PSS for Product Life Extension through Remanufacturing

B Walsh
The Centre for Remanufacturing and Reuse,
22-28 Cambridge St, Aylesbury, Buckinghamshire, HP20 1RS, UK.
Ben.walsh@remanufacturing.org.uk

Abstract

Remanufacturing is defined as a process by which an end of life product is returned to an as-new condition with an equivalent warranty. It is seen as an effective method for extending the life of product leading to an overall reduction in our environmental burden. Issues associated with remanufacturing include customer perception over reduced quality and limited access to end of life product. The implementation of product service systems is feasible way to mitigate these issues, delivering environmental benefits whilst ensuring that the user receives the services provided by the product. We will present examples including a refrigerated display cabinet remanufacturer, games console manufacturer, a vacuum pump manufacturer and an earth moving equipment manufacturer to highlight service providers using remanufacturing and remanufacturers offering services to increase their remanufacturing turnover. We will outline our activities to increase the level of remanufacturing in the UK, focusing on standards development, design initiatives and sector level engagement.

Keywords

remanufacturing, reuse, end of life, environment, service led sales, refrigerated display cabinets, vacuum pumps, earth moving equipment, games consoles

1 INTRODUCTION

Remanufacturing is defined as returning a used product, via a manufacturing-type process, to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product. [1-5] A remanufactured product should be practically indistinguishable from a new product from the purchasers' point of view. The process of remanufacturing involves disassembling a product, inspecting and replacing worn parts and consumables, applying a surface finish, reassembling the product and thoroughly testing it to ensure that the product complies with original performance specifications. Remanufacturing is an important, but under-exploited, method of reducing our environmental burden, and is estimated to be worth at least £5bn to the UK economy. [1]

It is important to state that there is a common misconception that remanufacturing and recycling are synonymous. Recycling is a process for reusing materials: During recycling the function or physical form of the recycled product and its components is lost through physical or chemical destruction. Remanufacturing is a process for reusing products, where the form and function of a device or its sub-components are retained to the fullest extent.

Remanufacturing a product removes the need to use virgin materials and consume energy in its manufacture. Broadly speaking, the remanufacture of a product produces fewer carbon dioxide emissions than manufacturing from new [7]. Also, because the embodied energy in the construction of the product is retained, remanufacturing involves a lower carbon footprint than scrapping and recycling materials and – all other factors being equal – is a preferential option to recycling. [8-12]

The exception to this occurs most often where the product consumes energy in its operation and where energy efficiency improvements in new product design have reduced the overall energy consumption of a device whilst in use. [13-16] Under such circumstances, savings made through delivering a remanufactured product may be lost through the inefficiencies of persisting with the use of an older design. This issue can be eliminated if a remanufactured unit can be upgraded to attain the energy efficiency standards of a new unit. [17]

Remanufacturing is an important and integral aspect of numerous UK sectors. Its prevalence and application are dictated by several factors including cost of original product, speed of technological advance and the ease with which a product can be disassembled and remanufactured. Industries such as aerospace [18] and automotive [19-21] are exemplars, in which remanufacturing is built into the business models of all component manufacturers and is seen as an essential way to reduce costs. The aerospace example also counteracts concerns that the remanufactured product will not perform as well as a new item. The wide-spread use of remanufactured parts in a heavily regulated and safety-conscious industry demonstrates that a remanufactured product can achieve as good as new performance and perform in a strictly delineated manner.

There have been several studies showing both the environmental and business benefits of remanufacturing. [22-24] In addition to the reduction in greenhouse gas emissions and material use delivered by remanufacturing, and the cost benefits realised by both remanufacturer and purchaser, there are several less measureable benefits from remanufacturing. These include: [17]

Enhanced skills and employment

Anecdotally, the skills level and pay of the staff involved in remanufacturing are higher than counterparts who are involved in recycling. The main reason for this is that the operations within a remanufacturing factory are more complex and the remanufactured product is significantly more valuable than equivalent recycled material.

A higher workforce skills rate has positive implications for the wider economy. A more skilled workforce is required to compete with our main international rivals: the higher skills

set and higher pay also result in a net increase in gross value-added per employee, which is a key indicator of economic success

Enriched customer relations

There are opportunities for remanufacturers to develop closer ties with customers. Where service-type agreements are developed, or where an organisation remanufactures products to order, there is greater contact between client and provider. Such activities lead to the development of good business relationships, which can lead to further business or the resolution of other areas of business where there have been problems. This is discussed further below.

Improved product failure knowledge

A key problem for OEMs is in obtaining statistical data on modes of failure of their products outside of warranty. Such data could be used to improve the reliability of their product. It will also highlight less critical failures such as unusual wear patterns or long-term unexpected behaviour of the product. Third party remanufacturers can use this to their advantage to design out any defects present in the original product, which can then be used as a selling point.

1.2 Remanufacturing industry profile

In general there are three classes of remanufacturer: The OEM, the contracted "official" agent, and the independent operator. In the first two cases, OEMs retain at least some control over both the rewards and the quality of the remanufactured product. [6] Relationships between contractors and OEMs can involve mutually beneficial information flows regarding both original design specifications and product failure modes and frequencies; these can be used to enhance product design, design for remanufacture and even upgrade paths for old generation products. Independent operators usually provide a service in segments where the OEM is not deeply involved in direct customer support (such as out-of-warranty automotive), or simply concentrates on new sales. OEMs may re-enter remanufacture where they recognise that their strong brand name is being parasitized, and technological advances offer strong upgrade potential. This has happened in the machine tool area, where computer control technologies may be retrofitted to high-longevity basic equipment. [25]

Remanufacturing shares many features of normal manufacturing, particularly in relation to the aspects of output quality control, materials flow handling, and other principles of lean manufacturing. [6] Significant differences do arise from the fact that the raw materials – core – at the input to the process is of unknown quality. This has implications for evaluation of suitability for remanufacture, and the processes of testing, verifying or remediation at the component level. A more serious challenge exists for independent remanufacturers. Access to product engineering data can be seriously restricted; in response leading remanufacturers have built reverse engineering capabilities that attempt to determine product specifications by deconstruction of original equipment items. [26] These issues can be seen as barriers to remanufacture or as points of attack by OEMs. However, the most advanced OEMs do not perceive remanufacturing to be – in principle – any different to new manufacture, and can run both operations in parallel at the front end, and sharing parts management, assembly and processes logistics at the back end. [27, 28]

1.3 PSS and remanufacturing

To derive maximum benefit, remanufacturing depends on the customer recognising the value of his end-of-life asset, and the manufacturer creating products that have the required durability in critical components. Both these motives can be enhanced if the goods can be seen less as products and more as a service. [21] Profit margins can be sustained or even improved over new sales, particularly if performance upgrades can be included in the remanufacturing activity. Customers can then stay up to date with respect to energy consumption, emissions controls or safety systems. In other cases "servicisation" offers remanufacturers an alternative way to compete with lower-priced products. [29]

To date, this has largely been a feature of business to business services, where – in general – there is a greater awareness of financial implications of purchasing decisions. Even here, however, there are plenty of opportunities for more informed purchasing based on life-cycle costing rather than "least cost, now". From the manufacturer's perspective, remanufacturing can provide a route to addressing Producer Responsibility demands. The necessary recovery systems are accountable and demonstrably more resource efficient when integrated with the management accounting of manufacturing processes. [30, 31]

This paper presents a series of case studies of remanufacturers that incorporate aspects of PSS into their business models. The provision of such offering has enabled them to establish this resource efficient activity as a profitable enterprise.

The case studies presented here were collected over a number of years through face-to-face and over the phone ad-hoc and formal interviews with key members of senior management and production staff at the various companies. Our remit, as a governmental funded delivery body, is to promote the benefits of remanufacture and reuse to business and government. The aim of these case studies is to provide insight

2 CASE STUDIES

2.1 Sony Computer Entertainment Europe and the Playstation

Sony Computer Entertainment Europe (SCEE) is responsible for sales, marketing, distribution and software development for the PlayStation® 2, PSP & PS3 Video game & Multimedia consoles. SCEE has offices around Europe, the Middle East, Australia and New Zealand responsible for the sales and marketing of these computer entertainment systems and associated software to a total of 94 territories. SCEE import units from its parent in Japan and in turn supply these units to SCE UK, who then sell them to retail outlets. Warranty returns are also the responsibility of SCEE.

The move to remanufacture

SCEE has always used a remanufacturing model to enhance its customer service offering. At the launch of the original PlayStation®, SCEE considered the idea to service warranty returns using a traditional repair model, where by returns would be dealt with locally at small Sony approved retailers. The problem would be fixed on site, and parts would have been ordered on an individual basis, with no thought given to recovery of defective parts by the individual repairers, either for reuse or recycling.

This model allowed for little or no quality control, economy of scale, or recovery of potentially valuable parts. It also meant that the repairs would be expensive, with this potential cost being incurred by SCEE. Customers whose unit failed out of warranty would face a bill for labour and parts, as well as a long wait for parts to arrive. This would have put many people off repair, and these units would have been discarded by the consumer. The business model for games console manufacturers and suppliers

relies on a large installed hardware base to enable the sale of games. The manufacturer charges licensing fees to third party games makers, the larger the installed base, the higher the revenue the console maker can make from the license. It is therefore in the console manufacturers' interest to ensure that as large as possible user base exists to attract games developers. Broken and faulty games consoles clearly reduce this revenue.

To maintain the large installed user base, SCEE opted to establish three large European refurbishment centres and two in Australia & New Zealand. This was a conscious effort by SCEE to cut the cost of its service operation and improve customer service, in a market where customer loyalty was vital to the success of the product.

In practice, a defective unit is reported to SCEE and a pickup time is arranged for the unit. At the point of receipt, a remanufactured unit is offered to the customer. A modest (less than £50) cost is charged for this service.

What are the benefits to the end user?

- Service replacement scheme means they are without a console for the minimum amount of time. (typically only 24 – 48 hours in the UK)
- The console is collected from their home, or other choice of address and a new one delivered. There is no need to take the unit to a shop.
- Using economies of scale and the use of reclaimed parts, SCEE have been able to reduce the price for out of warranty repairs to an absolute minimum.
- Customers know that their remanufactured console will have been through a thorough and consistent process, ensuring the highest standards of quality.
- Although the console they receive from SCEE is not the same as the one they send for repair, the remanufactured working model does enable them to use a console as fast as possible.

Reuse of Parts

SCEE identified that faulty modules removed from returned units have value and were stored for later use and analysis. They quickly began to utilise this stockpile of parts by cannibalising units to reduce spare part costs. SCEE then introduced reclamation and reuse to one of its service centres as a test case in 2000. The process was then gradually rolled out over a number of years and by 2004, all service centres were actively involved in reclaiming usable parts.

Benefits

The reuse of components from faulty units has clear benefits in terms of production, transportation and resource depletion. Although the volume of components reused is impressive at 6.8 million, many of these are very small items, so whilst they are important, the most important environmental benefit lies elsewhere.

The cost for repair of out of warranty units has been made affordable through SCEE's remanufacturing operation. A higher cost would force many users to purchase a new console, particularly as a model reaches the end of its life cycle.

SCEE estimates that around 40% of returns towards the end of a product lifecycle can be attributed to out of warranty units. If they did not offer an affordable option to customers, these units would likely end up as landfill and be replaced with new. Over the period 2004 to 2006, this would have prevented 3,000 tonnes of CO2 entering the atmosphere due to UK operations or 13,000 tonnes over the rest of Europe[2].

Further gains are made by the centralised collection of damaged units. The service centres can amass large enough quantities of Polycarbonate case components to sell as a feedstock for recycling. This is mixed with virgin polymer and used in mid grade polycarbonate components, such as internal components for photocopiers, pens or even plastic chairs.

2.2 Remanufacture at caterpillar

Caterpillar is the world's largest maker of construction and mining equipment, diesel and natural gas engines and industrial gas turbines. Sales outside the US accounted for 53% of CAT's $36 billion turnover. Its products include track-type tractors, hydraulic excavators, backhoe loaders, motor graders, off-highway trucks, wheel loaders, diesel and natural gas engines and gas turbines.

In 2005 CAT's global remanufacturing operation reused 43 million tons of core material. This means that by remanufacturing rather than recycling, CAT has prevented 52 million tonnes of CO2E entering the atmosphere. It also means that other associated waste due to raw material extraction has been substantially reduced.

Every remanufactured product that leaves the factory has been through a stringent quality test procedure, often having been passed along the same production line as a new product. This is backed up by a full warranty, the same as is issued with a new product.

Keeping Hold of core

When a customer purchases a remanufactured part from CAT it is delivered to them in a reusable container, for which they pay a deposit. When returning a worn part (core), customers are expected to use this container. Their site in Shrewsbury, UK, which is their European centre of excellence for Europe, Africa and the Middle East, site has reduced its wooden packaging waste by 70% using this system, reducing cost and making sure core arrives undamaged. The customer also pays a "core deposit" which is refunded upon receipt of their worn part (provided it is complete and has no unexpected damage). The worn parts are then sorted at Shrewsbury and given a basic visual inspection. Some parts will be remanufactured on site and others will be shipped to facilities elsewhere.

Process Simplification

The remanufacturing process at Shrewsbury uses patented processes, procedures and tools to dismantle, modify, and reassemble the products. This allows the plant to be flexible in the type of components it can remanufacture. With a skilled workforce, a wide variety of engines can be remanufactured on site without the need for expensive dedicated lines. Remanufactured products often leave the plant in "better than new" condition, as every part is modified to include the latest design features available at the time for the original specifications to which the product is remanufactured.

Overcoming challenges

Table 1 shows the key challenges that Caterpillar have been confronted with and how they have overcome these.

[2] These figures have been calculated assuming 40% of all consoles returned were out of warranty. The mix of "PS2" to "PS2 Slimline" was 1:1. The associated embodied CO2 for each device has been estimated from data produced by Best Foot Forward for a range of similar devices. The figures in that report have been benchmarked against other computing equipment. [An ecological footprint and carbon audit of digital radio A1 – DAB Acme Digital, Best Foot Forward, 2006]

Key challenges	Caterpillar Solutions
Making sure that core is returned to CAT rather than rebuilt by 3rd parties, who will not have access to the full technical data and test procedures.	The core deposit is set above the market price for the used part so that the customer has an incentive to return the core to CAT. Only CAT remanufactured parts will carry a full warranty and give the customer guaranteed reliability and performance.
How to gather together sufficient core when a new product is introduced?	CAT will offer customers new equipment at remanufactured process in exchange for used core.
How to persuade customers that a remanufactured product is as good as new?	The 'as new' warranty reassures customers that they will be buying a quality product with excellent after sales support should they need it. Strict quality procedures ensure that the customers experience is trouble free, building trust and confidence in remanufactured products.
How to find new ways of salvaging more components?	CAT is constantly developing new technology and methods of materials recovery and will continue to do so.

Table 1: Key challenges and solutions for Caterpillar remanufacturing operation in Shrewsbury.

2.3 Edwards Vacuum and low pressure vacuum pumps

Edwards is one of the leading organisations in the world specialising in the design and manufacture of vacuum and exhaust management products for both general vacuum and semiconductor applications. Edwards employs around 3,500 people globally, in the design, manufacture and support of high technology vacuum equipment. Its turnover in 2006 was over US$1bn. The company is a leading global supplier of equipment and services to the world's most advanced industries including semiconductor, flat panel display, chemical, metallurgical, analytical instrumentation and R&D. It is also a world leader in vacuum technology for industrial, scientific, process, and R&D applications including:

- Flat Panel Display
- Analytical Instrumentation
- Industrial Vacuum
- Process Vacuum
- Research and Development
- Thin Film Coating
- Semiconductor
- Renewable Energy

Edwards Vacuum supplies blue chip customers in Asia, Europe and the Americas through a worldwide manufacturing and sales network. Edwards was acquired by CCMP Capital, a premier global private equity firm, becoming an independent private company, in June 2007.

The Edwards Offering

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

Capabilities are not sold simply on the basis of repair and maintenance. Other major service attributes include:

- The ability to responsibly handle contaminated equipment: Fabrication applications in particular deal in potent toxic and corrosive brews which leave reagent and corrosion by-products within the casings. Decommissioning, removal, transport, disassembly and cleaning present significant health, environmental and even fire risks. The provision of a robust service that minimises these risks to the customer therefore attracts a premium. Edwards offers such services, which can be further mitigated by use of its associated emissions abatement units during normal operation.
- Lean manufacturing: Edwards seeks to minimise its own operating costs and improve product reliability with commensurate benefits to its customers. Lean manufacturing has been applied to the support operations to standardise techniques using on-line manuals, replacement parts and kits, and to track serialised items.
- Diversified repair, refurbishment and remanufacturing options: A significant change over the past twenty years – following the rising complexity and cost of products – is the recognition that customers need a range of options for buying and supporting equipment. Of particular significance is the adoption of a fully qualified remanufacturing programme offering as-new or better products (through upgrades to the latest build standard).

Evolution of Remanufacturing

The problem of out-of-service downtime was addressed by the concept of Service Exchange: Edwards would still sell a new pump, but on failure it would be replaced by another unit – a remanufactured unit that met the latest build specifications. The recovered units would be remediated and form an inventory for field replacements. Levels of work committed to the remanufacture entailed a higher cost for these items compared to repair, but offered significant warranty and – more importantly – up-time benefits.

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

The complexity of this scheme is higher than the service exchange programme because of the logistics, on-going support and need to maintain sufficient inventories, which does incur cost.

Environmental Benefits

The exemplar is a mid-range drypump undergoing an "average" remediation cycle. Remanufacture of this product involves the reuse of over 90% by weight of its components – with a corresponding saving in raw materials and their embodied carbon dioxide.

The once-through benefits of remanufacturing are amplified many times when we consider the life-cycle of a pump. As an extreme case, a device on a fab-plant duty may be overhauled every three months and see an installed service life of 10 years. Typically, the pump would then be exchanged or upgraded, but would undergo a complete overhaul for another 5-10 year cycle. Remanufacturing turnovers of 20-40 are therefore not unheard of in this environment, but more commonly are in the range 4-10 for less severe duties.

Key Competences

Edwards views its products as being differentiated on quality and performance.

These technically complex products have increasingly demanded sophisticated support options. This is one identifiable capability of the new Edwards Vacuum company; a suite of manufacturing, sales and support operations that meet the diverse financial and operational needs of the customers. These options require careful management in order that options are appropriately costed and controlled:

- Attention to quality in design and manufacture. Standardisation of procedures and parts kits using on-line service support guides has enabled rationalisation of components per service location, and consequently costs.
- Ability to handle entire life-cycle of product including decommissioning.
- Ability to track all registered components using centralised systems and to identify costs of replacement.
- A system whereby failures in service are captured, diagnosed and used to modify or upgrade current models or new evolutions. This capability has evolved over the last decade or so and has led to increasing integration of the front end design – design for disassembly.

2.4 Refrigerated display cabinet remanufacture by the Bond Group

What is an RDC?

A Refrigerated Display Cabinet, RDCs are devices that enable the sale and storage of chilled and frozen food and beverage products in a retail environment. They are common to all supermarkets and convenience stores selling chilled food. They serve two purposes: to ensure that the produce sold is fresh and to enable the customer to view produce prior to selection and purchasing.

The design, shape and size of RDCs can vary greatly depending on their specific use, but are a largely cosmetic feature of the overall functionality of a unit. RDCs operate in an identical manner to domestic fridges: A compressed refrigerant gas, cooled to below ambient temperature by rapid expansion, chills the air in the RDC via a cooling coil. The gas is then compressed, away from the cool zone, and the resultant waste heat is radiated (remotely in the case of a domestic fridge).

Remanufacturing RDCs

TBG is one of the largest RDC remanufacturers in the UK. Based in Sheerness on the Isle of Sheppey, Kent, TBG employs around 210 staff. TBG operate a product-oriented service business model: They do not own any RDCs but support RDCs already in the field (for extending life or upgrading) by remanufacturing on the retailer's behalf. In general, the old, remanufacturable cabinets are stored in TBG's warehouse. When TBG receives an order to refit a store, the number and type of RDC required is determined. The stored cabinets at TBG are remanufactured and the old in-store stock is replaced with the remanufactured units. Any salvageable cabinets from the in-store stock are placed in storage ready for remanufacturing, with the remainder being sent for disposal.

This system requires the retailer to have a surplus stock of RDCs, but allows the old stock to continue operating whilst TBG remanufactures the stockpiled cabinets. An advantage to this system is that the lead time between placing an order and installing the remanufactured cabinets is significantly shorter than buying new: The whole process takes between two and four weeks.

There are several other advantages to remanufacturing RDCs. For example, the ability to mix and match old functional store cases with remanufactured cases when performing a partial refit enables the store to keep RDCs looking aesthetically similar. The purchaser saves twice: Once from the reduced cost of the remanufactured product and again from reusing serviceable RDCs within the refit.

By holding older units in stock, TBG also has the facility to trade RDCs between retail companies to fill a large or unusual order. To service and repair such a wide selection, TBG has had to develop an extensive knowledge base, encompassing detailed technical drawings of hundreds of RDC models.

The remanufacturing process performed at TBG has been developed to ensure that the RDC reaches the retailer in the expected specified condition.

3 SUMMARY

Here we present a series of case studies of successful businesses employing remanufacturing in different service based systems. Event though the industry sectors are diverse, the over reasons for using remanufacturing were to save customers money and provide a service that added value to their sales proposition. There were also positive and measureable environmental benefits from remanufacturing. Clearly as both political and business agendas focus on improving resource efficiency, remanufacturing will be seen as a means to achieve this goal. As part of this solution though, product service systems will need to be employed to overcome inherent barriers (for example core collection or consumer perceptions) associated with such offerings.

4 ABOUT THE CRR

The CRR has been formed to promote, where appropriate, the activities of remanufacturing and reuse. Our work is largely funded by Defra (the UK environmental ministry) but we work with a range of regional agencies to reach our targets. We will work directly with companies, although individual support does require paid-for contribution. Work that assists sectors or helps not-for-profit and third sector organisations is free, as is our advice to the ordinary consumer.

We believe that remanufacturing and reuse (r&r) are underused means of conserving resources; significant extra savings in materials and energy use are possible whilst boosting skills, employment and economic activity. To this end, the Centre is developing an evidence base which will enable Government and industry to take actions to boost remanufacturing and reuse.

Core to our purpose is the implementation of actions that will boost - in particular - remanufacturing. These policies and strategies are designed to help businesses (both consumers of remanufactured goods and remanufacturers), governmental policy makers, OEMs and trade bodies to deliver more remanufactured goods

and thus reduce our impact on the environment, and at a profit. We generate the supporting information that the remanufacturing industry needs to make its case and raise its profile.

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