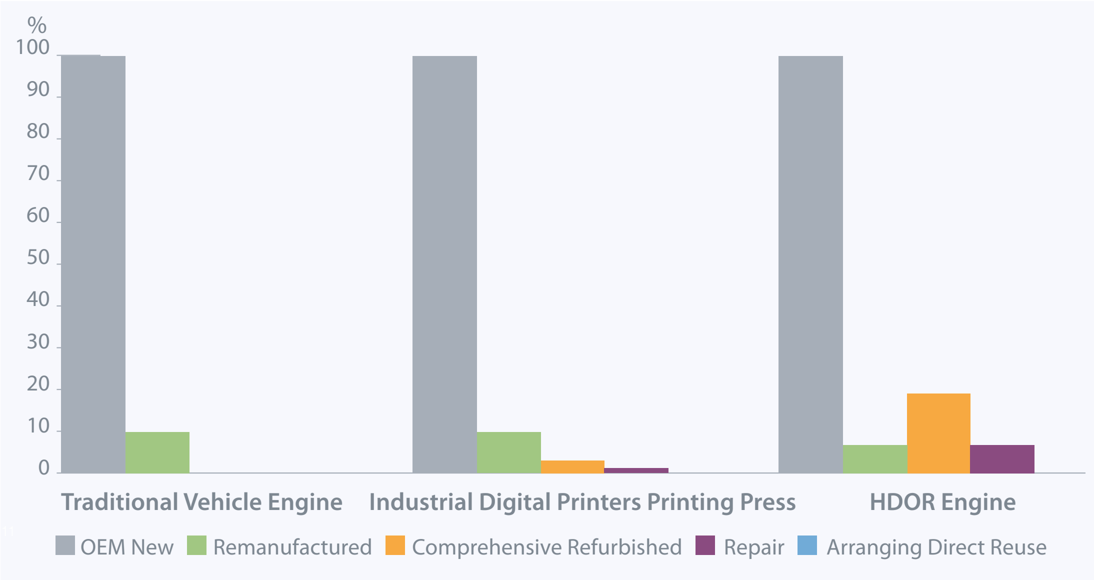
10- Note that there is typically no comprehensive refurbishment undertaken for vehicle parts, and there is typically no direct reuse arranged for HDOR equipment parts.

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

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 generate production waste. Remanufacturing led to a cut of about 90 per cent in production waste across the sectors and comprehensive refurbishment reduced about 80 per cent to 95 per cent of production waste. For detailed waste production per sector, refer to Figure 7.

Figure 7: Production waste impacts of VRPs relative to traditional OEM New production[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.

1.2. Economic benefits

Full service life VRPs of remanufacturing and comprehensive refurbishment offer a reduced cost to the customer, significantly reduced production waste, and an increased requirement for skilled labor which may create a relative employment opportunity.

Partial service life VRPs offer an alternative set of value-retention options for the customer that emphasize a significantly reduced cost, and almost no production waste generation. As expected, these less-intensive processes require fewer labor hours. Repair activities do generate a positive employment opportunity; however, it is significantly less than the labor required to produce an OEM New version of the product. Arranging direct reuse activities require labor to facilitate the reverse-logistics of the product, however the actual process of direct reuse does not require labor.

1.2.1. VRPs can create jobs – while costs being more than offset

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.

Specifically, remanufacturing and sometimes refurbishment have larger requirements for skilled labour than a linear production of the product (refer to Figure 8). Remanufacturing in some case studies 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.

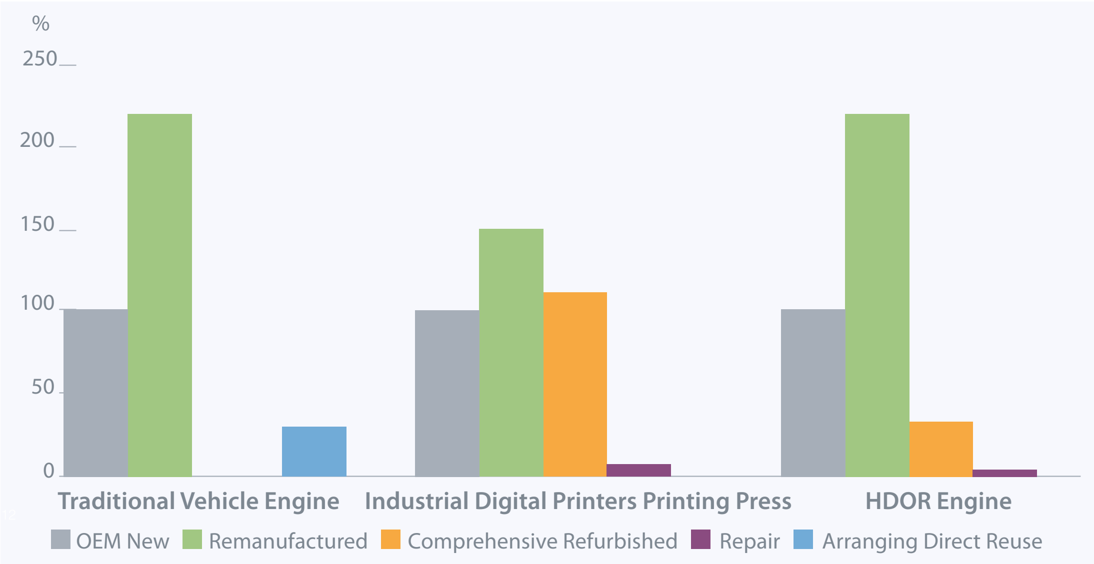
In the case of increased labour requirements, the labour costs are more than offset by the material and energy savings.

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.

1.2.2. 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.

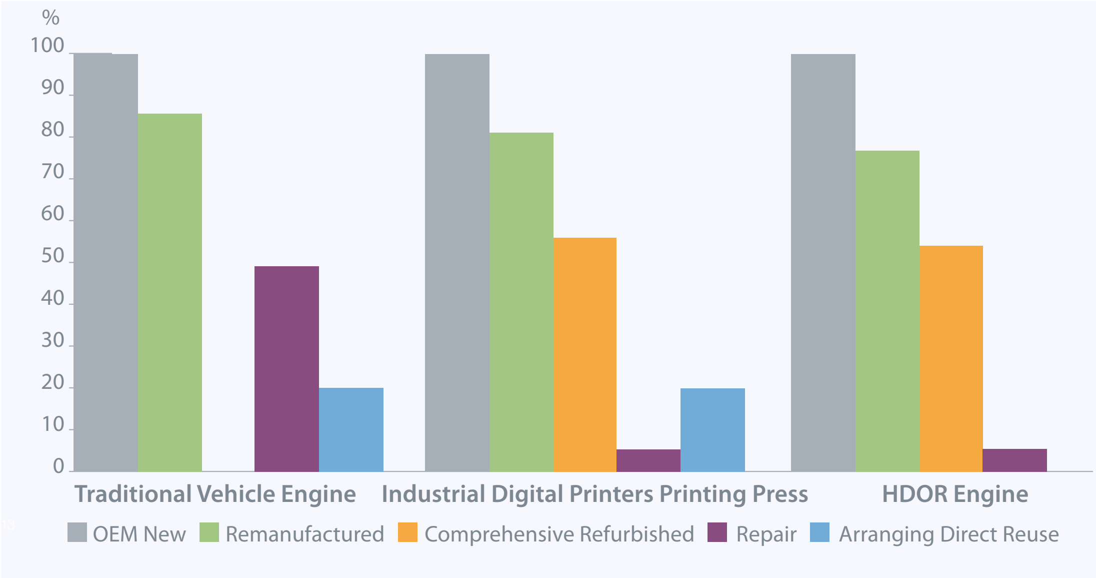
Figure 8: Skilled labor requirement for VRPs relative to traditional OEM New production[12]



12- 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.

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.

Figure 9: Cost of VRP products relative to traditional OEM New products[13]



13- 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.

1.2.3. VRPs enable new segments of customers to participate in the market

VRPs are not intended as replacements for OEM New products, and if differentiated and positioned appropriately, VRPs may serve to enable growth opportunities for the entire product segment by targeting and engaging new, previously untapped, market segments that are underserved by OEM New products.

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).

1.2.4. VRPs open export opportunities for VRP goods

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).

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.

2 Policy Leadership is Essential

The urgent need to kick-start, activate and engage in lower-impact, sustainable production practices is motivated not only by the current state of the global environment, but also by growth projections of global economies and populations, and related resource use.

Policy-makers must play an essential and pivotal role in the advancement of VRP-friendly policies and programmes, educating and informing political decision-makers, and engaging in collaborative initiatives with industry members. Specific strategies and recommendations for policy makers are outlined in greater detail in Section 4.

Guided by the important objective of increasing systemic value-retention, countries must assess their own unique economic and environmental needs and priorities in the context of circular economy. From this baseline perspective, policy-makers must then begin to develop meaningful strategies for pursuing circular economy; this requires the inclusion of VRP growth strategies as key objectives within national policies and industries.

The adoption of VRPs can lead to significant reduction in negative environmental impacts and positive economic opportunity at the product- and process-levels. Increased VRP adoption also has the potential to create significant net-positive resource efficiency opportunities in industrialized and non-industrialized economies by enabling more effective and efficient closed-loop systems for materials and product information flows.

In short, a bold change is required, and market transformation for circular economy ultimately relies on the strategic leadership of government policy-makers.

3 Key Insights & Strategic Recommendations

Circular economy, via VRPs, offers significant opportunities for countries to meaningfully pursue improved resource efficiency (via circular material flows and energy-use reduction), climate change goals (via reduced emissions generation), and even enhanced employment programming (via new demand for skilled labor).

Every country is faced with unique regulatory, infrastructure, technological, and market conditions that can enable or constrain the pursuit of these opportunities (See Figure 10). Achievement of circular economy benefits will only be possible if each country actively works to identify and eliminate, through various policy interventions and initiatives, the different barriers that restrict its particular circular economy and VRP adoption.

As there is no 'one-size-fits-all' solution, policy-makers must investigate, understand and consider what policy approaches will be most effective and appropriate for their country's unique circumstances and priorities. However, 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 following sections offer some overarching recommendations to support strategic policy-making for circular economy and VRP adoption.

3.1. All countries can benefit from the adoption of VRPs

3.1.1. Appropriate use of VRPs

Given the different environmental and economic benefits provided by the different VRPs (See Section 2), policy-makers must consider which VRP(s) are most appropriate for a given policy objective (e.g. employment versus emissions reduction), given the relative 'trade-offs' between the environmental and economic impact that can exist (See Figure 10). These trade-off insights are supported by the findings from each of the case study sectors assessed.

Figure 10: Relative environmental impact and economic benefit trade-offs of Full Service 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.

Given the increased labor requirement for remanufacturing and comprehensive refurbishment in particular, it is in the interests of economies seeking employment growth opportunities to allow for industry to engage in VRPs as a way of creating new opportunities for skilled labor, alongside opportunities for customers to participate in the market, and the pursuit of reduced per-unit environmental impacts of production.

VRPs may not be appropriate for all products, and policy-makers must consider the alignment of related policy objectives such as resource efficiency and climate change, with the system-wide implications of VRPs. For example, without appropriate policy guidance, the adoption of VRPs may serve to keep older, less energy-efficient technologies and products in the market (e.g. old diesel engines). This outcome may serve to offset new product demand and extended product service life, but it would also be counterproductive to a policy agenda pursuing energy efficiency and emissions reduction.

As such, when determining appropriate policy guidance related to VRPs, some important considerations must include:

- The nature of the product and components (e.g. durability, material composition);
- The use-phase energy requirement and energy efficiency of the product; and
- The residual value of the product at its EOU.

3.1.2. Growth opportunity for VRPs

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 that there is extensive opportunity for the growth of VRPs via adoption in industries that are currently engaged in VRPs; however, this also highlights the important need for a strong business case that includes customer interest and demand.

The study necessarily focused on case study products for which VRPs are currently employed, and which are therefore considered to be 'VRP-appropriate". There are many VRP-appropriate products that were not included in the study (Non-case study VRP-appropriate sectors), but there are also many products that are not suited for VRPs (Non-VRP appropriate).

As the share of VRP products as part of a country's production mix increases, the impact reduction potential becomes significant.

3.2. Strategy must be shaped by the barriers present in each country

All countries have the potential to optimize the role of VRPs within their circular economy strategy. Customer market, technological, infrastructure, and regulatory conditions affecting circular economy and VRPs can vary significantly between industrialized and non-industrialized countries.

However, there is no evidence that the 'developing/newly industrialized' status of a country affects its ability to fully engage in VRPs. Mexico, considered to be an advanced developing country, has demonstrated capability and high-performance in remanufacturing, largely enabled through trade and investment collaboration with entities from the US and Canada (U.S. International Trade Commission 2012).

Instead, **it is the presence and nature of barriers to VRPs that determine the opportunity, and the magnitude of, and speed at which the benefits of VRPs can be realized.**

For example, despite the fact that each sample economy in the study is considered to be highly industrialized and oriented towards circular economy, the presence of market access barriers (e.g. prohibited import of VRP products) and regulatory barriers (e.g. regulatory definition causing some VRP products to be considered 'waste') create the most significant constraints to the scaled adoption of VRPs and the achievement of environmental benefits.

Policy-makers must understand the different types of barriers to VRPs that can exist and must be able to identify these barriers if/as they affect their own jurisdiction (See Figure 11).

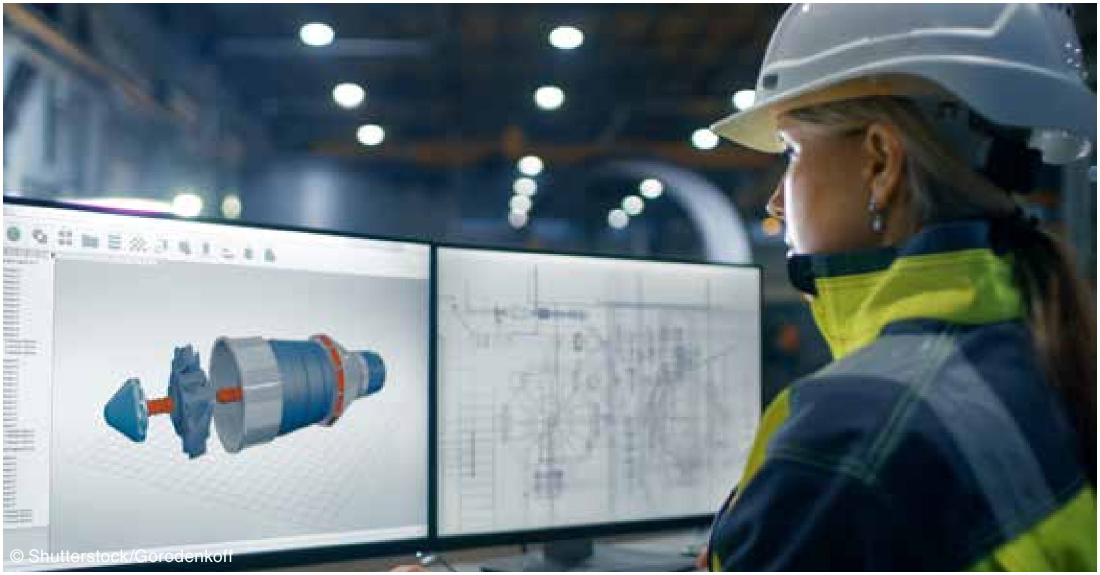


Figure 11: Summary of the barriers to VRPs within the economic system

Types of Barriers	Examples	Description of Barrier Impact
Regulatory and access barriers	• Complicated regulatory definitions for VRPs that affect import, export, and domestic production-consumption activities; • Lack of clear understanding and differentiation between VRPs; • Inputs to VRPs (product cores) often reflected as 'waste' under regulatory definitions.	Affects flows of finished VRP products from producers to customers in domestic and/or international markets (forward-logistics).
Collection infrastructure barriers	• Lack of policy requiring diversion of EOU products from waste; • Lack of efficient and/or effective diversion and collection infrastructure; • 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 VRPs (reverse-logistics)
Customer market barriers	• Lack of standards/certifications for VRPs and VRP products; • Perceived low-price = low-quality of VRP products; • High customer risk-aversion.	Creates capacity constraints for the domestic VRP customer market.
Technological barriers	• Increased production complexity with reverse-logistics and supply-chain considerations; • Specialized labor and equipment requirements; • Cost-burden of investment and R&D on individual organizations.	Creates adoption and capacity constraints for domestic VRP producers.

3.2.1. VRP policy strategy in industrialized vs. non-industrialized countries

Not all VRPs are appropriate for all products or all countries, and strategic policy responses must consider the current conditions (e.g. what barriers to VRPs may be present in the country), as well as policy goals and priorities (e.g. whether employment opportunities are more or less important that achieving climate change targets).

The mechanisms by which an industrialized country pursues circular economy and VRPs may necessary differ from those appropriate for a non-industrialized country, largely because of varied technological, infrastructure, market, and regulatory conditions that can increase the cost and effort required to achieve the desired transformation.

Industrialized Countries

- Often better positioned to pursue higher-value VRPs (remanufacturing and comprehensive refurbishment) because they tend to have fewer regulatory barriers.
- Typically have more mature industrial sectors and established waste management programs and infrastructure that can be leveraged to support the advancement of VRPs.
- Existing production, logistics and collection infrastructure are typically well entrenched (lock-in), and the business case for overhauling these systems in pursuit of maximum VRP efficiency may be difficult.
- Short-term policy initiatives should use an incremental (e.g. process-level) approach that presents tangible and cost-effective options for change. These may include subsidy programs for existing producers to help offset the costs of adopting VRPs, as well as efforts to improve the efficiency and accessibility of existing collection infrastructure and systems and targeting improved collection rates for designated products (e.g. EOU electronics) and materials. Improving market awareness and education with regard to VRPs is also an important policy priority in the short-term.
- Complementary longer-term policy priorities should include radical (e.g. system-level) approaches that look at broader system-modifications to support and enhance VRP adoption. Similar to the approach utilized by the EU in the development of its Circular Economy Package (Bourguignon 2016), this must include the engagement of key stakeholders including industry members, civil servants, interest groups, and consumers in the development of a shared vision for VRP adoption and circular economy transition. It must also include investments to develop programming and infrastructure that will facilitate circular product and material economies through policy interventions similar to those used to kick-start diversion and recycling programs in the past.

Newly-Industrialized and Non-Industrialized Countries

- Often have very high levels of activity in lower-value VRPs (repair, arranging direct reuse, and refurbishment), but typically lack the formalized infrastructure that facilitates the collection EOU products (cores) as inputs to higher-value VRPs like remanufacturing and comprehensive refurbishment.

- Face significant pressure to avoid the sustainability-related pitfalls of industrialization by leap-frogging over less efficient production systems and technologies but must also figure out how to strategically building-up production, logistics and collection infrastructure where none currently exist.
- Producers often lack the necessary process know-how, product knowledge, and skilled labor that are needed to optimize existing VRPs and adopt higher-value VRPs such as remanufacturing.
- Strong reliance on informal repair activities and a low level of formal industrial capacity, means that policy-makers should avoid seeking to displace lower-impact repair and direct reuse activities with higher-impact VRPs in the short-term, as this approach may have relatively significant negative economic and environmental implications.
- A considered short-term policy approach should focus on the identification of access and regulatory barriers to VRPs that may unintentionally exist due to related policy priorities (e.g. consumer protection, anti-dumping, and domestic trade). In addition, incremental (e.g. process-level) objectives of improving the efficiency and value-retention ability of the existing partial service life VRP systems, and potentially expanding those systems to achieve better outcomes for market participants.
- Longer-term policy priorities must focus on radical (e.g. systems-level) transformation of both economy and infrastructure, including expanded technological capacity of producers via the expansion of a skilled workforce, and enhanced access to product and process knowledge (e.g. via technology transfer opportunities and trade).

3.2.2. VRPs should be leveraged as a gateway to recycling

Policy-makers must continue to advocate for and develop efficient and effective programs and systems that recover valuable materials *and*

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products, and that recirculate those materials and products back into the circular economy.

However, every product will eventually reach a point at which it no longer qualifies for arranging direct reuse, repair, refurbishment or remanufacturing – either because of the associated cost, or because its implicit quality and utility-potential has been degraded. At that point, there is still an essential need for efficient and effective *material* recycling systems to facilitate a circular materials economy.

Policy-makers must pursue language, definitions, and programming that reflect a complementary approach that:

- Updates the traditional waste hierarchy to encourage the options that offer the greatest value-retention potential, thus promoting VRPs to positions that are preferred over recycling, where appropriate;
- Allows for end-of-use products to be collected for value-retention purposes, and enables the use of cores (domestic and imported) as an input to VRPs; and
- Facilitates the collection and recycling of materials once products are no longer viable for use in VRPs.

VRPs and recycling are complementary processes that, if pursued strategically, can enable faster achievement of circular economy. Countries with diversion, collection, and recycling systems in place can even adapt infrastructure and programming, formally or informally, to include diversion to secondary markets for reuse and VRP production. Policy-based reliance on recycling alone will ultimately lead to lost value for the system and customer and reduced economic opportunity.

Collaborative initiatives between domestic industry decision-makers and policy-makers to share information and to identify opportunities for improving circularity is needed: via closing loops and mitigating system losses; and via implementing the adoption of VRPs and VRP products in a manner that works within the existing production and collection infrastructure.

3.3. An integrated approach works best

3.3.1. VRPs are enabled via integrated innovation, technology, and environmental policy

Innovation policy, technology policy, and environmental policy approaches offer complementary opportunities to encourage environmentally-preferable technology solutions to circular economy and VRP challenges (Río del González 2009, Rio del Gonzalez 2004).

Policy measures can support and facilitate both the supply-push and the demand-pull of eco-innovations to this end. For example, technology development to support VRP adoption by producers (supply-push) includes the provision of research and development subsidies as well as access to capital for facility upgrades. The technological capacity of VRP producers (which includes aspects of both innovation and technology) is a common barrier across all sectors in both industrialized and non-industrialized economies.

Alternately, market development to encourage VRP adoption (demand-pull) includes public procurement policies that promote VRP products, as well as market education and awareness initiatives that highlight both the consumer and end-of-use opportunities within the circular economy.

VRPs and circular economy systems can benefit from initiatives to advance and enhance national Science, Technology and Innovation (STI) systems, which can include broad-scope of VRP-targeted policy initiatives and investments such as:

- Collaboration and partnerships with **universities, research institutes, and public organizations** to connect new insights and innovations with potential users;
- Development of **networks and clusters** to facilitate the sharing of knowledge, innovation, and resources between members;
- Provision of **funding or subsidies** to kick-start and support R&D and innovative entrepreneurship within small, medium, and large enterprises;
- Implementation of **workforce training programs** and other workforce skill enhancements to ensure sufficient skilled labor to meet the needs of producers wanting to expand VRP production capacity.


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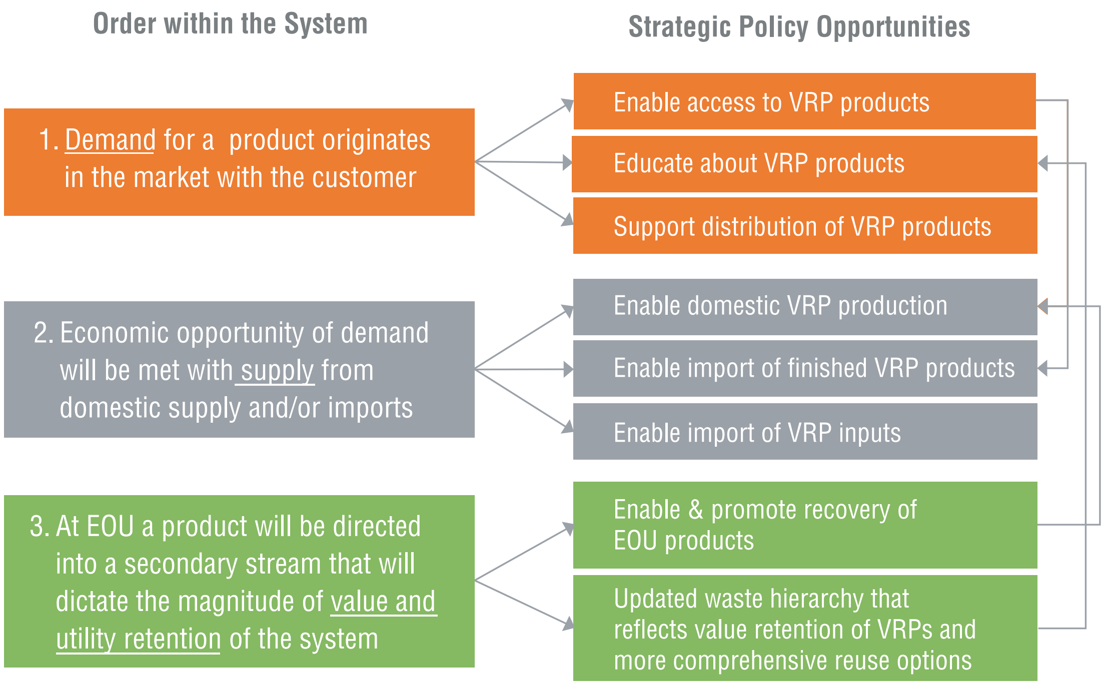
3.3.2. Existing policy tools and instruments can be harnessed

VRPs are not intended as replacements for OEM New products, and if differentiated and positioned appropriately, VRPs may serve to enable growth opportunities for the entire product segment by targeting and engaging new, previously untapped, market segments that are underserved by OEM New products.

The objective of increasing the scale and prevalence of VRPs and VRP products within an economy requires an expanded systems-perspective, and an appreciation of the barriers present within that system.

There is an underlying order within the system that must be acknowledged to optimize strategic policy response (See Figure 12).

Figure 12: Inherent system order enables priorities for alleviation of VRP barriers



Accordingly, strategic policy interventions to support the growth and success of VRPs must consider the flows of VRP inputs and finished VRP products, as well as the capacity of the economy to fully engage in VRPs:

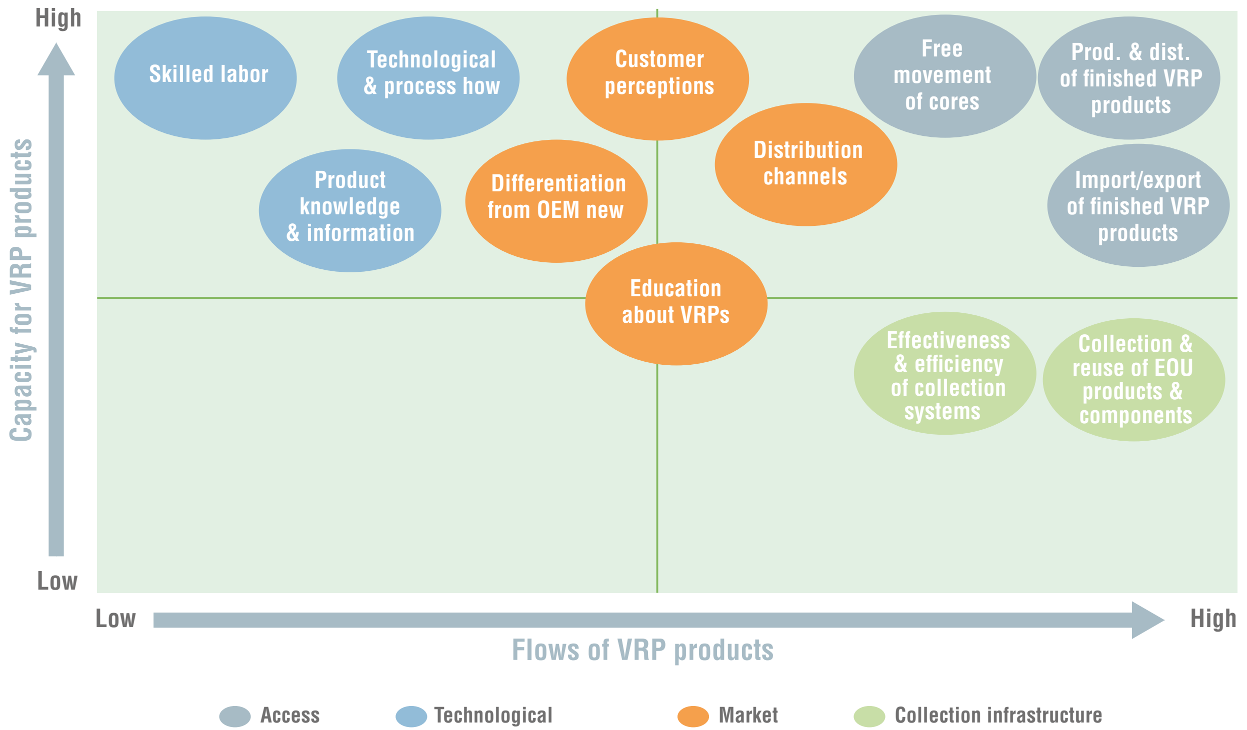
1. Barriers that inhibit the generation of demand for VRPs, such as restrictions that prohibit VRP products from entering the market, are particularly problematic for creating the business case for domestic producers to increase VRP production capacity. Examples of correlated policy priorities are shown in the top-right quadrant of Figure 13.

2. Barriers that restrict the VRP producers' access to technological capacity, skilled labor, process know-how, and/or essential inputs to VRP production, ultimately restrict production capacity even in markets where demand may be prevalent. It is important to have effective and efficient collection infrastructure that facilitates a circular economy for EOU products and parts for VRP inputs. Examples of correlated policy priorities are shown in the top-left quadrant and bottom-right quadrant of Figure 13.

3. Where demand and access exist, there is an opportunity for OEMs and third-party entities to initiate strategic responses and/or innovative business models that make sense for their organization. Although some OEMs may be concerned about the potential for cannibalization of their OEM New product offerings, it must be acknowledged that the failure to offer VRP products is ultimately a missed economic opportunity. Examples of correlated policy priorities are shown in the top-center of Figure 13.

Economies face distinct combinations of VRP barriers and may have unique objectives for VRPs as part of an economic or environmental agenda. As such, there may be a range of potential strategic interventions available to policy- and decision-makers depending on each unique situation, as demonstrated in Figure 13.

Figure 13: Differentiated barrier alleviation strategies for different economic objectives



There is a range of policy tools, to be used in combination, that may be effective at facilitating the transition to circular economy, depending on the unique conditions of a particular production-consumption system.

A range of policy tools, some of which may be effectively used in combination, can help to facilitate the transition to circular economy. Depending on the unique conditions of a particular production-consumption system, a mix of the following policy tools is needed:

- **Command and Control:** Demonstrated effectiveness at facilitating incremental changes (e.g. within VRP process adoption by firms), but may be less effective at radical systemic change (e.g. circular economy) than market-based mechanisms (Río del González 2009, Rio del Gonzalez, Carrillo-Hermosilla, and Könnölä 2010). These tools may be appropriate for facilitating the alleviation of access and other regulatory barriers (See top-right quadrant of Figure 13).

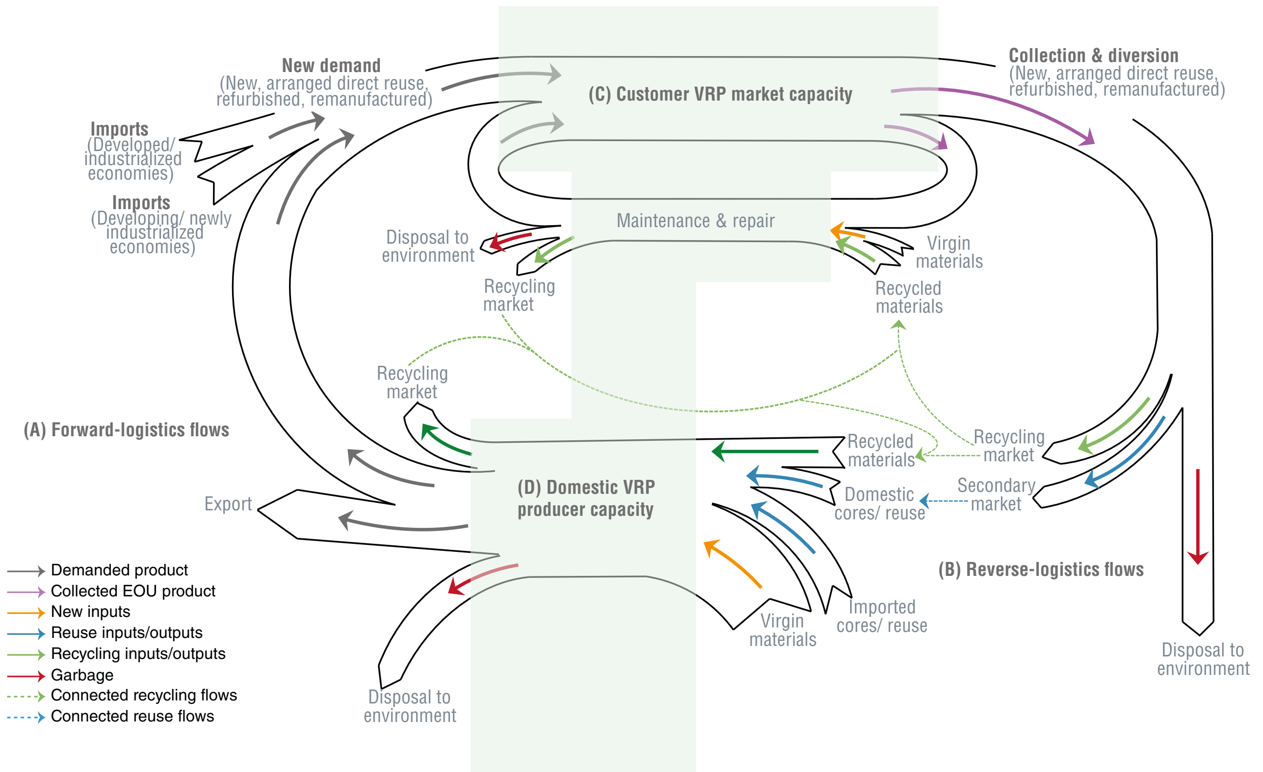
- **Voluntary Agreements**: May be appealing to individual and diverse stakeholders as they allow for longer-term planning and dialogue. However, there are risks that desired impact and outcomes that must be managed (Rio del Gonzalez, Carrillo-Hermosilla, and Könnölä 2010). These tools may be appropriate for facilitating the alleviation of collection infrastructure and systems barriers (See bottom-right quadrant of Figure 13).
- **Market-Based Instruments**: Often most effective at enabling a demand-pull effect to facilitate adoption of innovative products in a market, in the case of VRPs these can include information-sharing, eco-labelling, financial incentives, and environmental-awareness raising (Rio del Gonzalez, Carrillo-Hermosilla, and Könnölä 2010). These tools can be appropriate for facilitating the alleviation of customer market barriers (See top-middle section of Figure 13).
- **Financial Instruments**: Often most effective at facilitating a supply-push effect to facilitate the adoption of innovative processes by producers, these can include technology-focused R&D subsidies, low-interest loans, investment subsidies, and the development and exchange of best practices to limit learning curve requirements (Rio del Gonzalez, Carrillo-Hermosilla, and Könnölä 2010). In addition, instruments that reward positive externalities (e.g. pollution reduction) may help firms to overcome the pressure to focus on profits (Ghisellini, Cialani, and Ulgiati 2016). These tools can be effective at facilitating the alleviation of producer capacity and other technological barriers (See top-left quadrant of Figure 13).

3.3.3. Different actors have different roles

The expanded systems perspective highlights the many different stakeholders and perspectives inherent to VRPs that must be engaged for successful circular economy transition (See Figure 14).

Policy-makers must recognize the need to collaborate and work with industry decision-makers in order to effectively address barriers to VRPs that may occur at various points within the circular system (See Figure 14).

Figure 14: Descriptive circular economy system model for VRPs

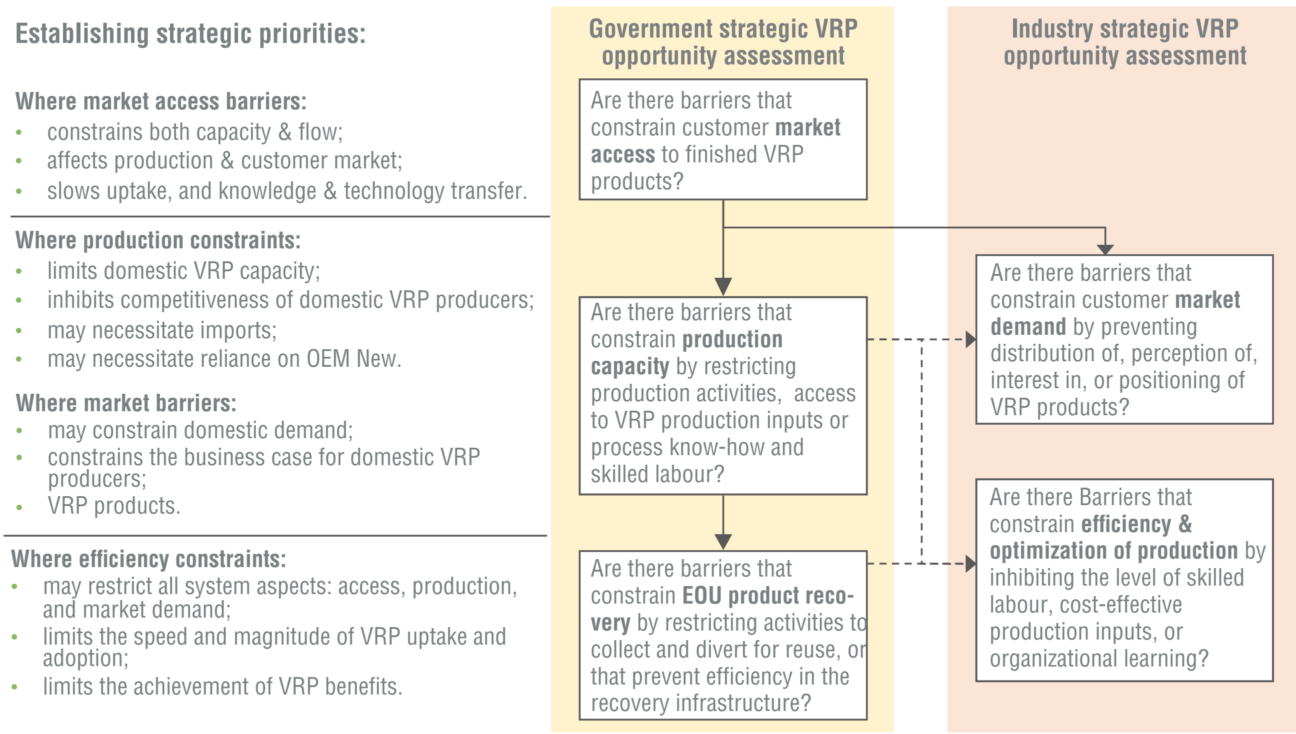


Policy-makers have a central and pivotal role related to the presence and alleviation of regulatory, access and collection infrastructure barriers that can affect forward-logistics flows (A, e.g. the flow of VRP products) and reverse logistics flows (B, e.g. the flow of inputs to VRPs). Other stakeholders, including industry, must be involved and collaborate with when addressing barriers affecting the customer market (C, e.g. education about VRPs) and technological capacity of producers (D, e.g. access to skilled labor, equipment).

As a top strategic priority, it is essential that policy-makers prioritize the identification and alleviation of barriers that constrain customer market access to finished VRP products (See Figure 15). Where customers cannot access VRP products, there can be no business case for producers to engage in VRPs, and the alleviation of other barriers becomes less meaningful.

A two-pronged collaborative approach between policy-makers and industry decision-makers is appropriate where VRP production constraints, market barriers, and/or VRP infrastructure and efficiency barriers exist.

Figure 15: Role of government and industry decision-makers in assessment of VRP barriers and strategic priorities



When considered at the macro-systems level, there are additional opportunities for policy-makers to work with industry members to combine sector-specific insights with cross-sectoral perspectives:

- While VRP opportunities are often specific to product-type, changes to the larger circular economy system can provide efficiency opportunities across sectors (e.g. shared reverse-logistics and/or collection system infrastructure) (Heaton and Banks 1997).
- Policy approaches must be innovation-friendly in order to appropriately engage diverse stakeholders in dialogue and consensus via open, flexible, and reflective multi-stakeholder collaborations (Jänicke et al. 2000). A key policy priority for the effective transition to circular economy must be to overcome the current passive throw-away culture exhibited by both consumers and producers in economic systems around the world (Ghisellini, Cialani, and Ulgiati 2016).

As such, effective policy approaches for VRPs must integrate producer and consumer perspectives, and incorporate the following characteristics:

- **Innovation-Focus:** This should include capacity-building focus on providing technological assistance, R&D support, and training programs that can help to facilitate interest, comfort, and ability to transition towards circular economy and VRPs, and to mitigate the risk of asymmetrical information across circular economy stakeholders;
- **Environment-Focus:** This should include the requirement, via policy, for producers to continuously-improve their environmental performance, their environmental responsibility, and their engagement of consumers in facilitating reverse-logistics for VRPs;
- **Small-Medium Enterprise (SME)-Focus:** This should include SME-focused initiatives that can support SMEs as essential launch platforms for VRP systems, and the growth of circular economy service providers and value-chain stakeholders;
- **Strategic Niche Management:** This should include technological network development and growth strategies that are complementary to environmental policies (e.g. eco-innovation, green business), and must focus on supporting the agents within the VRP system through technology policy, and R&D support; and
- **Public Procurement:** This must include governments leading-by-example via procurement policies that provide a level playing-field for VRP product options in order to establish/create new markets for early

stage product innovations and/or low rates of adoption for innovative processes. An example of this is the US's Federal Vehicle Repair Cost Savings Act, which directs and encourages all US federal agencies to use remanufactured vehicle parts in the maintenance of federal fleet vehicles (U.S. House of Representatives 114th Congress 2015).

From this perspective of VRP stakeholders within a circular economy, additional policy measures may include:

- The provision of adequate and required infrastructure to facilitate product reverse-logistics, particularly for SME actors within the VRP and circular economy system that do not have the scale or capacity to efficiently engage in reverse-logistics independently;
- Systems-level promotion and education programs targeting both producers and consumers, helping to alleviate some of the capacity-burden from SME actors.

4 Conclusions

VRPs offer an opportunity to achieve significant value-retention and environmental impact reduction, while also creating economic opportunities for cost-reduction and employment opportunity. Remanufacturing and comprehensive refurbishment VRPs offer full, or *almost*-full, new service lives to products, and offset significant environmental and economic costs associated with production. Arranging direct reuse, repair, and refurbishment VRPs offer additional options for customers to extend the service lives of products at relatively low environmental and economic costs (See Figure 3). While remanufacturing and comprehensive refurbishment are relatively more industrial and intensive processes than repair or direct reuse, they also offer significantly greater service life potential and value-retention within the circular economy system.

Regardless of how quickly, or to what extent VRPs increase within the production mix and/ or market demand, the potential to offset new material requirement, and retain value within the system is automatically increased with the alleviation of barriers to VRPs. While the absolute magnitudes of new material offset, energy requirement, and emissions generation are dependent upon the magnitude of the domestic industry and production level, the opening of markets and alleviation of barriers leads to net positive impact avoidance, and automatic improvements in material efficiency. The rebound effects of increased VRPs present legitimate concerns, however when the appropriate systems-perspective is utilized, there are strategic opportunities to mitigate and/or manage these effects.

There are inherent systemic barriers to VRPs within an economy's production-consumption system that, if not appropriately addressed, can severely inhibit the adoption of VRPs, the achievement of associated environmental impact reduction, and the successful pursuit of circular economy.

Technological and customer market barriers constrain the *capacity* for producers and consumers to engage with and adopt VRP options; in contrast, regulatory and access barriers, and collection infrastructure barriers interfere with the *flows* of VRP products and inputs between producers and consumers, and across economies via trade (See Figure 13). Based on the case study products and economies of this assessment, regulatory and access barriers presented the most significant constraint on the adoption of VRPs, preventing the flow of VRP products to potential customers, and eliminating the business-case for producers to engage in VRP practices. A top priority for policy-makers must be the enabling of VRP production and the consumption of VRP products if material efficiency and optimized environmental impact reduction are to be achieved.

Finally, there is an essential need for enhanced coordination and alignment between policy-makers and industry decision-makers. Developing the appropriate systems, incentives, programmes, infrastructure, definitions, and governing policies are essential functions for policy-makers. However, these efforts must be informed by, align with, reflect, and acknowledge actual industry practices, needs, and requirements. The move towards international standards regarding the practices, processes, and qualifications of VRPs must include industry, government, and market stakeholder perspectives.

From this assessment, fourteen policy priorities are recommended to facilitate the adoption of VRPs as part of national circular economy strategies:

1. **Eliminate** regulatory barriers that impede and/or prohibit the movement of finished VRP products within and between countries.

2. **Eliminate** regulatory barriers that interfere with the movement of cores[1] within and between countries and ensure that cores are as far as possible considered as ‘non-waste’. This effort must be balanced with equally important measures to prevent dumping (e.g. e-waste) that may occur under the guise of VRPs.

3. **Accept and align** VRP definitions across different countries, particularly within trade policies, trade agreements, and between trade partners.

4. **Adopt** the definitions of each class of VRP (See Figure 1) and ensure alignment of these definitions within related national waste hierarchy, waste management, and other diversion policy language.

5. **Expand** existing 3R's approaches to integrate VRPs alongside traditional recycling policies, and position VRPs as gateway activities to improved recycling.
6. **Engage** with stakeholders (producers, distributors, sellers, customers, collectors, policy-makers, political leaders, research and education institutions, etc.) to communicate and ensure clear understanding of these VRP definitions and the opportunities inherent to expanded adoption of VRPs.
7. **Establish** clear standards and guidelines for each class of VRP, which are accepted by industry and government, and which can be used to effectively differentiate VRPs and VRP products from traditionally manufactured options.
8. **Establish** review and compliance mechanisms for defined VRP standards and definitions to prevent misuse of VRP product labeling in the market.
9. **Enforce** VRP standards and guidelines with domestic VRP producers to ensure that practice in the market reflects accepted definitions and expectations.
10. **Align** the regulatory treatment of validated remanufactured products with the treatment of OEM New products in both domestic and trade policies. Validated remanufactured products meet or exceed the quality and performance specifications of OEM New products and should thus be treated equally.
11. **Lead-by-example** by adopting VRP-friendly public procurement practices and policies to facilitate awareness, adoption, and stimulation of domestic demand for VRP products.
12. **Invest** in accelerated VRP adoption and capacity by providing funding to VRP producers for R&D, capital acquisitions and workforce training.
13. **Implement** customer market education and awareness campaigns to encourage the acceptance of VRP products and to strengthen the business-case for VRP producers.
14. **Encourage** participation in circular economy and VRPs by investing in accessible and efficient end-of-use (EOU) product collection programs and infrastructure and restricting options for EOU products to be disposed into the environment (e.g. landfill bans).

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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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For more information, contact:
Secretariat of the International Resource Panel
Economy Division
United Nations Environment Programme
1 rue Miollis - Building VII - 75015 Paris, France
Tel: +33 1 44 37 30 09 - Fax: +33 1 44 37 14 74
Email: resourcepanel@unep.org
Website: www.resourcepanel.org