Resource Recovery Forum

Remanufacturing in the UK: a significant contributor to sustainable development?

Oakdene Hollins

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Resource Recovery Forum

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The Resource Recovery Forum is a network of organisations with a shared interest is seeing society achieve more sustainable waste management - making better use of waste that is produced. The Forum works towards this goal by:

* promoting the best practicable environmental options for waste
* collaborating in research and development
* providing links between local authorities, industry and waste managers
* producing accessible information
* liaising with the government, institutions of the European Union and other decision-makers

RRF uses the diversity of its multi-sector membership to develop broad, inclusive projects, funded principally through the landfill tax credit system in conjunction with the waste management industry, and also by direct grants and membership subscription.

Oakdene Hollins

Oakdene Hollins was established in 1994 by David Fitzsimons and Nicholas Morley, and employs seven people in total. Our area of consultancy is in the sustainable use of resources at strategic, research and implementation levels. All of Oakdene Hollins' personnel have substantial industrial experience allied with excellent academic qualifications, including five honours degrees from Cambridge or Oxford and three MBAs. Our activities range across:

* the management of government programmes related to resource, reuse and sustainability issues
* investigation of, for example, specific legislative impacts on behalf of private and public organisations, such as OECD
* publicly supported research into, for example, uptake of new technologies on behalf of the Carbon Trust, and this Biffaward project
* direct in-company intervention in Lean Manufacturing and Resource Efficiency programmes
* independent evaluation of the potential of novel technologies and business models to effect more sustainable consumption or production

There is more information about Oakdene Hollins at **www.oakdenehollins.co.uk**

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Oakdene Hollins is proud to be a founder member of RRF.

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In December 1997 Biffa Waste Services agreed to donate landfill tax credits to the Royal Society of Wildlife Trusts (RSWT) to administer under the fund name Biffaward. Grants made from the fund currently amount to more than £63 million, supporting many worthwhile environmental projects.

Biffa is a part of Severn Trent Plc and is one of the largest single suppliers of waste management services in the UK. It collects, treats, recovers and disposes of municipal, commercial and industrial waste nationwide and in Belgium.

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GLOSSARY

AMUSF	Association of Master Upholsterers & Soft Furnishers
BRA	British Refrigeration Association
BVA	Branded Vehicle Assembler
BSRIA	Building Services Research Industry Association
EAMTM	European Association of Machine Tool Manufacturers
FER	Federation of Engine Remanufacturers
FIRA	Furniture Industry Research Association
OEM	Original Equipment Manufacturer
OFFMA	Office Furniture Manufacturers Association
ONS	Office of National Statistics
PC	Personal Computer
PCB	Printed Circuit Board
QC	Quality Control
RDA	Regional Development Agency
REMA	Rotating Electrical Machines Association
RIC	Remanufacturing Industries Council
RMA	Retread Manufacturers' Association
RRF	Resource Recovery Forum
SBAC	The Society of British Aerospace Companies
SEEDA	South-East England Economic Development Agency
SIC	Standard Industry Code as used by the DTI to categorise industries & services
TIC	Tyre Industry Council
UKCRA	UK Cartridge Recycling Association
UPS	Uninterruptible Power Supply
UTWG	Used Tyre Working Group
WRAP	Waste & Resources Action Programme

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SUMMARY

Remanufacturing is the practice of taking end-of-life goods and re-engineering them back to as-new condition, with warranty to match. Figure 1 places remanufacturing within the hierarchy of recovery techniques. In the USA, the practice has been well documented and quantified, and now attracts government subsidies to promote its benefits as a contributor to sustainable development. No such analysis has been conducted in the UK; this study is the first to attempt such a task, but also to question the business enablers for remanufacturing with a view to proposing actions that could boost activity.

Lund (1996) estimates the GNP of remanufacturers in the USA to be over $50 billion. They are also responsible for the direct employment of around 500,000 people, and many others in connected industries.

Our study concludes that remanufacturing in the UK, driven by economics rather than environmental motives, is making a significant contribution to materials efficiency embodying substantial equivalent carbon savings. This unrecognised sector is contributing around £5 billion to GNP, recovering around 270,000 te of materials with an equivalent carbon saving of 800,000 te CO_{2e}, and employing around 50,000 people (see Table 2).

Enlightened remanufacturers are often at the forefront of marketing novel product-service offerings, usually entailing greater profit margins than "make and sell" businesses. Those sectors that compete on lowest price – whether manufacturers or remanufacturers – are suffering against lower price competition, commonly from abroad. Leading edge remanufacturers also embrace state-of-the-art manufacturing processes – lean techniques, investment in people, material traceability – because they are key to business success.

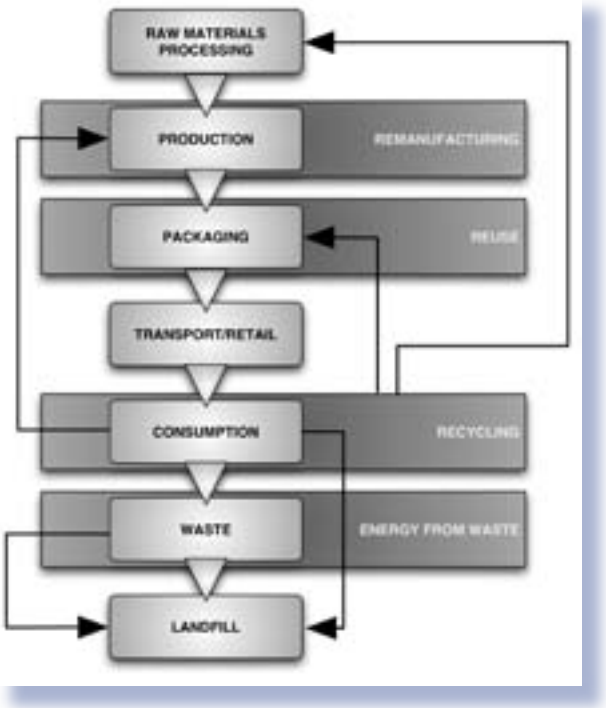
Remanufacturing has the potential for even greater contribution to sustainable consumption, and there are steps that all stakeholders can take to enable this. Foremost amongst these are elimination of legal impediments such as:

* denial of access to manufacturer design information
* banning of remanufactured components in new goods
* redefinition of what constitutes waste

Removal of these would increase competition and force evolution of improved services, including remanufacturing. We do not recommend unilateral fiscal measures to skew markets towards remanufacturing, even if this achieves the sustainability objective. These moves would create artificial markets, and ultimately stifle healthy competition. We believe that there is a place at a multilateral level for such policies as freedom of information, lifetime warranty to spur design fitness, and a liberalisation of the distinction between waste and resources to encourage trade in exploitable materials.

Further success of remanufacturing will also entail concerted efforts by companies and industries to drive out poor operators, and establish reputation for quality through branding. There will be opportunities for brokers and other agents to source and sort cores for a range of sectors. There could be significant opportunities for companies capable of facilitating vertical integration, reverse logistics and core broking. For example there is a role for waste management companies to provide a more comprehensive "waste resource" service to return end-of-life products back into the manufacturing chain.

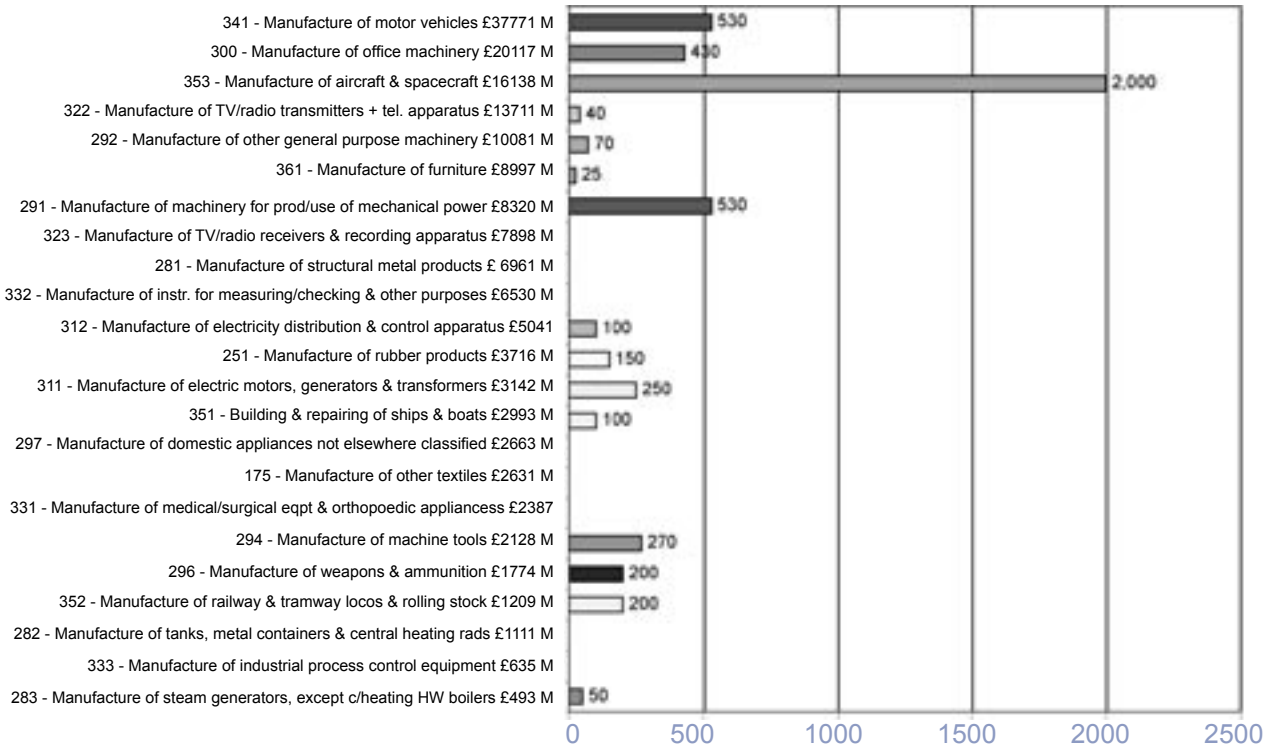
Figure 1. Hierarchy of recovery techniques in value chain



Highlights

Remanufacturing appears to some extent in every industrial sector of activity, being performed by OEMs, contracted parties and independents. We

Figure 2. Remanufacturing economic value by sector (£ M)



estimate economic value to be around £5 billion at the manufacturing level. This places it on a par with the recycling industry. A breakdown by sector is presented in Figure 2 (see above, and at the end of this report).

A rough assessment of resource impact suggests that remanufacturing is saving in excess of 800 kte CO_{2e} pa, and directly employing around 50,000 people. A breakdown of material and CO_{2e} savings is presented in Figures 3 and 4, respectively (see over, and at the end of this report).

Remanufacturing is largely unrecognised as a term and a practice – even amongst the cogniscenti of the environmental world. This research shows that it offers an economic realisation of sustainability with growth, and therefore deserves recognition for its practitioners.

It is least prevalent in areas producing consumer goods subject to fashion or status-related purchasing decisions. It is most prevalent, and holding up, in sectors of very high value or technological content such as aerospace, military and power turbines; it also thrives in sectors which have embraced the concept of "servicization" – the substitution of goods by services – where there are shared motives for product longevity, durability and performance. In these cases, remanufactured goods have significantly higher profit margins than new. Scope for remanufacturing has increased where industries have embraced new technologies for the restitution of components. This has enabled greater material recovery and even the retention in-house of capabilities that may have been outsourced previously. The improvement in service and margin that this affords can offset loss of business through general enhanced longevity of industrial items.

Remanufacturing is under threat in those sectors which are increasingly seeing low cost imports of improving quality goods from abroad. The relatively high UK labour cost content of remanufactured goods means that it is cheaper to purchase new than recondition. Remanufacturing is doomed to failure when used to compete in markets where price is the only basis for competition, unless a low cost source of labour is available.

Barriers to remanufacture

Barriers to remanufacture include:

* prevalence of cheaper, often imported, equivalents (largely through greater productivity and lower labour cost)
* for consumer goods, poor public perception

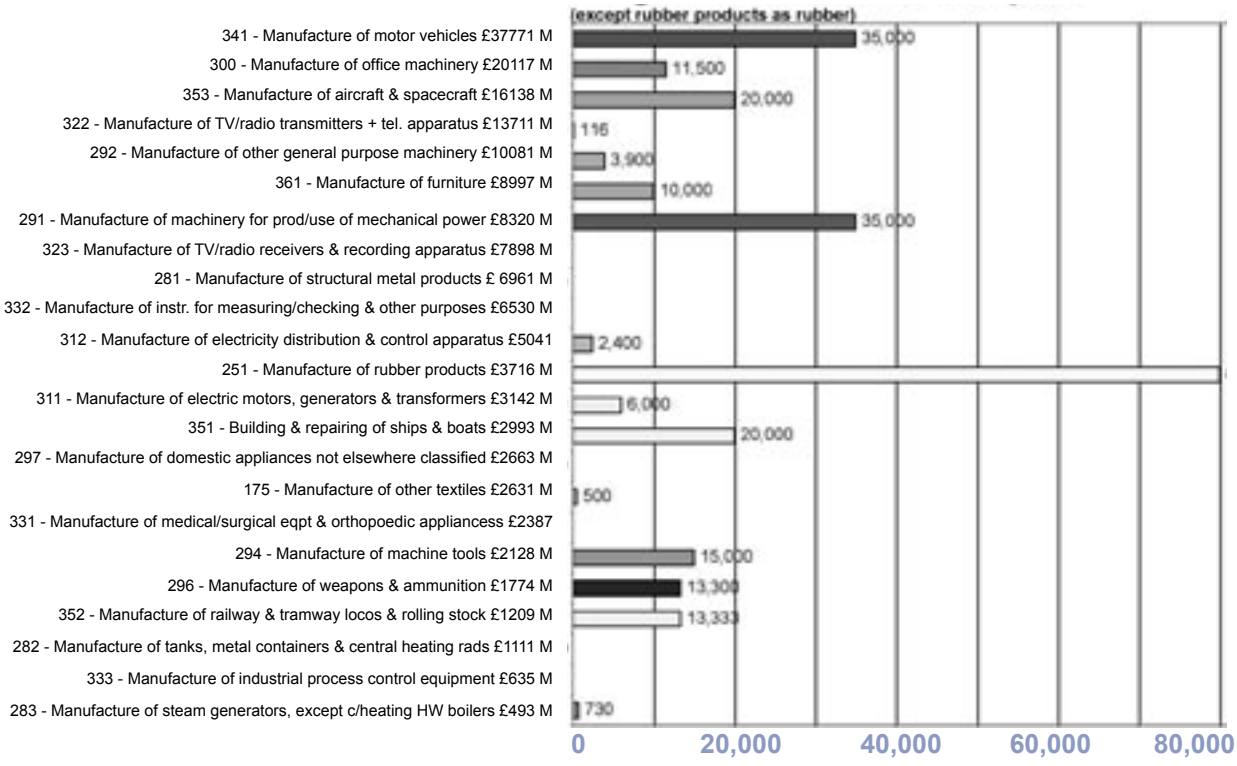
(based on variability of standards, fragmented supplier base and general lack of brand warranty)
* OEMs withholding technical information or introducing anti-remanufacturing devices to thwart independents (particularly of concern in the electronics and automotive sectors)
* lack of technically skilled and motivated personnel coming from colleges (and inadequate promotion of this branch of engineering compared to office-oriented, IT, media and service industries)
* poor design for remanufacture (ease of disassembly, irreversible closures, multiple materials (esp. plastics) surface coatings, glues and labels, insufficient materials information)

Opportunities for remanufacture

Factors that could assist remanufacture include:

* active support of remanufacturing by corporate and public purchasers
* concerted efforts by organised, large-scale, low labour cost organisations to establish brand credibility in selected markets
* changing basis of competition from cost to service or other innovation; this may require new partnerships or alliances
* concerted efforts by trade organisations and industry associations to defend and promote standards of bona fide operators, and share practices
* development of more conducive materials of construction, simplified assemblies and research into material remediation techniques
* incentives for long-lived goods or remanufactured items
* increasing prosperity abroad redresses cost of goods
* true carbon taxes redress the materials/labour cost balance
* pro-actively set up remanufacturing facilities in developing countries to exploit labour differentials
* promotion of remanufacturing as a more rewarding and skilled activity to encourage entrants to the workforce
* emergence of brokers of a multiplicity of core goods who can leverage economies of scale in logistics

Figure 3. Remanufacturing materials saving (tonnes steel equivalent) by sector



Possible actions & opportunities for businesses

Low labour cost operations move into remanufacturing:

* in direct competition with low cost imports, only organised, low cost organizations will be able to engage head to head
* reputation, warranties, relationship with OEMs, and excellent bi-directional logistics will be major competitive issues for local contenders

Modify basis of competition:

* do not compete on price: provide complete supply and maintenance and refurbishment service to reclaim value chain directly
* back-integrate into customers operation to in-source aspects of operation related to use of the equipment
* ally with other service providers (eg logistics agents) where this service is beyond the scope of knowledge, or is at another business interface
* become local maintenance and remanufacturing arm of a reputable foreign importer, particularly if they have no presence in the UK; consider profit share or equity stake of OEM in business
* insurance and warranty companies promote uptake of remanufactured goods
* ally (eg trade associations), lobbying for changes to legislation that unfairly harm competition

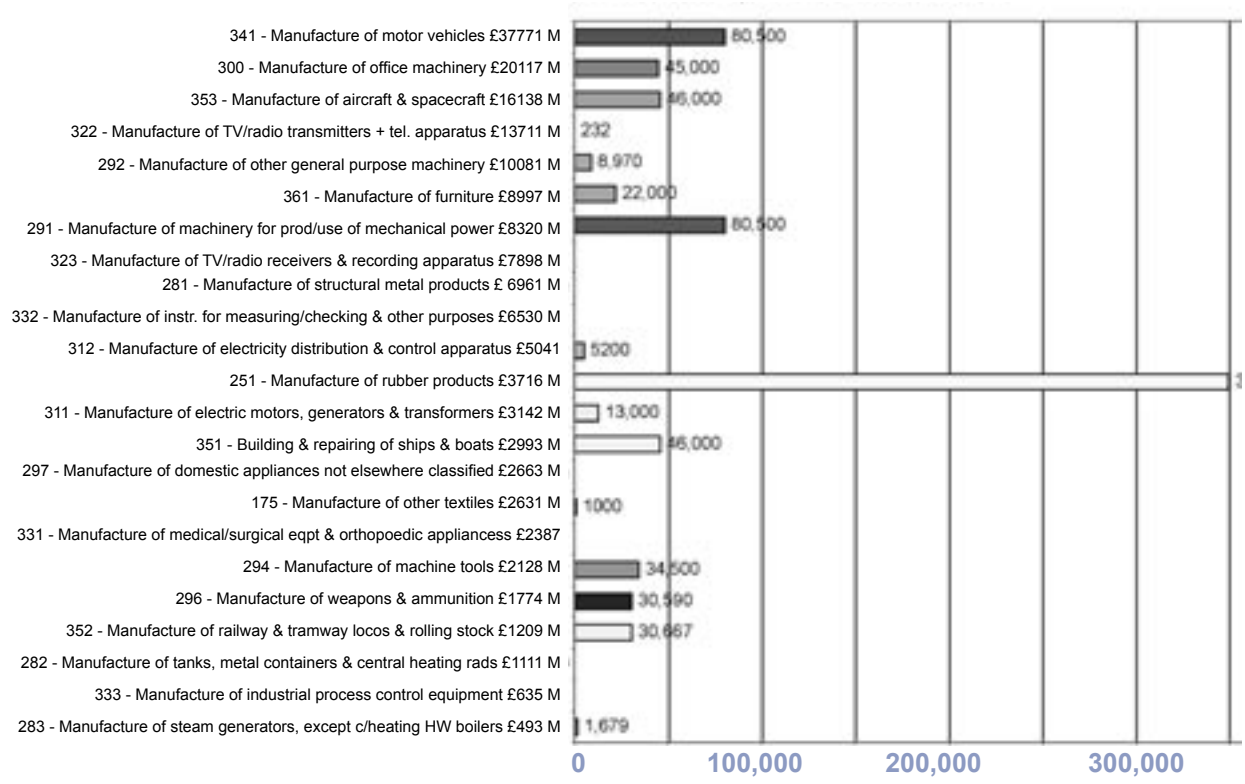
Seek alternative markets:

* do not remanufacture for primary home, European or other Western markets, but rather secondary markets
* relocate or create subsidiaries in developing markets to take advantage of local cost structures; this creates a foreign remanufacturing operation at point of high demand, but also capability to re-import cost-effectively

Create new businesses:

* consider opportunities in logistics and brokering of core components using existing skills, and leveraging economies of scale

Figure 4. Remanufacturing tonnes CO_{2e} saving by sector



Possible actions for RDAs

* promote purchase of remanufactured goods in corporate activity, and publicise this; push for publicly declared standards – preferably through a trade association – as a condition of purchase
* publicise centres of remanufacturing excellence, identify flagship enterprises
* considering target clusters, work with training and enterprise councils to boost skills in critical functions using remanufacturers as a basis for training, not direct employment
* considering target clusters, consider initiatives and workshops that address pressures in the business environment – such as environmental legislation – and how solutions to these may involve remanufacturing
* consider role as a portal to connect suppliers of services to users of services
* as part of community sustainability agenda, consider how community needs could be depersonalised, dematerialised and contracted out to service providers eg utility services, domestic services and group transport share schemes
* favour contracts with organisations that offer solutions to practical issues of waste management where it meets remanufacturing ie core broking and reverse logistics management
* mobilise MEPs to be alert to implications of impending EU legislation where an unnecessarily narrow definition of recycling or recovery might compromise justifiable remanufacturing ventures

Late breaking news

As this report neared completion, we received news of a significant milestone in the struggle of remanufacturers trying to establish a fair field of competition. The sector in question is that of photocopier, toner and inkjet cartridge manufacture.

As reported in detail elsewhere in this work, the above sector has been subject to intense manoeuvring by OEMs and Remanufacturers to claim their share of this lucrative market.

Lately, certain manufacturers have begun to employ electronic measures to prevent reuse of consumables by other than themselves in an attempt to shore up sales of new consumables.

On behalf of the refilling industry, UKCRA had been lobbying the EU – championed by MEP Chris Davies – on certain clauses in the forthcoming WEEE directive. As originally written, the wording would offer no protection against the use of such counter-measures, widely seen as anti-competitive. Davies finally achieved amendments to the legislation forbidding the inclusion of blocking technologies, unless they could be shown as providing some incontrovertible advantage.

Whilst this legislation was not originally constructed with remanufacturing in mind, it is sobering to note how simple omissions, based on limited views of what constitutes materials recovery, have the potential to disrupt major classes of activity.

INTRODUCTION

Remanufacturing - the process of returning a used product to at least Original Equipment Manufacturer performance specification - appears to have been in decline for several years. This environmentally important industrial activity has a low profile in policy terms and, as a sector, it is highly fragmented.

However, in the USA the practice has been highlighted for its significant contribution to the U.S. economy, as well as its potential to contribute to a more sustainable future. Economic instruments to further stimulate it are being considered. In the U.K. the industry's scope and its impact on the national economy have yet to be established, but recent research, undertaken at the University of Plymouth, University of Sheffield (WAMTECH, now defunct) and elsewhere, suggests that it may be a more widespread phenomenon in the U.K. economy, and may present a greater opportunity than has been previously realised.

Of all the current "secondary market" (used product) processes, remanufacturing requires the total dismantling of the product and the restoration and replacement of its major components. It concentrates on activities higher in the value chain than reuse or recycling (Figure 1), considering cost-effective expenditure of materials, energy and time. It appears to be strongly represented in the automotive, refrigeration, office equipment and aerospace/ defence sectors. Here, we assume the commonly held view that reuse corresponds to employment in a lower grade function, probably not the original market or application; and recycling requires destruction of original form to facilitate chemical or physical reprocessing.

The briefest of surveys reveals a range of products which are currently remanufactured in the UK including:

* machine tools
* electrical motors and compressors
* starter motors
* automatic transmissions
* car and truck engines
* office photocopiers
* excavation equipment
* power bearings
* defence equipment
* computer and telecomms equipment

A few examples of larger organisations exist. For example, Vickers has a specialist engine division practising re-manufacturing in Crewe, and ATP in Staffordshire has a significant operation for remanufacturing automotive transmissions. Xerox has practised remanufacturing for many years in the photocopier sector. Solectron, a multi-billion dollar company with world-wide operations, has plant remanufacturing computer equipment in Wales; the facility was originally founded to remanufacture for BT, and then Nortel. However, most remanufacturing companies are small, engineering-oriented companies with only a few employees.

Of late, many remanufacturing organisations have come under strain; this is particularly ironic considering that the practice shows great potential as a pragmatic approach to the sustainability objective which governments, development agencies and NGOs are struggling to articulate as a working concept. Prior to the study we can speculate on the reasons why: pressure from primary producers, foreign competition, failure to adapt, lack of skills, globalisation issues.

This project aims to

* understand to clarify the reasons behind this
* identify the potential value of remanufacturing and in what areas
* identify barriers to increasing remanufacturing - economic, social and technical

Relevance to sustainability

Our initial studies reveal that remanufacturing has generally been employed as a means of exploiting specific business opportunities for profit. It is almost unknown for the practice to be employed by altruists as a response to particular environmental concerns. However, at a higher policy level, the attention to remanufacturing, in particular in the USA, has been driven by its pertinence to sustainable development policies, in particular:

Producer responsibility and take-back schemes

These requirements have forced companies to consider the material efficiency and end-of-life issues associated with their products, and even co-dependent items such as packaging and supplements (refills, consumables etc.). In general, the primary effect is to eliminate use at source, or to increase the recycled material content of new-formed components. However, an effective strategy may be to implement re-manufacturing. The primary producer thus unambiguously retains ownership of the product, and has a vested interest in design for re-use, refurbishment

and longevity. Such a policy will directly impact material efficiencies. Appropriate targets, measures, incentives and penalties are required to stabilise at a new business model.

The "servicisation" of the economy

Replacement of product purchase by the purchase of services represented by those products will be a major contributor to sustainable development. Such trends encourage moves towards a leasing model for the product (with a corresponding expectation of finite service delivery), thus prompting the Original Equipment Manufacturer to design "quality" products, but capable of re-manufacture as a whole, or on a component by component basis. We note that in such cases, the cost of the product may rise, but is recouped through repeated, cost-effective leasing and refurbishment. Overall, higher value may accrue to the OEM through its investment in long-lived products, suitably designed for refurbishment.

A preference for actions at the upper levels of waste management hierarchy

Addressing resource use at a higher level generally results in lower overall use of energy and materials. Lower levels of activity such as recycling preserve existing economic structures (based on material throughput) and are thus relatively easy to implement. However, high levels of recycling result in increasing secondary resources and oversupply. This depresses the prices of virgin and recycled material, necessitating export. Recycling can therefore reduce waste, but does not result in the dramatic falls in the volume flow of resources that remanufacturing targets. Remanufacturing, being a high level strategy, aims at reducing material and energy use, the basis for a sustainable economy.

Undoubtedly, a number of markets have recognised the role of remanufacturing, and have begun to exploit it creatively in defining new service offerings, simultaneously reducing waste of materials and resources. In general, these have not adversely affected the profitability of primary producers (OEMs). Additionally, several studies conducted in the US have assessed the profitability of remanufacturers. In many cases, they show greater value added than the OEMs, and is testament to the inherent value of much so-called end-of-life equipment.

However, it is not obvious that, even given knowledge of the concept and benefits of remanufacturing, all potential markets will adjust spontaneously to accommodate the practice. Significant barriers to change will exist - some listed earlier. The question to be answered is how might a climate for remanufacturing, as a route to sustainability, be encouraged.

REVIEW OF PREVIOUS WORK

In the UK remanufacturing has attracted only relatively small interest from academic researchers in comparison to efforts on recycling, manufacturing and design. The most notable current activity is that of University of Plymouth Enterprise which, under the guidance of Dr Jan Bennett, has conducted a number of studies into – in particular – the electromechanical sector. This encompasses numerous businesses centred on motors, such as automotive applications, refrigeration and air-conditioning, food processing machines and quarrying equipment.

Recently, a PhD student, Winnie Ijomah, has completed a thesis (Ijomah, 2002) exploring the implementation of remanufacturing principles into an operating environment. Necessarily this work, exemplified in such papers as (Ijomah et al., 1999) has sought to set production management issues in a semi-theoretical framework, and is understandably detailed in its analysis, deconstruction and definition of the processes being undertaken. For the purposes of this study, the Plymouth work is a sound basis for framing how decisions upon the implementation of remanufacturing principles may impact the needs for organising, operating and controlling a production unit. As such these experiences are invaluable examples for case studies to exemplify remanufacturing in action, aspects that are too detailed for this study. The thesis also provides a comprehensive literature review in this area.

In 2001, Lee Altman at Sheffield Hallam's WAMTech (now defunct), conducted a study into remanufacturing activity in the South Yorkshire area. He revealed a mixture of organisations operating across a range of scales and values, and supporting many traditional industries. Many of the organisations were charitable or supported, were marginally economic, and fulfilled a social objective of offering employment to the otherwise disadvantaged. Often, the outputs were cascaded into lower value secondary markets.

Of historic interest is the work of Tim Cooper, contributing to the New Economics Foundation, and now at Sheffield-Hallam. In the mid 1990s, Cooper (1994) produced a number of articles for the Foundation berating the poor longevity of capital – mainly consumer electrical – goods. His articles addressed the factors that were driving the cost-performance trade-offs, and mechanisms to redress the material-labour balance to favour longer-living goods. He assessed the potential of classes of consumer good to be re-engineered in this way, and a number of his policy actions, if modified or extended, could be adapted to address the similar concerns over the economics of remanufactured goods.

Cooper continues to be active in this field at Sheffield Hallam.

Something of a lone voice has been that of Walter Stahel at Institut de la Durée, Geneva. Stahel has been the guru of the European remanufacturing and recycling cogniscenti for at least a decade, placing the technique within a comprehensive policy and business service framework.

Building on Cooper's themes of durability, Stahel also advocates legislating for minimum warranty periods, promotion of use of used components in new builds, changing measures of economic growth to account for resource effectiveness, research into materials and design, and even mild social re-engineering. Stahel also berates current recycling drives as a necessary but inadequate step:

Recycling ultimately does not reduce material usage, merely upsets pricing structures. Mandatory recycling leads to better recycling technologies, not better products; producer responsibility drives better products and efficient economies. Stahel has other thought-provoking ideas for the simultaneous growth of developing nations.

The servicization concept has received more attention, presumably because it appears to be a straightforward extension of traditional marketing concepts and an observed trend to services. Lately a fashionable Eco-Service concept has been growing. Undoubtedly this is inspired by the need for companies to appear green, sometimes employing dubious justifications; difference in behaviour can therefore appear arbitrary, piecemeal and inconsistent across a sector.

Very little fundamental analysis of what constitutes an eco-service exists, but it is likely that some form of life-cycle analysis is required, though more complex to account for multiple impact forms – energy, pollution, waste. Surrey University's Centre for Environmental Strategy is working in this area together with a number of "clean technology" design researchers in Europe, USA and elsewhere. A number of British Universities now offer "Design for Environment" modules that may, conceivably, broach issues relevant to this field.

It is still a matter of debate as to whether ostensibly

"environmental" business practices are truly beneficial to the environment. Remanufacturing is another practice that must be justified by financial worth and, in future, judged against other measures using a coherent assessment technique: Eco-design impact assessment techniques could also be used to generically quantify the benefits of remanufacturing, thus putting the activity on firmer ground to argue its corner.

In addition, market forces may not overcome all barriers to changing market structures. Matthew Cooke at Cranfield University's Business School (Cooke, 2002) has examined the receptivity of organisations to the eco-service concept and identified a number of internal factors, such as strategic orientation, structure and capabilities that will also be relevant to the adoption of remanufacturing concepts.

Findings of previous work

As noted previously, by far the most significant and reputable attempt to quantify a nation's remanufacturing activity has been that conducted by Lund (1996) in his seminal study of the US.

Lund noted activity across a wide range of manufacturing activity, mostly in business to business transactions, but significantly also in the automotive after-market. He estimated a total economic activity of all 73,000 firms engaged in some kind of remanufacturing at over $50 billion, and employing 480,000 people.

Lund's spin-off, the National Center for Remanufacturing & Resource Recovery at Rochester Institute of Technology, estimates that remanufacturing is saving 16 million barrels of crude oil equivalent in energy, equal to eight nuclear power stations. They do not state whether this is extrapolated from the USA experience, which we believe to be untypical of the rest of the developed world. (In contrast they may underestimate the benefits of the developed world, where the disposable society cannot be afforded.)

Remanufacturing typically occurs in industrial and machinery sectors. Here, end-users are very price and performance-sensitive, although they may be constrained by short planning and investment horizons. They are therefore looking to find products that "deliver" in a reasonable period. Such products may take the form of services if a reputable and stable supplier can be found – this aspect is not covered in depth in Lund's report.

Remanufacturing also takes place in constrained markets where a backlog of old technology still functions. To some extent this describes the automotive market, where remanufacturers often pick up vehicle manufacturers' end-of-lines, but is very true of military applications.

In this field, the long proving and qualifying periods, coupled with a need to extract maximum value from expensive, customised equipment means extended support of sometimes anachronistic equipment.

Legislative pressures provide fertile ground for remanufacture: the aviation industry, military considerations aside, is effectively forced to remanufacture many systems simply to ensure safety performance. Altman's (2001) report "Survey of Remanufacturing Industry & Opportunities in South Yorkshire" provides a good semi-quantitative overview of the types of industries, OEM relationships and business climate in that region.

Headline findings are reproduced here.
As background to the industrial composition of the region, Figure 7 (see pages 73 - 79 for all figures) shows the heavy bias of the area to automotive activity. This reflects the ongoing and well-established role of the automotive sector in general, and the persistence of local interest in engineering. Of those engaged in remanufacturing, Figure 8 shows approximate percentages of OEMs, contracted agents and independents. This is broadly in the ratio 1:2:4.

As a point of interest, it appears that – in the automotive sector at least – the truly independent remanufacturer is a dying breed: Many are also partially foreign agents or spares suppliers for OEM, and much rationalisation has occurred. In contrast, ownership of the cores is biased towards the customer or independent remanufacturer, indicating that remanufacturing is generally regarded as a service. In addition, there was a low prevalence of OEMs using their relationships to gain feedback on the performance of their products in the field.

The companies surveyed were typically SMEs, employing less than 200 people, and average turnover of c. $6m. Larger operators were generally OEMs with integrated service facilities or the larger contractors.

Apart from these limited studies, no generalised review of UK activity has been conducted, nor any attempt to place it in the context of other recovery methods.

Match to previous work

Lund's survey was conducted by three researchers over at least two years as part of the school's business research programme. Questionnaires were distributed to over 20,000 companies and returns received for around 2,000.

The scope of the present study does not replicate the extent of this pioneering work. Rather, it attempts, in a limited way, to take assess the depth of remanufacturing in the UK using the American study as a basic set of industries to query. Whilst it is relevant to quantify the contribution to sustainability, it is more important to determine the trends, the reasons for the trends, and the overall impact on resource use and waste. This may then frame policy changes.

This study does not take a rigorous analytical approach to the task; preliminary research has revealed that remanufacturing activity is not as recognised or organised through trade groups and associations as in the USA; neither does appreciable quantitative supporting data exist. We have therefore been forced to synthesise fragmentary views, information and opinion from industry practitioners, and extrapolate these into similar industrial sectors. However, this work differs from Lund's in its desire to understand the climate in which remanufacturers operate.

The purpose is therefore not primarily to catalogue the state of the economy, but rather to understand the influences and possible counter-measures. It is a study conducted as a basis for further investigation, and as input to informed decisions around the relative importance of recycling and reuse. This makes it unique.

Parallel work

We should attempt, briefly, to place this study in the context of other (ongoing) studies into "sustainability" issues. Apart from the theoretical aspects already covered in the literature review, various bodies are engaged in assessing, measuring or modelling resource flows within the economy as a precursor to long-term monitoring and consideration of action. Biffaward also sponsors some of these key initiatives. Perhaps the most ambitious work is the UK Mass Balance. This attempts to map key material flows – down to a regional level – and to attribute energy and pollution costs with the activity. The RDAs tentatively presume that this will assist in benchmarking their sustainable growth remits objectively. A mass balance for the Isle of Wight – a somewhat more bounded task – has been completed and disseminated. The Wuppertal Institute has been researching national resource productivities related to economic outputs, as conventionally measured by GDP or GNP.

Basic research into low resource intensity products and processes is a key theme of several government-sponsored research (LINK) programmes. As well as themes to address the issue within initiatives for targeted sectors, a dedicated strand, the Sustainable Technology Initiative (STI), considers these issues directly, independent of sector. Extended life-cycle and design for reuse are qualifying criteria for the programme. STI follows on from a related programme, Waste Minimisation, Recovery, Reuse and Recycling in Industry (WMR3), a research-based precursor to the WRAP initiative.

At the operations end of the spectrum, Ijomah's work has contributed directly to another Biffaward study into the potential for remanufacturing of white goods (strictly remarketing, which implies some other standard of refurbishment). This has identified a vast global opportunity; whether this can be realised will depend critically on consumer behaviours.

As noted previously, Tim Cooper at Sheffield Hallam University UK continues to pursue themes of product longevity. The Wuppertal Institute in Germany is pioneering in frameworks and metrics for assessing economic activity and environmental impacts. Numerous American universities coordinate research on eco-design (UoC Berkley, Carnegie Mellon, MIT, UCLA, GIT, MTU…). Holland is also a centre of activity with interests at Delft and Eindhoven University of Technology, which has expertise in Reverse Logistics.

One of the most relevant issues related to remanufacturing is that of servicisation. This encompasses aspects of dematerialisation, relinquishing ownership, service innovation and shared benefits of suppliers and purchasers. In many areas this may be a necessary precursor to remanufacturing since longevity of the good core to the service is no longer the responsibility of the user, but of the supplier; they are incentivised to minimise the life-cycle cost of the service.

The concepts behind service innovation have been explored by the Green Alliance (2002), building on the work of the Swiss Product-Life Institute, and the Wuppertal Institute. Of special relevance is the ongoing work of the German NGO, IÖW, which is attempting to identify for each of the Länder opportunities to develop market and non-market services. The IÖW has also been party to a study of eco-efficient producer services across Europe (Zaring, 2001). Such initiatives may be transportable to the UK context.

DEFINING REMANUFACTURE

According to Plymouth University Enterprise (Ijomah, 2002) and others, a robust academic description of remanufacturing is:

"The process of returning a used product to at least Original Equipment Manufacturer performance specification and giving the resultant product a warranty that is at least equal to that of a newly manufactured equivalent"

As described in a variety of sources, researchers generally require the remanufacturer to display a distinct set of capabilities to meet these objectives, including:

* sourcing cores
* inspection and classification on arrival
* disassembly
* component testing
* remediation, repair or replacement
* re-assembly
* assembly testing and despatch

This definition is robust, and necessary to circumscribe a clear domain of academic study. In our experience, the words and practice of remanufacturing (and its definition) are not universally understood, used or applied strictly in this manner. We note the use of the words reconditioning and refurbishment in addition to repair, which may appear interchangeable to some and as fine gradations of quality to others. (Ijomah (2002) differentiates and defines these activities with respect to remanufacture.)

These uses may occur even within the same business sector. In general, however, it is acknowledged that the concept of remanufacturing - if not the practice - aspires to the highest standards of product performance.

This tension in definition of the performance standard may be key to the acceptance of remanufactured goods more widely in the economy. It is clear that some markets are constrained by the reputation of the products of those remanufacturers who provide a lower standard of remanufacturing – for example, by not replacing components that are almost certain to deteriorate within the next operating cycle.

Such practices, whilst certainly not illegal, hamper the establishment of an acceptable universal performance standard. In such markets, remanufacturers rarely become direct suppliers to the ultimate customer. In contrast, it is possible to identify markets where remanufacturing is a necessary and embedded practice, and synonymous with repair. This is the case, for example, in the aircraft industry, where third parties (often regulatory) have imposed safety criteria which imply Quality Control practices typical of that required for remanufacturing. Here, a level playing field has been established by external forces; it is then up to the purchaser i.e. the airline, to justify the rigour and frequency of maintenance to underwrite its own license to operate. Such examples provide pointers as to how to frame a working standard for remanufacturing industries that does not draw the practice into disrepute.

With respect to other researchers, we note that the studies of Altman (2001) and Lund (1996) took a much more inclusive approach to the definition of remanufacturing. Altman considered a number of companies and NGOs in the South Yorkshire area whose activities might be described as global or local. Amongst the latter, he described communal and charitable organisations catering for the needs of local disadvantaged "customers". Here, customer expectations were not so great, so aesthetics were not as important - although goods clearly complied with legislation. Such products could not, therefore, be considered suitable for reintroduction into a primary market of the highest quality.

We believe this to be true also of the American study, where it is also known that a more liberal attitude to the definition exists. Lund study broad classes of industry, and according to the self-defining sets of Remanufacturing Associations. These will include a range of standards, and also co-dependent suppliers that may also supply into primary or other markets in addition to pure remanufacturing. Taking these factors into consideration, and mindful of a need to compare on a like-for-like basis, we too will pursue a broader definition of remanufacturing. Ultimately this is justified by the overall aim of defining a climate in which profitable businesses may thrive, whilst reducing the use of resources.

With this intent, we must applaud and encourage the efforts of all firms that engage in returning goods back to the operating cycle. It is then (merely) another element in the product mix, defined by mutual agreement of the remanufacturer, retailer and distributor, as to the required performance standard of the goods or service, and which must be unambiguously described to the end user.

Tolerating such ambiguity necessarily allows wide error in the estimate of economic activity and resource conservation attributable to remanufacturing.

PROFILING EXEMPLAR UK COMPANIES

This section describes a portion of the work in which detailed interviews were conducted with a number of British companies that were known to be remanufacturers.

On the whole, these companies are unlikely to be known to the general public: As noted by Lund (1996), most remanufacturing companies – or certainly, third party remanufacturers – operate at a very low level of public visibility.

However, the companies that we consulted would certainly be considered as high-end operators by their peer groups. We believe, therefore, that their experiences are valuable and possibly exemplary of business possibilities.

Purpose of activity

The purpose of this phase of activity is described below.

To confirm the existence of remanufacturing in the sector

The target companies broadly represented sectors identified in Lund's study as being of economic significance in the US. Our purpose was therefore to briefly validate this report as a basis for examining the UK economy, by establishing that remanufacturing was occurring, and at a significant level.

It should be noted that, due to time constraints, the candidate list was much longer than could feasibly be interviewed, and represented more activities. However, the data that was gathered was rich, and a number of common themes presented themselves.

To assess the markets and trends from perspective of leading practitioners

Leading operators are generally likely to be those who, by dint of capability or available resources, have a better than average understanding of the business environment. In particular, it is reasonable to assume that their longevity has exposed them to this environment for long enough to discern and describe changes, and to speculate upon the underlying causes. This background information also sets the context for describing the industry, and relating to other participants. Such views must be tempered by whether the interviewee is an OEM, contractor or independent operator.

To understand their concerns & barriers to development

A description of the changes in the business environment is not a basis for action. More relevant is the perception of those operators concerning impediments to business and what actions might be taken to assist in overcoming them. These contribute to setting the recommendations by sector or industry.

To determine critical success factors

Target companies were generally enthusiastic about remanufacturing as a business opportunity. Most of them also saw it as adding an extra dimension to their product mix. Often this had required changes to the business and operations structures, the way they related to the external environment, and the rigour of their tracking and control processes. As a result, they displayed characteristics of top-performing and motivational companies. There behaviours may translate into success if applied elsewhere.

Establish depth of remanufacturing

Repeatedly, the question of the definition and meaning of "remanufacturing" was raised. There was widespread acknowledgement that the terminology may have been used indiscriminately, sometimes to the disadvantage of growth in the sector.

Understand role of structural factors (eg rate of technology change, relationship to OEM, consumer attitudes, foreign competition)

Questions on this aspect, if not covered under other sections, produce simple categorizations that help to understand the reasons for the success of otherwise of remanufacturing. This can be used to predict the likelihood of success of other products as remanufactured goods.

Sectors

The following sectors were interviewed:

* ABRO - military logistics support
* Alstom - power turbines
* Blackhill Engineering - process plant (quarry)
* Central Bottling International - food packaging
* Comptec - refrigeration compressors
* Danwood - office equipment

* Electroversal - electronics
* Mercia Laser - toner cartridges
* Milliken Carpet - industrial carpet
* Perkins Engines - commercial & industrial engines
* Powerhire - process plant (quarry)
* Solectron - IT & telecommunications equipment
* Vickers SE - engines (military, commercial) & APUs
* Wealdstone - automotive engines

Methodology

This aspect of the study was conducted simply as a set of face-to-face interviews with a single representative of the relevant organisation. This individual was either the managing director (in small organisations), business or marketing director for larger companies, or a technical manager where the scope of the technology required this, and where available. Often, one person's role might include all of these aspects, particularly in the owner-managed organisations.

The planned nature of these events was conducive to greater preparation, and the use of a more formal approach to information gathering. Therefore, a question list was used as a template, as shown in Appendix 7.

The scope of this was not merely to discover the nature, depth and scope of the remanufacturing activities, but to examine something more of the business environment, changes observed over time, extrapolation into the future, and barriers and enablers of business expansion.

In addition, the nature of relationships to other organisations – OEMs, third parties or customers – could be explored. Topics on the question list were not probed in sequence, but allowed to emerge, or were triggered at an appropriate point in the conversation.

Reports

Inclusion of each of the interview outputs from the interviews were compiled into the fixed format reports of Appendix 6.

Findings

What is most apparent is that, except in one case, all remanufacturing businesses were grown in response to a business opportunity. They were not driven by an altruistic green mission. Even for the one exception (Milliken Carpet), a product was established in anticipation of a perceived future threat to business operation by a far-sighted owner-director; this is coincidentally the product nearest to what might be termed loosely "designed for remanufacture".

Our companies covered a range of products at various stages in the life-cycle, of varying product maturity/evolution, and a range of values/profit margins. Some sectors appear to be in decline (or change) as far as remanufacture is concerned. These may be attributable to the entry of cheaper, mass produced units from the Far-East (motors) or improved functionality at limited lifetime of competitive imports. These have reduced the viability of some products as stand-alone goods.

However, other mass-produced products are thriving in this environment. In general, these are associated with more evolved, service-oriented products that increase the range of options open to the purchaser whilst increasing loyalty to the brand. Examples include photocopier markets where all options from purchase, upgrade, pay per use, remote billing and maintenance, to profit-share are employed. At the other end of the price range, the same model exists for power turbines and diesel traction units, and at increased profitability over straight sales.

Some products are open to remanufacture (or repair) but have little overall value currently largely because of the relative cost of labour in relation to energy and materials. However, their impact on the resources in future e.g. artificial fibre clothing, may represent a significant carbon reservoir.

Our scoping study reveals that remanufacturing exists in the valuable sectors identified in the US study, but to a somewhat lesser extent, judged by limited perceptions of manufacturers. It is clear that remanufacturing is enabled by emergence of new repair techniques, such that, for example, machine tool pieces may now be offered on a per-use basis.

Top flight remanufacturers appear to be flexible and adaptable in coping with the business environment, and the manufacturing task. In very high value products, the organisational competencies are significantly affected by whether the company is remanufacturing its own, or another party's goods. Here, issues of product knowledge determine the need for permanent reverse engineering

capabilities, and also channels for returning a validated, endorsed, branded product to market. This can be a significant barrier to operations. In certain areas, this has already led to squeezing out and consolidation of smaller operators to service the needs of large global OEMs eg automotive.

It is also clear that a different skill set, problem-solution-oriented, is required in many of these organisations. This is necessary in order to cope with the "unknown input-known output" transformation model. Generally, such mechanical skills are hard to find, given a decline in the apprentice stream for craft skills in the UK; IT literacy is not a strong differentiator in these industries. However, workers in these businesses often appear more motivated and interested, considering these prime jobs in the field. Remanufacturing activities may therefore be a significant and unrecognised contributor to quality of work-life.

Although remanufacturing is more manually intensive and problem-oriented than manufacturing, many improvement techniques are still relevant. Exemplary companies can still operate lean and cellular manufacturing, and tend to display high levels of competence in inventory control, component tracking and maintenance history, largely driven by the need for warranty and liability.

They also tend to be very conscious of the cost components of manufacture and have waste recycling channels. In the USA, Caterpillar operates a world-class and highly materials-efficient remanufacturing programme that extends reverse logistics into the dealerships. It also aggressively pursues emergent engineering techniques that can lead to greater reclamation of used components.

These interviews have revealed an ingenious, valuable and largely unrecognised set of industries driven with a clear grasp of the economic value of their services. (Most remanufacturers describe themselves as service providers). In numerous cases, the limitations to growth are set by customer perception of the second class nature of remanufacture goods.

Cases in point here are fashion-oriented, lifestyle or status products: cars, white goods, attire. In some cases, barriers are introduced by original manufacturers – covertly and overtly. Elsewhere, skill shortages limit capacity to remanufacture. Cheap imports will continue to erode the viability of low-end engineering products until labour costs abroad rise. However, this does not rule out competition from low-cost, well-organised and networked organisations that can credibly intermediate between suppliers and purchasers of goods.

EXAMINING THE BROADER UK CONTEXT

Purpose

The purpose of this activity was to address the primary objective of the work, namely:

* to identify areas of remanufacturing in the UK, estimate their contribution to the economy, and assess their role in achieving a sustainable manufacturing society
* to project this across all sectors to totalise UK activity, extrapolating into areas of sparse data
* to estimate the potential contribution of remanufacturing both economically, and as a waste management tool

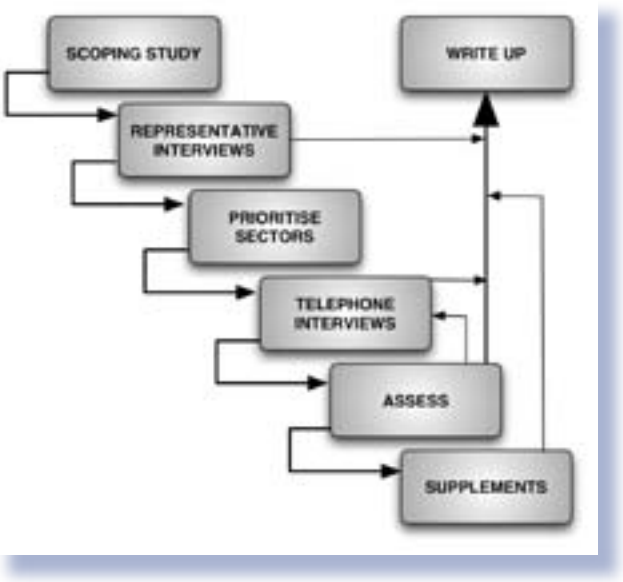
It should be recognised that this is an ambitious objective conducted using limited resources, and hence will produce only a crude estimate of activity and opportunity.

However, we hope that our approach is sufficiently explicit, the assumptions clearly expressed and the analysis suitably presented that the whole can justifiably form the basis of further detailed examination or research.

Methodology

The broad approach taken is illustrated in Figure 5.

Figure 5. Overview of economic assessment process



Our entry into this process has been realised through collection and absorption of background research, and thinking, and following those leads into industries and products of likely relevance. As guidance we were also aware of the sectors addressed by the Lund study of US remanufacturing. Subsequently we have approached a variety of trade bodies and associations, scanned trade journals and publications and then contacted various exemplars of the activity.

As a result of this high level activity, we have developed an understanding of the sorts of products that are likely to be remanufactured. Briefly, these are characterised by:

* higher value
* complex
* durable
* de-personalised (ie not lifestyle or status oriented)

This simple categorization ignores issues of, for example, barriers to entry placed by manufacturers or distributors, or the pricing of competitive goods, such as imports; it merely indicates a potential for profitable remanufacture. We note also that this might exclude some goods known to be reused, even when resold at much reduced price. These "grey" markets are recognised and may be substantial whilst falling outside the strict definition of remanufacturing. (Later, we attempt to bracket our findings by postulating "core remanufacturing" and the "grey market").

Next, we examined the classes of industry code (SIC), as used by DTI and Customs & Excise. In particular we focused on divisions 28 through 36, a large component of Manufacturing (Group D), but excluding basic materials extraction and synthesis.

We have justified this subset because, in general, remanufacturing companies are:

* associated with the production of durable manufactured assemblies, mostly - but not exclusively - metal
* not classifying themselves (yet) in the service sector, and not explicitly within codes G (wholesale, retail and repairs), K71 (renting of equipment without operator), or even D37 (recycling)

We note that no general categorisation exists for tracking

and accounting for the trade flows associated with remanufacturing in ONS or DTI statistics. Similarly, trade directories cannot distinguish such activities.

For each reported sub-class (as shown in Appendix 1) we applied a crude screening - based on the judgment criteria outlined above - into the following categories, subject to qualifications described:

* included as Higher Priority: Sector capable of analysis, feasible data collection, suspected or known significant remanufacturing activity and total activity of significant economic value to the UK or SEEDA economy (SEEDA is the third party supporter for this study)
* included as Lower Priority: Sector capable of analysis, feasible data collection and of lower total significant economic value to the UK or SEEDA economy, or suspected lower remanufacturing activity
* included as an Extrapolated Sector: Sector not amenable to detailed analysis, but judged similar enough to another sector to justify applying statistics from there onto it
* excluded: Low total economic value or suspected or known low remanufacturing activity

As a result, we generated the priority action list of Table 1 to guide our data-gathering approach. For the majority of classes, down to three-digit codes, it is possible to obtain turnover statistics related to domestic sales and export sales from the ONS. It is also possible to obtain trade-in data (import/export) data by sector from the same source, but different department. These have been synthesised to create a net consumption of sector products by value.

In effect, these numbers broadly represent the maximum target of remanufacturing across each sector assuming elimination of all new product into the system.

Our analysis is complicated by the fact that sectors rarely are composed of a homogeneous set of products; further they may find themselves destined for use in a diversity of end products, which themselves are the subject of other sectoral activities; worse still, companies are generally allocated to sectors based on the SIC of their main product or activity, which could be distorting the basic figures. This is most likely to be the case for large, diversified companies; hence it was necessary to determine the classification code when interviewing these larger operators, and to quiz them as to the allocation of turnover to the product in question.

Table 1: Group Categorisations

Priority	Number of Groups (SICs)	Data Extraction Process
Higher	12 (init. est.)	Determine whether Groups must be subdivided to into a number of eg product manufacturers. Contact trade associations, industry bodies and trade journals to establish: significance of remanufacturing in the sub-sector, background data, quantitative data - if available - further references and sources of knowledge, major operators in the sector. Meet these contacts if appropriate. Identify selection of companies (10-15) to engage in substantive telephone interview. Capture large companies to judge impact of large operators. Small companies to assess “tail” and business pressures. Mail to pre-warn, interview and assimilate data. Synthesise raw data, project value and impact, postulate potential level.
Lower	14 (init. est.)	Determine whether Group must be subdivided to into a number of eg product manufacturers. Contact trade associations, industry bodies and trade journals to establish: significance of remanufacturing in the sub-sector, background data, quantitative data - if available - further references and sources of knowledge, major operators in the sector. Meet these contacts if appropriate. Identify small selection of companies (4-8) to engage in substantive telephone interview. Capture large companies to judge impact of large operators. Small companies to assess “tail” and business pressures. Interview and assimilate data. Synthesise raw data, project value and impact, postulate potential level.
Extrapolated	<10	Find comparable sectors based on value and complexity of equipment, user relationship etc. Take average of comparable sectors and impose on sector value. Where possible, spot-phone to gauge typical unit embedded resource ie mass, material. Convert to carbon equivalent.
Excluded	Balance	Ignore.

In this context, Excluded covers only the SICs concerned with manufacturing (28-36); services are excluded by default.

Even so, substantial judgement is required in assessing the relative contributions of each product type to a sector, and the proportion of remanufacturing in each. This coverage is necessarily thin in a study of this magnitude. Notwithstanding these complexities, we have pursued the investigation by firstly contacting trade bodies, industry associations and trade journals.

These have proven fruitful sources for identifying whether remanufacturing is at all recognised and, if so, background information - sometimes quantitative - on the subject. They have also been able to identify key industry operators and other principle contacts to follow up in detail.

Depending on sector priority and complexity, a number of companies have been interviewed in a structured manner. The interviews have generally followed the proforma of Appendix 2, which is itself a cut-down question list from the face-to-face interviews conducted in the scoping phase of the project.

Lastly, in order to consider the profile of remanufacturing more widely, we have used the membership lists of the Resource Recovery Forum (including the Warmer Bulletin) to request instances of remanufacturing known to the membership. This rather arbitrary approach at least indicates the profile of the activity within the community, albeit a rather selective one. In any case, there is always the chance of uncovering some unexpected industry.

Accounting for savings

We have attempted to assess crudely the value of remanufacturing from a number of perspectives and measurement frames. Of primary interest is the value of the activity as described by GDP (sales as reported to the ONS), as far as can be de-convoluted.

However, the presence of an economic activity does not necessarily relate to the impact on sustainability. In this study, we have therefore attempted to describe the impact of remanufacturing in terms of a simple and understandable metric.

The measure we have chosen is the carbon equivalent (strictly CO_{2e}). Our rationale is this:

* in general, remanufacturing will be applied to durable capital goods, composed largely of metal, commonly steel
* most of the metal will be retained during the remanufacturing process
* remanufacturing therefore displaces the extraction, refining, smelting and forming of material (steel) equivalent to the weight of the remanufactured part
* this analysis is simplified by ignoring replacement of elements, transport, labour, mixed materials and overheads associated with remanufacture. We assume these are offset by ignoring the supplementary processing steps applied to raw steel to produce the new good in the first instance
* this analysis will underestimate the savings for components made of more energy intensive metals, such as aluminium and magnesium
* for cores made largely of plastic, the conversion energy of plastic will be converted to CO_{2e}, assumed to be 20% of the weight of plastic (as oil)

Standards of conversion

For the purposes of working to a common standard, we have taken the CO_2 equivalence figures published by the Carbon Trust, and available on the website at www.thecarbontrust.co.uk.

In general, with our base material as steel, we are benchmarking against a range of processes supplying the alloy, and employing varying smelting technologies based on chemical or electrical methods. Accordingly, with the balance in the UK towards chemical routes, an appropriate conversion factor is that relating to coke, ie 0.37 kg/kWh.

Obtaining definitive figures for the energetics of steel production is more problematic. For example, the analysis by Stubble et al. (2000), conducted on behalf of the US DoE into energy consumption in US steel mills takes account of many processes and scales of operation. There is great diversity amongst the efficiencies of various routes, but primary steel production seems to require c. 15 GJ/te.

After shaping, forging, rolling or even casting in secondary materials, we shall assume that this figure is nearer 25 GJ/te (or 6900 kW.hr/te). We note that this is lower than the value for the Basic Oxygen Furnace of 33 GJ/te, reflecting some conservatism. Combining the two former figures yields a CO_{2e} burden of 2.5 te/te.

FINDINGS BY SECTOR

This section describes the broad findings of the surveys and discussions that have taken place with representatives of the sectors chosen for investigation. These comprise a mixture of quantitative, semi-quantitative and qualitative data that form the basis of more detailed analysis elsewhere. For example, economic analysis is presented in relevant appendixes and in relation to manufacturing in general.

Automotive remanufacture

The area of automotive remanufacture is extensive and complex, embracing a wide range of components, relationships and scales of operators from one-man bands to multi-million pound companies. Whole-car remanufacturing as such does not exist to any significant extent. Rather, there is a thriving market in valuable component parts - mostly "under-bonnet" ranging from engines, fuel injector systems, gearboxes, transmissions, starters and alternators, pumps and turbos, ABS units, air conditioning, clutches, radiators and drive shafts. Of increasing importance and cost is the electronic engine management unit. All of these are relatively durable and intrinsically valuable enough to warrant the effort of recovery and reprocessing.

The passenger car market in particular is characterised by intense promotional activity from the Branded Vehicle Assemblers, positioning the car as an aspirational good that should be replaced at a frequency commensurate with the "status" of the purchaser. (That cars are still viable is evidenced by the buoyant second-hand market.) New car editions are now generally defined by fashionable variations in styling, non-essential luxury features and statutory or peer-group pressure upgrades in economy, emissions or safety.

Of these, it is the bodywork aspect that generally defines the newness of the article.

In practice, the passenger automotive market is tightly controlled by the BVAs, firstly through their quality control and purchasing policies, and secondly through their dealership policies. Concerted lobbying is also an important element in controlling the rate and extent of change in obligation. Automotive is a global market, with maximum exploitation of regional cost structures and prices, subject to geographical and institutional barriers. Profitability is built on the pillars of reducing costs, including intense supplier price competition, but requiring high volume throughput. Increasingly, profit is gained through the after-market service operations, with a high mark-up on spares and servicing activities. Any activity that appears to jeopardise this structure can be subject to pressure from the BVAs by a variety of mechanisms – derogatory PR to defame remanufactured goods, withholding technical information, exclusivity of licensing tooling with preferred suppliers, dealer ostracization to prevent unauthorised part sales.

As a result, remanufacturing is often seen as diverting from the main business of making and selling cars. However, this must be reconciled against the needs of warranty repairs (and out-of-warranty replacements). BVAs have recognised that significant value can be recovered by remanufacture of key components (we note, for example, that VAG owner handbooks advertise the possibility of authorised reconditioned [exchange parts] as a cheaper alternative to new items. These always carry at least one year's warranty) - particularly the engine - as an alternative to replacement, but often requires the assistance of third parties. This is because remanufacturing operations often require a different skill set and operations from conventional lines.

Therefore, remanufacturing is often tolerated as a necessary evil, but limited largely through the availability of core components.

As described previously, some BVAs (Ford, Landrover) have outsourced their (eg engine) remanufacture. Others (VW, Peugeot, Fiat) have retained it in-house.

We know only one (Renault) that actively publicises its remanufacturing as a distinct customer service. In addition to this official activity, there are a vast number of operators, mostly 1-20 person organisations, which undertake bespoke, specialist, one-off or classic automotive remanufacture (official channels are reluctant to support engines greater than 10 years old).

In the view of some observers, this fragmented, unendorsed market is as large as, or greater than the contracted remanufacturing activity (excluding captive remanufacture by VW et al.).

Relevance to remanufacturing

Despite its current low profile, automotive remanufacturing has a long history in the industry. This was necessitated by the relatively low reliability of early engines, which typically lasted only 80,000 km before the

war. On the other hand, labour was cheap, and engines small and technologically simple, so remanufacture was an obvious solution. As late as the 1950s, BMC was remanufacturing 50,000 engines per year out of a total market of 1 million.

Since then, the market has grown by 150%. Today's engines are more complex, lighter, with finer tolerances and increased durability, possess improved lubrication, create fewer emissions, and are equipped with advanced sensing and control electronics. At first manufacture, suppliers of these items are subject to some of the most rigorous inspection and quality control techniques to be found in industry. Subsequent remanufacture is subject to equal levels of control throughout the process (we note that Quality Control representatives of the BVAs are often located within 3rd party remanufacturing facilities).

Benefits of remanufacturing

On balance, although the level of remanufacturing has fallen in each component class, it is still a viable option for many broken or under-performing components, with significant savings in embedded energy (emergy). With increased car features, the scope for remanufacturing has expanded horizontally. The components of interest are largely metallic, comprising steel, copper, aluminium and magnesium. We estimate that in excess of 100,000 engines per year are remanufactured in the UK. Taking an average weight of 150 kg saving per engine, this equates to a metal recovery rate of 15 kte p.a.

Further, we estimate the weight of other remanufacturable components to be 100 kg per vehicle. Assuming, crudely, that the same number of these components is remanufactured compared to engines, then this equates to a further 10 kte p.a. equivalent of components.

The total equivalent mass of remanufactured components is therefore in the region of 25 kte pa; in Appendix 3, other approaches to this calculation suggest upwards of 30 kte per annum. In summary, therefore, we estimate an industry value of £350m and carbon equivalent savings of 100 kte CO_{2e} per annum at least.

Advanced automotive engines are generally built from magnesium or aluminium alloys, materials of significantly higher energy content than steel, accordingly, the carbon savings are understated.

Potential of remanufacturing

Although remanufacturing already encompasses diverse products and a wide range of company sizes, by and large its effect is restricted to the after-market. To our knowledge, only one company, BMW, is reputed, but not confirmed, to be placing remanufactured goods into its new vehicles.

There is an obvious opportunity for remanufacturing therefore to be extended into the new vehicle operation. The scope of this will be limited by the constant evolution of component parts with new materials and added functionality, although a more integrated relationship between manufacturing and remanufacturing could obviate this.

A significant unreported opportunity for remanufacturing lies in a less glamorous, low profile sector namely agricultural and industrial vehicles. Engines in this sector are generally diesels, and tend to have a longer use life than passenger vehicles.

For comparison, the latter last 12-14 years, the former often over 20. In this period, significant technological advances have been made resulting in cleaner emissions and better economy. It is feasible for such equipment to be upgraded if not to modern standards, then at least substantially better than design or current performance.

Such improvement is unlikely to happen voluntarily, and will require motivation of either legislation or inducement by penalising the true cost of running such equipment.

The analogy in this sector of the market is with:

* power turbines: remanufactured items have been successfully upgraded to conform to latest emission standards
* military equipment: eg vehicles and aircraft are routinely refitted with improved electronics and braking systems

Barriers to increased remanufacturing

Independent remanufacturers are unanimous in their opinions about barriers to expansion of business. (We ignore general decline in business levels due to improved longevity of OEM product).

Largely, these issues relate to the availability of technical

information by which manufacturing specifications and tolerances are defined. This is particularly important in today's markets as components are subject to a high rate of evolution, making reverse engineering an increasing component of the operation, yet with shorter production runs in which to recoup that cost.

In contrast, the USA operates under the Freedom of Information Act, which allows general access to such information. UK remanufacturers are often forced to engage USA channels to determine information relevant to UK manufacture. Similar provisions exist in some European states.

Secondly, business can also be limited by the availability of cores. In theory, dealers are supposed to return defective cores through BVA channels for in-house or outsourced remanufacture. In practice there is a significant grey market, and slippages from the system, and unofficial brokerage operations.

There is also a significant loss through cars going to scrap without recovery of reusable components. Note that impending ELV directives will merely force the recycling of materials, not necessarily remanufacture. Invariably this will encourage the cheapest option, probably metal recovery. Improved breaker practices and broker channels would assist here.

There is also a remnant of reputation of remanufacturing quality with the public. This is more likely to be with the smaller operators who are meeting the needs of independent service stations. The larger remanufacturers are now having to comply with the Quality Control requirements of tier suppliers to the extent of having BVA representatives on-site.

To some extent this is also the attitude of BVAs: When asked whether they included remanufactured parts in their new cars, one BVA expressed great concern over how the buying public would perceive a new article ostensibly containing re-used parts.

Even large, well-known brands such as this therefore feel daunted by the task of tackling public opinion. To our knowledge there is only one BVA reputed to be reusing parts for new builds – this is unconfirmed. A more serious barrier to inclusion in new cars is the legal definition of new, which essentially prohibits the supply of anything other than virgin metal components in these circumstances.

Air conditioning & refrigeration compressors

The air-conditioning and refrigeration equipment market is extremely active in the USA, primarily as a result of the more extreme climate, and a greater reliance on artificial climate control mechanisms. Such basic needs have therefore spawned an active remanufacturing sector. In the UK, the activity is smaller commensurate with the size of the basic demand.

Within the UK SICs, confusingly, trade statistics for the sector are buried within Compressors and Pumps. In this context, "compressors" includes not only refrigeration but every other form of gas compression too. However, these products generally find use within industrial application, and are therefore likely to offer similar opportunity for remanufacture. On the other hand, compressors for domestic refrigeration are categorised separately. Such items are at the centre of current debates over end-of-life treatment. Our survey of operators in the industry reveals that, due to size and construction methods, domestic compressors hold little value for remanufacturers. There is therefore little incentive to remanufacture from the supply side.

We should note that many compressors are driven by electrical motors, and that electrical motor rewinding is itself a vibrant, if cutthroat, activity. There is therefore a possibility of double-counting in this area if motors are also considered under another SIC.

Compressor repair as remanufacturing

Operators in these classes increasingly deserve to be known as remanufacturers. The activity is soundly based on engineering capability in machining fixed and moving components to high tolerances, requiring liability and warranty. Preference for working with known, capable suppliers has forced much of the rogue element out of the market. A growing element of the activity is involved with system diagnosis and rectification, not simply component repair.

Industry dimension

The supply of new equipment into the UK is dominated by foreign imports, or goods made by UK-based subsidiaries of mainly American majors. This reflects the

predominance of the US as a consumer and purchaser of such products, and the relative immaturity of the UK market.

According to BISRIA, there are around 40 registered remanufacturers of refrigeration compressors in the UK. These encompass both OEMs and independents, foreign and domestic owned.

Industry trends include a move to outsourcing the supply of refrigeration and HVAC services. In practice this is achieved most easily on new buildings, which come equipped with multiple external bays where portable units may be hooked up to the building distribution systems. This allows facilities managers to match capacity to demand, often seasonal, without excessive spend on underutilised capacity. Such moves may be beneficial for remanufacturers, since facility providers have a direct interest in cost-effective uptime.

Movement in legislation on refrigerants (CFCs, HFCs, HCFCs…) comes as a mixed blessing: For manufacturers it represents an opportunity to sell made-for-purpose equipment. Similarly remanufacturers may be able feasibly to convert old machinery to new systems, if there is materials compatibility.

However, this is not always the case, and can be hampered by a cyclical background trend in preference for particular machine types, which also places last generation equipment at a disadvantage. Combined with a general trend – as elsewhere – for durable and cheap new equipment, remanufacturers find themselves squeezed.

Remanufacturing dimensions

The remanufacturing element is not as far advanced as the US. It is also important to differentiate the remanufacture of system components from entire systems: To our knowledge, only one company is selling entire systems as refurbished units, whereas over 40 companies are remanufacturing the core of the units, compressors.

Note also that our consideration of remanufacturing in this sector is limited to refrigeration. Gas compression in general is industrially significant, and generally involving machines of greater intrinsic worth than refrigeration alone. However, our investigation of pump remanufacture under the same SIC would suggest that industrial applications are undergoing significant reconditioning. This is covered further under a later section, Pumps.

Geographically, pump remanufacturers are spread through the industrial heartlands of the East/West Midlands, Yorkshire and the North-West. However, there is a significant cluster of activity in the South-East centred on Reading. This results from the presence of subsidiaries of foreign-owned majors in the region.

Benefits of air-conditioning & compressor remanufacture

We interviewed a selection of medium to large operators supplying compressors. As a result, we estimate that around 45,000 units per year are being remanufactured. According to the protocol of Appendix 3, the turnover in this area is around £25m. We have been conservative with pricing and believe this figure to be light. In addition, each unit weighs an average of 100 kg, indicating a material saving of 2,500 te per year, or 5,500 te CO_2 equivalent.

Note also that these figures relate to the compressor remanufacturing, not entire units, and so should be aggregated with the figures for the section Pumps below. As noted previously, actual remanufacture of entire systems is limited, but growing. The assessed value of this activity is less than £10m, with proportionate savings in materials (<1,000 te, <2,000 te CO_{2e}).

The wider ventilation and environment conditioning market has not been examined in detail, but operators report that most manufacturers undertake some element of remanufacturing. We estimate therefore, that total activity in this sector probably matches the compressor turnover around £25m.

Potential of remanufacturing

The under-exploited area in this category is that of whole system remanufacture. For example, food stores rarely consider reconditioning of their refrigeration cabinets when equipment is relocated or store refurbishment takes place. In effect, equipment is swapped out, and usable components distributed through a broker to other remanufacturers.

The exterior of the equipment appears to fall into the category of domestic white goods: It must appear to be new, or certainly not reused. We located only one operator who refurbishes complete units.

Barriers to Increased remanufacturing

Remanufacturing of refrigeration and air conditioning units excludes domestic fridges. These are a significant class of good that is covered strictly under Electrical Equipment.

Fridges are smaller, hermetically sealed units that do not justify labour input to rectify for mainstream operators. In addition, there are significant liability and logistics problems around maintenance and warranty of domestic items that limits application.

In the mainstream industry, operators of equipment are now aware of the presence and capability of remanufacturers. Remanufactured equipment is unlikely to be considered for new installations, but rather for repair or possibly extension as a swap-out.

This is because, like other industries, cheap quality imports are highly competitive with remanufactured products. To counter this, remanufacturers increasingly have to extend the scope of the service to become systems rather than component repairers. A general over-supply of remanufacturers allows price competition by large operators.

The biggest barriers to maintenance of the sector is lack of new technicians and apprentices entering the system; access to the technical design specifications of the OEMs; poor design for remanufacture (particularly in whole systems); and access to end-of-life cores.

Most major manufacturers engage in some remanufacturing either themselves, or through contracted agents. This has resulted in better branding for the reuse market and may be assisting growth in the sector.

Actions

The key actions for the increase in remanufacture are:

* in line with other sectors this activity could benefit from image improvement, with bona fide operators recognised as reliable suppliers contributing to industrial sustainability
* a legal framework that prevented withholding of design information, as in the USA, would assist
* actions that boost the availability of technicians with a blend of electrical and mechanical skills would head off an impending personnel shortage

Aerospace

The aerospace sector is one of enormous economic importance to the UK. It represents not only an income stream of over £18b per year and profits of nearly £3b, but is a highly visible, globally renowned operation with a reputation for technical excellence and innovation in military and civilian applications. Over 400 UK companies provide services in total aircraft systems, engines and equipment (SBAC, 2002).

Aeronautic systems generally represent considerable investments for reasons of reliability (safety) and/or functionality. Consequently, operators are highly motivated to ensure that components and systems consistently operate to high standard, that potential failures are obviated, and that key systems are upgraded for improved functionality or efficiency.

A typical example of this is jet engine development, where materials improvements, blade design changes and burner modifications have enabled higher fuel efficiencies even on existing engines. Such requirements have enforced the need for significant spending on repair and overhaul activities, and to a highly certified standard. However, as a result, airplane "systems" show remarkably low depreciation rates. (Figure 6 shows the time-value comparison of a typical airplane and a passenger car.)

Overhaul as remanufacturing

The distinction of remanufacturing within the aerospace sector is confused both by the alternative terminology employed – for example overhaul and rotables are interchangeable descriptors of the activity – and by the almost unique statutory certification regime imposed on the industry, civilian and military. In particular, this last constraint requires virtually every system and sub-assembly to be performance tested, certified, and history logged throughout its life.

Additionally, they must be subjected to an enforced maintenance or overhaul regime scheduled to some critical operational measure – hours, hours in service, number of operations, cycles, loading regimes etc. In this respect the "end-of-life" criterion normally applied to remanufacture is not applied. Indeed, if it were, the consequences of such failure could be tragic.

Aerospace overhaul regimes go beyond conventional remanufacturing requirements. However, the objectives

and methodology are effectively the same: To maintain assemblies to a working standard commensurate with demands of safety and performance. These require the application of familiar processes of disassembly, testing, repair, reconditioning or replacement and reassembly, coupled with traceability to materials source. This degree of rigour is exemplary of management systems that might be applied in other sectors.

Notwithstanding this aspect of forced maintenance, there is undoubtedly a large amount of conventional remanufacturing. In particular this is applied at the component level. We have talked to several companies applying state-of-the-art metallurgical and mechanical techniques to recover valuable components in the civilian and military arenas. Indeed, the Army's own remanufacturing unit, ABRO, routinely applies these methods in the repair of transport and weaponry.

Industry dimensions

As described the total value of the industry is over £18b per annum, which includes military and civilian applications. According to SBAC, of the value of sales into new civilian aircraft, approximately 50% is attributable to aircraft and systems, 20% to engines, and 30% to equipment; in the military sphere, the corresponding shares are 40%, 20% and 40% attributable to a higher proportion of guidance, control, life-support and weapons systems.

Across all areas of the industry UK companies offer world-class capabilities, performance and cost-competitiveness, selling into and servicing a global market.

Remanufacturing dimensions

Given the previous reservations regarding the meaning of remanufacturing in this context, it is clear that overhaul activity represents a major component of expenditure in both civilian and military applications. Systems and sub-assemblies of a wide range of sizes are repeatedly returned to service. Generally, equipment disposal occurs only for the most basic of items – or parts of items – designed to be quickly and cheaply replaced.

Certain consumables and instrumentation would qualify in this category. One company that overhauls 3rd party landing gear systems, is known to turnover around £300m, mostly in the UK (typical landing gear on a Boeing 707 would cost in excess of £250k per installation) ; this must be a mere fraction of the market. Other operators estimate remanufacturing in their field as 30% and upwards in higher margin areas. From other industries we know that related items, such as turbines, are increasingly remanufactured; the same is true in aerospace applications.

If we assume conservatively that only half of the UK turnover is attributable to remanufacturable systems (the other 50% being attributable to airframes), and that 30% of the spend in this activity is dedicated to remanufacture, then this implies an industry of at least £2.7b per annum.

Our research has concentrated mainly on equipment manufacturers and 3rd party overhaulers. We note also that much scheduled overhaul activity is also undertaken by fleet operators either in-house, or to contracted agents who operate globally.

This line of enquiry has not been pursued in great depth, but we note from published accounts that maintenance activity at £673M represents around 8% of, for example, BA's operating spend. In the USA we know from The Engine Yearbook (2002) that TWA spends £60M per year on engine overhaul alone. BA spend almost certainly exceeds this value. Another marker for this industry is an engine overhaul company called TMU, which has global sales of $600M. It is therefore believable that £1b is being spent in the UK on such activities.

Benefits of rotables

Assessment of benefit in this sector is subject to extreme inaccuracy due to the diversity of activities in the field. In addition, much activity is actually occurring within the service sector of airline operators' engineering units: This does not appear within engineering turnover figures, but probably constitutes orders worth several £100m.

The previous section has outlined a crude analysis of the sector. These appear to bracket remanufacturing activity between £1 and 2.7 billion. This lower estimate is extrapolated from the implied spend by civil aircraft operators, which then seems at odds with the statements of remanufacturers themselves. However, in this we have ignored military spend, which will be significant, although unlikely to match the spend of civil fleets.

Consequently we assign a conservative turnover value of £2 b, and a general estimate of 30,000 te CO_{2e} saved.

Potential of remanufacturing

The industry is clearly very aware of the value of remanufacturing, although this may be known by other terminology. Safety requirements have enforced and validated remanufacturing in this sector. As a result, transformation through adoption of remanufacturing is unlikely, and further growth will come organically through implementation of new remediation techniques, or the imposition of new legislation such as the WEEE directive, since electronics is an increasing component in this sector.

Barriers to increased remanufacturing

Mainly imposed by technical ability to remediate parts, potential legal considerations of component reuse or recycling (positive and negative effects), and rapid evolution of technology in some areas. Access to skilled personnel will impact on future capability.

Enabling features

A long history of remanufacture and of working to exacting military and civil engineering standards stands this sector in good stead. All operators in the field are familiar with operating to ISO 14000 standards, and many with issues of traceability and component history logging.

Actions

No industry-specific actions.

Electrical equipment

Electrical equipment includes a multiplicity of products from personal grooming devices, through brown and white goods (treated separately above), through to industrial transformers, switchgear and distribution systems.

We have seen little evidence of the remanufactured domestic electrical product market (e.g food mixers, shavers, hair-driers… SIC 29.71) being of any significance economically. Similarly with brown goods (SIC 32.30) such as TVs, videos and hi-fi, which have little more than scrap or possibly electronic component recovery values.

White goods (also SIC 29.71) are more interesting. At the higher value end, they too have significant economic value embedded, yet there is little or no incentive to remanufacture for primary markets, even though they form one of the most visible categories of waste from the public's perspective. Recent stories of fridge mountains highlight the issues facing society in an obvious way and are enhanced since it is the purchasing behaviour of the public itself that bears much of the responsibility: purchase on price rather than functionality, and a desire to replace (more than necessary) rather than repair or upgrade.

Like cars, white and brown goods are price sensitive, but their newness confers some form of status on the owner. The societal pressure to replace rather than reclaim is intense and embedded. This should be contrasted with topical reports of fridge and washing machine mountains that will force recycling options.

The current business model and consumer expectation dictate wholly against remanufacture except for secondary markets. Product life of less than 10 years, intense price competition on manufacturers, and generally improved reliability are dictating low cost products unworthy of remanufacture. A minority of used white goods, where they can be collected in a reasonable state, are being reconditioned for sale to disadvantaged consumers, usually by charitable, low-cost organisations. These initiatives attract the support of the retailers, perhaps spurred by PR considerations, but do not threaten the current economic model.

Industrial electrical products (SIC 31.10 & 31.20) are widely remanufactured. As usual there is a preponderance of activity at the high value end: motors and generators above, typically, 7.5 kW, large transformers and some switchgear, if part of an upgrade.

Rewinding as remanufacturing

Products in this sector are based on electromagnetic effects where electric currents interact with magnetic fields to inter-convert motion and electricity, or to transform voltages. Manufacturing requires knowledge of these principles, and the mechanics of magnets, wound wiring for armatures and bearings (for motors). The major operators in these sectors are usually servicing the needs of OEMs, industrial users, or other large contract service agents. They are therefore required to work consistently to uniform standards. The production techniques applied in these disciplines are similar to those applied in the parallel automotive remanufacturing industries, requiring receipt, inspection, disassembly and component testing

before rebuilding. However, it appears there are not the barriers of withheld technical information that plague the automotive sector.

In the industrial arena, clients are well versed in the capabilities of remanufacturers, and are not reluctant to engage them. They appear to trust the standard of workmanship, with most remanufacturing concentrated into the hands of limited and well known OEMs and middle-ranking independents. It is generally accepted that remanufacturing is worthwhile for items if the cost is not above c. 75% of the equivalent new component.

Domestic good refurbishment as remanufacturing

In no sense could the products handled be described as remanufactured; most undergo statutory electrical appliance testing, may have components replaced, come with limited warranties and are sold at very low price into secondary markets – typically disadvantaged communities, shelters etc. Any changes to the exterior of devices are cosmetic if anything.

Despite this, some operators employ relatively sophisticated machinery to assist in rebuild procedures for certain goods. In some cases, because the workforce is to some degree physically disabled (Renew, Remploy, Create etc.), robust and reliable automatic handling and positioning systems are required to even consider the task. It is likely that such techniques, more widely applied in other remanufacturing sectors, may improve efficiency in volume-related operations, since these operators are already servicing the demanding automotive chain. There is virtually no remanufacture of brown goods.

Industry dimensions

The industry is of high relevance to the UK economy, both in terms of turnover and employment, but also because of the impact on the waste stream. For example, 2 Mte per year of durable goods enter the economy, and 1 Mte of electrical appliances. Domestic appliances are recorded under SIC 29.71 and account for £4 billion (including imports) of activity per year. Brown goods under SIC 32.30 account for at least £7 billion.

Motors, generators, transformers and distribution apparatus is recorded under SIC 31.10 and 31.20, and accounts for £8 billion of activity per year, and an unknown mass of products, but probably of order 400,000 te based on a value of £20,000 per te.

Remanufacturing dimensions

Our interviews have revealed a high inclination to remanufacturing in the industrial sector, amounting to over 60% (in numbers) of products being returned to functionality in some instances. This number is consistent with the alternative view provided by the pumps and compressors sector. Certain sizes of motors will not be remanufactured: the indicative cut-off point for this is around 7.5 kW, but this represents perhaps only 10% of the market.

Transformers are generally bulky, capital intensive items very amenable to remanufacture. One company that remanufacturers its own as well as others' equipment estimated a 50:50 split in remanufactured to new business turnover. The top end of the market will be catered for by global majors such as ABB, Alstom and Wilsons, an Australian company.

On the other hand switchgear, though bulky, is relatively unsophisticated. The trend is for installation of new equipment on new-build projects, with remanufacture considered largely for replacement or expansion projects. We have therefore rated this equipment at a lower level of activity compared to motors and transformers. On the other hand, the overall value of Electricity Distribution and Control Apparatus (SIC 31.20) is substantial with a domestic turnover of around £3b. In practice, there may be a large element of imported components which are merely assembled within the UK.

In the white and brown goods sector, "remanufacturing" is limited to robust durable items such as fridges, cookers and washing machines. It must be emphasised that these goods cannot be classified as being fit for primary markets, as is the practice with industrial products, but generally service secondary markets populated by the disadvantaged. The resale value of these products is underlined by the fact that refurbishment is intensive and carried out by a similarly disadvantaged workforce: long-term unemployed, prison workforces, disabled and the like. Refurbishment generally occurs at a local, occasionally regional, level under the wing of well organised charities.

The fate of these goods is typical of the domestic market. However, major retailers are co-operating and often encouraging the practice by per machine subsidies, or by integrating old core collection into their new product delivery logistics. For example, COMET has

an arrangement with RENEW. Virtually all of these operations, including CREATE, RENEW, Recycle-IT etc. operate on a semi-charitable status, financed by environmental or regeneration grants. Overall, this route probably accounts for around 50,000 units per year. In total however, the market for these goods is presently worth only several £10m's.

Amongst the smaller electrical components, there is evidence of remanufacture of electrical hand tools. For example, Black and Decker operate a remanufacturing and distribution unit on Tyneside (McDougall, 2002).

Other majors, such as Bosch, are likely to do so too. However, these operations probably account for relatively small overall turnovers.

Benefits of electrical remanufacture

Given the overall low level of true remanufacture, it is impossible to claim any real benefit for domestic products. It is estimated by ICER (2000), that this grey remanufacturing market is responsible for preventing around 2500 te per year from being shredded and recycled. Most other arisings (350,000+ te, 7+ million appliances) are being shredded for metals recovery, incineration or landfill.

On the other hand, substantial rewinding is taking place, probably amounting to several 10,000s of tonnes per year, and including the more massive transformers, perhaps 50-100,000 te per year. These estimates assume activity is primary manufacturing. In reality, recorded activity probably also includes, as in other sectors, import and sub-assembly as part of a value chain. We therefore take a lower estimate for this sector of 50,000 te of steel.

Potential of remanufacturing

The industrial sector represents an area of traditionally high remanufacturing potential. This is evidenced by the fact that the larger operators report historically high levels of remanufacturing, and that level is now lower than in the past.

Mostly, remanufacturing has been eroded by the prevalence of cheaper imports which closely match the remanufacturing costs, even though they endure only a single cycle of use compared to perhaps five or six for reconditioned items. A practical upper limit for this market would be 75-80% recovery.

The domestic electrical product market represents perhaps the highest profile potential for remanufacturing. However, this is unlikely to happen in the current climate where ownership of white-good capability is seen as measure of personal GDP.

Real advances in this area will likely be dependent upon three factors:

* the further development of remanufacturing capability to demonstrate the feasibility and standards that may be achieved, particularly if these can access primary as well as secondary markets
* desire for longevity in goods and design for remanufacture, which may entail a rise in basic unit price
* the emergence of services which displace the need for white goods, and hence depersonalize the products

In this last category, it would clearly be beneficial, for example, to reinstate the concept of household laundry services. Remote facilities would then be motivated by the need to purchase cost-effective products

Barriers to increased remanufacturing

In industrial markets there are no technical or quality barriers to remanufacture. Remanufacturing is simply being driven out by the price of cheaper imports. In domestic markets, customers demand lower priced goods even if they are aware that such items will break down in a known period.

On top of that is an extreme aversion to buying what is perceived to be a second grade remanufactured item when new is available.

Electronics, ICT & business machines

This product area is extremely diverse, covering a vast array of consumer goods, information processing equipment, office equipment and telecoms apparatus.

It cannot be considered as a homogenous group and, even within a product class, there is great variation depending on the end user type.

The descriptions below correspond to commentary on consumer electronics and business electronics:

Consumer Uses

This is a product area that has seen huge expansion over the last decade. Mass production of micro-processors and memory, an active complementary software industry, firm industry standards and intense brand competition have fuelled PC, games and telecoms markets. The industries are based on the manufacture of competitively priced equipment of distinctly limited useful life. A feature of the PC market, for example, is the interactive nature of software and hardware design that encourages replacement after ~3 years.

Other electronics, such as mobile phones, are driven by a fashion element, and are also subject to rapidly evolving technology-based services that force obsolescence. Very few mobiles, games or PCs are remanufactured, and measures are only now beginning to come into force that encourage recycling for parts or materials reuse of any sort.

The Fonebak initiative was launched in September 2002 with the cooperation of major network operators and retail outlets. The objectives of this programme are 1 million phones recovered in the first year. This follows a pilot scheme set up by Ectel in 1997, Eurosource in 2001 (reselling into Africa) and Oxfam. Fonebak is, however, the first to attempt refurbishment for secondary markets.

Business Uses

Although it is not possible to distinguish completely between domestic and business users, in general there is a tendency towards higher volumes of purchase, and of higher value items. For example, photocopiers rarely appear in homes but are ubiquitous in business. With a trend to outsourcing and shorter budgetary horizons, such items are commonly leased or on service contract and, increasingly, as a per-use service i.e. complete servicization.

This is consistent with our finding organizations that contract to repair and remanufacture such equipment on behalf of branded suppliers.

Large business also tend to block purchase IT and IS equipment from top name suppliers, cascading use internally, and disposing in a more planned manner. For PCs, there are several channels for reusing equipment. IS equipment, such as servers, routers and telephone exchanges are more amenable to upgrade or value recovery through sale to remanufacturers. There are indications that this is a growth area, particularly in the post dot com boom, where a more questioning attitude to the benefits of electronics evolution has settled.

The ICER (2000) report estimated that around 45% of PCs were refurbished in 1998. Most of these were likely to be from corporate users and manufacturer take-back schemes, and represent about 45 kte of materials (over 500,000 PCs and VDUs combined). We have discovered limited evidence for true remanufacture in this area although, significantly, EuroPC is offering refurbished (stripped, tested and rebuilt) IT equipment from major brand names, and including three year manufacturer's warranties, at prices 30-60% of new. Other large operators are Ceres in London, Fraziers in Scotland and RDC Trading. It is therefore possible that, within the corporate purchasing sector, a more considered approach to replacement and reuse is being adopted, leading to emergence of dependable agents. However, there is little evidence for this extending into domestic markets.

Electronics remanufacture as remanufacturing

Theoretically, electronic equipment is amenable to remanufacture. It is modular, built of testable components of value, most of which perform adequately for long periods. However, current trends to miniaturisation in consumer electronics do not encourage remanufacture. The drive to compete on price with little thought for end-of-life care has created products of low value. In addition, jointing (soldering) is a significant barrier to disassembly. Consumer electronics is therefore unlikely ever to be considered for remanufacture. Instead, efforts should be placed on disassembly for recycle. In contrast, subassemblies – such as modems, network cards, hard discs etc. – are worthy of limited remediation.

Photocopiers and telecoms exchange equipment are relatively complex systems, but also now technologically stable (print engines are not evolving, merely the software that drives features in, say, printers), with enhancement through integration of features and service elements. Knowledge should therefore not form a barrier to remanufacture, and modularity should assist in redesign and upgrade. Such equipment is therefore relatively amenable to recognised remanufacturing processes.

PCs might be considered to be in a grey area. Their modularity should imply remanufacture. However, rampant co-evolution of software and hardware, and

constant changing of interfaces and packaging drives perceived obsolescence in the eyes of the consumer. This perception may now be starting to change.

There are a number of companies that refurbish PCs largely for reallocation to schools, charities and special projects. A selection of these are listed in Appendix 5; in the UK, there are few operators who remanufacture PCs, but the closest representatives of the practice are Fraziers in Scotland, RDC Trading and Ceres Logistics in South-East England, Recycle It in the North-East. Even so, the classification is marginal; warranties may not match those offered by similar operators in Holland, for example, whose services also include support and maintenance.

Industry dimensions

The industry is extremely large, with a combined manufacturing turnover above £10 billion.

Remanufacturing dimensions

Whilst most PCs etc. are made redundant well before the end of their useful life, there is surprisingly little full-blown remanufacturing occurring. What little that is taking place produces appliances of extremely low value, and of interest to bulk purchasers such as schools, hospitals and charities. Little is being returned to premium users such as businesses. In large part this is due to intense price competition on new goods, with heavy marketing and a coupled software industry, which is feeding a climate of planned obsolescence.

Some refurbishers of PCs exist, following continental models of Netherlands, for the redistribution of used IT equipment to schools, other institutional purchasers and disadvantaged purchasers. This amounts to around 50% of the disposed equipment. However, remanufacturing is even lower; this is largely because the rate of evolution in the speed and capacity of PCs leaves a low residual value for disposals. In addition, PCs are often cascaded within the home for low level and child use, and this can also exacerbate loss of utility. The value of this combined reuse market is probably around £40m per annum, assuming 500,000 PCs are reused in some way at £80 per PC.

On the other hand, there is a well established market for the remanufacture of Photocopier equipment. A diversity of models persists for this activity including OEM, contract and independent remanufacture; many operators have successfully integrated remanufacture as an expansion of their business options offering a continuum of purchase, hire, upgrade, remote service, billing and pay-per-use, and profit sharing – some of the most sophisticated service models in business.

A number of third party remanufacturers are supporting OEM products on their behalf. This appears to be tolerated especially in countries in which the OEM does not have a strong base from which to support sales.

This has not prevented the emergence of completely independent remanufacturers such as Danwood, who have a totally flexible approach to product reuse, offering this class of product as stand-alone sale, upgrade, pay-per-use, and profit share in copy shops for example. Some operators put the proportion of remanufacture as high as 60% (for single pass reuse, at least).

On the other hand, high end server, router and telephone exchange equipment has much greater value. Our survey suggests that much of the activity in this sector is carried out on behalf of OEMs as a contracted warranty and upgrade service.

In the UK, this market probably has a value in the range of £100-200m per year (5% of total market?), and may be saving 1000 te per year of electronic waste. The nature of remanufacturing is such that the core parts are usually "internals" that require replacement of one or more defective components on a board. The business – analogous to automotive remanufacture – is not competitive with OEM business. OEMs may be placing remanufactured parts into new systems, and certainly into upgrade systems.

It should also be noted that perhaps the most famous OEM remanufacturer exists in this category, namely Xerox. Xerox took the decision in 1991 to remanufacture copiers, printers, scanners and other equipment to cope with valuable end-of-life product returns which were accumulating in its warehouses. According to ENDS (2001a), remanufactured output now accounts for 25% of output despite double the labour cost compared to new equipment. Globally, it is estimated to have saved $200m and recovered over 25,000 te of materials that would have been landfilled.

Benefits of electronics remanufacture

The total value of remanufactured equipment within this sector is estimated to be around £3-500 million.

Materials savings are hard to estimate (and exclude a very large volume of recycled components), but are estimated to be in excess of 10,000 te/year steel for electronics, photocopiers, PCs, toner cartridges etc.

Potential of remanufacturing

There are signs that markets such as PCs are beginning to saturate. Under such conditions suppliers, under threat of declining margins, will need to differentiate their products. A feasible way of doing this could be by remanufacture to create layered markets of higher and lower specification. This will require significant improvements in warranty on such goods, as has been demonstrated in the Netherlands.

In the wider telecomms market, it is already apparent that total service provision for product life-cycle management is a viable route forward. In such cases, affiliated remanufacturers can offer manufacturing, repair, remanufacture and upgrade services on behalf of branded suppliers. In addition, they become adept at managing the supply chain, inventory and end-of-life issues. Such businesses will increase in importance as legislative pressures – such as the WEEE directive in Europe – come into force.

Barriers to increased remanufacturing

The cost of purchasing equipment to effect repairs to high end equipment is a barrier to entry in these markets. In addition, remanufacturers will require access to cores, which tend to come through official channels, or by dint of organisational size and reputation. Most operators will be contracted in part to one or more OEMs. Other barriers can arise from the ambivalent attitudes of OEMs: Remanufactures may often provide a valuable third or fourth party warranty service, but are still often perceived as damaging to sales of new items. In the PC markets, rapid technology evolution quickly devalues old stock.

Enabling features

This sector demonstrates graphically the role of good product design as an enabler of remanufacture. Xerox, for example has reduced the range of plastics (the most difficult part to reuse and remanufacture) and components it uses, replace screws by snap fasteners and selecting based on life-cycle costs.

As a result it claims that 90% of products are remanufacturable. This has only been achieved by allowing "joined up" design – front end designers working with back end demanufacturers to harmonise the build features. Océ, a Dutch company, is the most pioneering European company in this area. They have moved to designing their photocopier systems for remanufacturability, with modular components that are reapplied in successive generations of equipment. Many advocates of recycling hail the leasing concept as the driver for remanufacture.

This example suggests that it is the other way around – demanufacturability enables leasing. A competitor to Xerox, Pitney Bowes, also introduced leasing in 1991, but gains were modest in comparison; its remanufacturing operation has been described as salvage of reusable components; there has been no management commitment to modifying the business or product design process.

Other segments, such as PCs and laptops, also operate a leasing model, but this has not driven recycling rates. However, despite the high-tech gloss, much of the industry is built around standard component blocks, a concept which has been extended by some manufacturers, such as Océ, into sub-systems. Extensive reuse of components stripped from redundant electronics is difficult due to uncertain provenance (although a recent Eureka project promises a diagnostic tool to help manufacturers assess this **Eureka: Project E!1689 "Electronics Materials & Ageing"** at www.eureka.be), and the general irreversibility of the assembly process. Barring fundamental changes to manufacturing technology, there is little likelihood of significantly greater value being recouped from waste electronic components.

We note that some reports estimate the value of WEEE of all forms in the 100s of billions of dollars (**Remarket: An investigation into the remarketing of white goods parts", DARP Environmental, 2002**); certainly this may be the retail value of as-new components, but is unlikely to be realised due to highly dispersed nature, logistics costs, disassembly costs and rejection rates.

Actions

The key actions for the increase in remanufacture are:

* remove barriers to third party remanufacture, especially freedom of information over design
* research design for manufacture and demanufacture

Industrial machinery

As in the USA, industrial machines of all types are being remanufactured. These encompass traditional lathes, cutters and grinders – tooling machines – through production line equipment servicing the food, plastics, chemicals, construction and multiple other sectors. Broadly, these are classified under SICs 29.40 and 29.50. A flagship sector for this industry is machine tools. The health of this industry has generally reflected the state of manufacturing industry.

Machine tool remanufacturing

It is clear, simply by examining only a limited number of end products in any depth, that many goods in this category embody significant value that may be recovered through remanufacture. Artefacts are invariably precision-engineered to run reliably, at high throughputs with low variability. The fact that, for example, grinding machinery may run for thirty years before major overhaul is required is adequate testament to the durability of the goods. Often, only minor physical changes are required, such as skimming of surfaces, replacement of screws and bearings. However, given the lifespan, technological advances have embraced significant changes in control and measurement systems (such as CNC in the machine tools area). Frequently these may be included into remanufacturing.

Industry dimensions

As a whole, machinery manufacturing accounts for around £9 b turnover in the UK for domestic consumption. In addition there is an active import/export trade amounting to around £5 billion (both ways). The proportions of this component vary widely according to sector of application. For example, in the food and pharmaceutical sector there is a 70-80% export of new machines, and an even greater export of 2nd hand and refurbished machines into developing countries. The SIC for this sector embraces not only machine tools, food processing and pharmaceutical packaging: Printing and plastics processing are significant users, and with significant residual value.

Remanufacturing is represented across the diversity of this class. For example, mining machinery (crushers, grinders, screens and conveyors), construction equipment, shredding and bailing packages, and a multiplicity of production line equipment. However, the climate for remanufacture is not equivalent for them all.

Remanufacturing dimensions

As usual, the level of remanufacturing reflects both the inherent value of the object under consideration, and risk factors associated with purchasing machinery whose lifetime could conceivably extend beyond the user's survival horizon! In addition, the competitive nature of imports, particularly from Eastern Europe and the Far East, erodes the incentive for the purchase of remanufacture, especially from the larger OEMs who bear greater overheads.

Remanufacture is therefore being increasingly squeezed into those markets where more specialised and complex machinery exists, and where small, lean, niche remanufacturers can undertake bespoke work for discerning customers with a redeployable installed core.

Such considerations are also subject to the cyclical nature of the economy. Operators we have interviewed Machine Tools is the classic area of remanufacturing, and is often quoted as a bellwether of British manufacturing. Our survey indicates that remanufacturing across most of the sectors of this type is in decline.

Undoubtedly, British manufacturers still build amongst the most robust and technically competent machinery in the world. However, price competition is intense from the American and Far Eastern markets and, in the short term, is not a sustainable basis of competition. Consequently, margins for remanufactured items are squeezed, and preference is given to imports. It appears that, in many cases, purchasers are prepared to buy with short-term objectives, knowing that equipment will perform with a limited life: planning horizons are too short to contemplate otherwise.

Selected specialised areas can still sustain remanufactured goods: One such field is grinding machines, such as those made by Jones & Shipman, now part of Renold plc. J&S machines are industry standards, some instances surviving over fifty years and several cycles of remanufacture. Far East competitors are still unable to match the absolute quality of new equipment.

For many years, J&S has been parasitised by 3rd parties offering independent remanufacturing services; lately, in response to the high cyclicity of the manufacturing sector demand, it has moved positively to offering a remanufacturing and maintenance service. This is now more profitable than the new sale.

However, grinders represents a small component of the machine tool industry. New machines dominate sales. We therefore rate the overall level of remanufacturing activity as relatively low (albeit cyclical), probably varying between 10% and 20%. Resale prices follow the industry average of 30-60%.

Our straw poll of manufacturers in the food sector indicates that purchasers at least are keen to obtain remanufactured equipment. In general, the large multinational purchasers will buy new and run to destruction; residual value may be minimal in Europe.

However, there is a significant release of equipment from redundant lines, and from smaller manufacturers including fire sale items. These feed a vibrant 2nd hand market that probably exceeds the activity of main dealers. Reputedly, there are around 10-12 SMEs of around 20-30 people servicing remanufacturing elements in this market, mostly located north of Birmingham, and a large number of 1-2 man companies trading on. These latter typically do not remanufacture themselves but may engage OEMs or others to refurbish. About 25% of food machinery may be being treated in this way.

The Pharmaceuticals industry is somewhat more specialised and restricted in the number of operators who remanufacture: There are perhaps 4 or 5 main dealers prepared to engage in remanufacturing, and many more small operations composed of previous workers in the industry. Again most of this machinery is exported into developing countries at 30-60% of new price. Given the generally better operating climate of pharmaceuticals operations, these types of machines attract both better prices, and have a higher reuse rate of around 30%.

Benefits of industrial machine manufacture

Industrial machines are almost entirely metal constructs, and generally high grade steels. In principle they are therefore easier to assess in terms of material saving; in practice, the numbers of equipment and weight are unknown, comprising diverse sizes and functions. In Appendix 3 we estimate that business to the value of at least £110m is occurring. This has a material benefit of around 8,000 te per year, or 18,000 te CO_2 equivalent.

Potential of remanufacturing

This diversity of this sector means that it is not possible to definitively categorise it regarding business climate. In some parts, such as paper and pharmaceuticals packaging, the market may be quite stable, and represent a significant fraction of the machinery in circulation. At other points, such as machine tools, there has been a rapid decline due to cheaper foreign imports.

Despite the cyclicity induced by the variable demand in the user industries, this sector has the characteristics of one suited to remanufacturing. However, it does not seem to have adapted, or cannot be adapted, to a different mode other than make and sell, as has happened in other highly competitive sectors. If this could be made to happen, the sector would possess large potential for material recovery.

Barriers to increased remanufacturing

In line with the above comments, in some parts of the sector, remanufactured machines do not represent an attractive value proposition to purchasers. Although quality of imports is rising, often they have a limited life which does not detract purchasers. The essential barrier to purchase either lies in the mind of the purchaser and their perception of planning horizons, or the too traditional offerings of remanufacturers and manufacturers.

It is notable that perhaps the most famous name in British machine tools, Jones & Shipman, has recently moved to remanufacture its own machines. This comes after many years of third parties undertaking parasitic remanufacture. J&S can now offer, new, reconditioned and upgraded machines in any combination, and see much higher margins in a business that was previously struggling.

Enabling features

Being a classic engineering application, this sector benefits from many of the remanufacturing attributes that we have identified. In particular, the machines are large, robust, and have a high initial value. Often standard engineering tolerances may be applied to the builds, and an increasing range of mechanical techniques is available for recovery of components.

Actions

The key actions for the increase in remanufacture are:

* at the risk of simplifying the analysis of a very diverse sector, it would appear that it could

benefit by taking a different approach to selling its products. In particular, these would need to incorporate a greater service element, or revenue based service to spread the cost to the user, and to justify building machines of higher longevity, capable of remanufacture. In this respect, the sector probably offers greatest potential to visionary OEMs who can offer an all-round service.

* this might require a radical rethink of the business models; for some equipment, such as bottling and packing plants, it may require alliances or joint ventures with other parties.

Marine industry

Like aerospace, marine is complex activity covering military, merchant and domestic shipping activities. Functionally it can be decomposed into manufacture of superstructures (hulls), rigging and topsides, propulsion and rotating electrics, and electronic equipment.

Shipbuilding as remanufacturing

For the purposes of this study it has not been possible to analyse the industry as described above. This is because rotating electrics, propulsion and electronic goods have been generically covered in other sections, and we wish to avoid double counting. Effectively, therefore, remanufacture in this context implies the traditional crafts associated with shipbuilding, or conversion and refitting.

Industry dimensions

The decline in British shipbuilding has been well documented. It has also been the topic of a recent study by University of Plymouth Enterprise (Beer et al., 2001), which has reviewed activity by region in the UK.

Remanufacturing dimensions

We believe that there is little remanufacturing activity in the domestic sector – mostly pleasure craft, yachts and boats. Undoubtedly there is significant repair and maintenance activity that, is necessary to the upkeep of long-lived and valuable items. In this sector there is a thriving market in second-hand craft. True remanufacturing is likely to be confined to conversion of existing cargo shipping, such as double-hulling tankers, to refits of cruise and pleasure ships, and to planned overhauls and systems upgrades on military craft.

Benefits of conversion & refitting

The benefits of remanufacture are roughly assessed as equivalent to the building of a medium size cargo ship per year, or around 20 kte of steel.

Potential of remanufacturing

Opportunities for growth may exist in the leisure craft sector, where the sale of navigational aids, furniture and fittings is expanding with consumer expectations and increasing wealth. It is unclear whether electronics remanufacture could be significant given the general trend to lower cost and miniaturisation.

Barriers to increased remanufacturing

None identified beyond other sectors; benefits appear to be recognised in commercial sectors.

Office furniture

Office Furniture is part of the larger furniture sector. In the UK this is a huge industry worth over £6b per year for domestic consumption. The majority of this is attributable to home use: Lounge, dining, bedroom, kitchen and the growing home office segments. Office Furniture describes industrial and office furniture, encompassing traditional desks, cupboards, filing cabinets, partitions etc., and seating and upholstery for public spaces, reception areas and retail.

Furniture refurbishment as remanufacturing

It is not over-simplifying to say that virtually no domestic furniture is remanufactured in the sense of this study. For sure there is restoration of antiques and heirlooms, but these activities are conducted for individuals on personal goods for largely aesthetic reasons. They are not conducted to restore functionality so that the goods may be resold in an open market.

Industry dimensions

The size of the office furniture market is around £1.9b (FIRA, 2002) including imports, which account for about 17%, supplied by over 1000 companies. It has a very wide customer base, with purchasing following the fortunes of the general business climate. Technological changes and the need for more flexible office space has recently driven replacement of old furniture, and this has been further stimulated by the easy availability of newer,

modern designs from overseas. According to FIRA, there is also a market for good quality second-hand furniture, generally sold through dealers and auctioneers after company rationalisation. Larger companies may also cascade furniture internally. The size of this market is probably around £75m per annum in the UK, pertaining to around 100,000 te of waste, and accounting for about half of used items.

Remanufacturing dimensions

Remanufacturing is difficult to quantify, largely because it has low visibility even with the industry research body. The High Wycombe area is traditionally associated with furniture manufacture of all sorts. Here, one company, Birko, is known to be remanufacturing office furniture. In contrast, there is a wide range of companies engaged in refurbishment, largely related to re-covering and re-upholstering.

Benefits of furniture remanufacture

To all intents and purposes there is no remanufacture of furniture outside the office equipment sector. Although there is a small furniture lease sector, this is not set up as a true life-cycle maintenance activity, but merely as a means of amortizing the costs (at substantial profit) of a single-cycle/multi-user product.
Even in consideration of office equipment there are limited examples of large scale activity. Accordingly, we would assess the value of activity certainly below £100m, probably below £50m.
Materials savings, however, may account for 10,000 te per annum.

Potential of remanufacturing

Considering the size of the total activity, the sector has potential for substantial increase in recycling, let alone remanufacturing.

Barriers to increased remanufacturing

To a large extent, furniture replacement is linked with fashion and organisational prosperity. Remanufacture sales therefore suffer from some perception problems. In addition, it is clear that new ways of working demand adaptable and flexible furniture solutions to enable varied communal working and coping with the needs of IT infrastructure, for example. Older designs may therefore become outmoded.

Furniture is not constructed in a manner conducive to remanufacture. It is likely that appearance will be a major factor in decisions to purchase pre-used goods; the industry will therefore need low cost, sustainable techniques that reclaim, re-laminate or redecorate surfaces, particularly in simulating hardwoods; a further enhancement would be modular constructions both at the unit level, and to enable reshaping of work surfaces. This will require development of new surface treatment techniques, and jointing technologies, perhaps involving reversible adhesives. The industry appears reluctant to engage in such activities, perhaps due to perceptions of the customer needs, and also because of the climate of price competition. These comments apply to the wider attitude of the industry to waste, demonstrating efficiency practices generally well behind other industries.

Enabling features

Office furniture, which is the most likely candidate for remanufacture, appears quite well suited to the task. Increasingly, today's offices are oriented towards modular design, and the furniture designed to suite: Standard carcasses are supported on relatively simple steel frameworks. With modest effort, it is feasible to rework these constructional elements to be disassembled and reassembled in new configurations in a similar way to kitchens and bathrooms. Methods of restating surface finishes may be required. The industry is characterised by a number of large chains of providers of equipment, who would have the branding and market strength to carry such an initiative.

However, furniture in general could represent a good opportunity, given the volumes of material generated. Much lounge and bedroom furniture is hand-assembled and so, unlike many other industries, manually-based remanufacture will not represent such a disjoint in cost.

Remanufacture will require a number of enablers:

* a reclamation, logistics and sorting channel that can deliver economic volumes to a processor
* a processor of adequate competence and cost to make the venture worthwhile
* suitable constructional techniques to remediate, coupled with goods of basic mechanical integrity, and capable of upgrade to modern safety standards
* access to channels to sell reputable, branded products

Actions

The key actions for the increase in remanufacture are:

* greater emphasis on construction for reuse in FIRA sustainability strategy
* engage interest of reputable mass operators capable of undertaking domestic remanufacture

Pumps

In the UK, pumps are considered under SIC 29.12 Manufacturer of Pumps and Compressors. As such, they form a more generalised case than the refrigeration application considered previously. Pumps find application in a wide range of uses from small-scale domestic duties to megawatt industrial drives. The market is dominated by around ten major manufacturers, and a host of support organisations offering repair services. There is also a high degree of interaction with the electric motor suppliers, as a majority of large industrial pumps are fitted with external drives. In consequence, a number of companies straddle both sectors.

Pump services as remanufacturing

Like automotive and other rotating electrics, pumps are well suited to remanufacture. They are modular systems with replaceable components, often amenable to upgrade through improved control systems on drives, or changes to impeller design, for example. Since pumps are a relatively established technology, there are many independent operators who may offer reconditioning services. As a result, all major pump OEMs, who tend to operate globally, operate schemes that offer repair, maintenance and upgrade services, often on immediate call-out for critical duties.

Industry dimensions

The pump industry is a relatively buoyant sector. Although the bottom end has seen erosion – like many other sectors surveyed – from the low-price imports, a number of factors have assisted in supporting activity. For one there has been a general move to develop more efficient products for more demanding applications in exotic materials.

Secondly, manufacturers have recognised early on the potential of remanufacturing for enhanced profitability, and have successfully marketed the lifetime supply and maintenance of pumps and pump installations as a service. This is particularly prevalent in the water industry with its cost pressures and demand for modular design and expansions. In 2001, the home manufacturing market for SIC 29.12 was worth £1.4b. (Note also the import of pumps worth £1.5 b.) Our previous of analysis under refrigeration compressors estimated a market of order £100m total. Thus we see that the majority of activity in this sector is attributable to pumps and to non-refrigeration compression[7].

Remanufacturing dimensions

In short, major pump OEMs see remanufacturing as a core element of their service. They realised a long time ago that the value in first sale was being eroded by local competitors and remanufacturers, and so are working to reclaim that value.

One area of expansion is in facilities management. For example, it is now common in the water industry for the design, maintenance, operation and upgrade of a pumping station to be outsourced, commonly to a pump major. Such services are sold on the basis of an explicit lifetime costing of the facility, with a large element of annual revenue to pay back both capital and operating charges. Remote monitoring, logging and control are implemented to operate and identify problems without the constant presence of operations staff.

In other sectors, such as chemical, a full service provision may not be desirable due to the highly integrated nature of plant operation. Even so, with many pumps running on exotic and demanding duties, they still require on-demand maintenance and remanufacture. The nature of chemical processes implies that they are unlikely to be re-employed on anything other than the original duty. Conversation with industry representatives suggests that, in value terms, a large fraction of pumps are open to remanufacture. (Commonly, such action will be considered if the projected cost after remanufacture does not exceed around 70% of a new pump. Generally, this implies a lower pump value of around £1000.)

Benefits of pump remanufacture

Considering the whole market, and the high degree of reported remanufacturing (c 50%), we estimate the value of the activity to be around £250m. Materials savings will be of the order 6,000 te per annum, taken as steel, or 13,000 te CO_{2e}.

Potential of remanufacturing

This is a sector that has already adjusted to remanufacturing to a high degree. Further potential is therefore limited in comparison to other sectors.

Barriers to increased remanufacturing

Notwithstanding the comments above, there are few barriers to remanufacture.

Enabling features

Essentially durable goods, of modular design, built to generally widely understood engineering standards. In addition, customers are often keen to outsource the solutions to pumping needs to third parties.

Actions

None recommended.

Toner & inkjet cartridge refilling

In the words of Lund's report, toner cartridges represent a rapidly expanding newcomer to the remanufacturing scene. In the five years since that report, laser photocopiers have established themselves as a standard fixture of the business office, and a component of many home offices. This growth has continued to fuel a vigorous market in consumables, a billion dollar area of contention between OEMs and remanufacturers. Inkjet cartridges have also only recently expanded as a growth area for remanufacturing.

Five years ago, although commonly available, colour inkjet printers were significantly more expensive than today's models, with consumables expensive yet affordable. Since that time, intense price competition and a desire to expand the related digital photography market has forced down the capital cost for even quality devices.

Manufacturers attempt to generate revenue through consumable sales that, in general, are now relatively more expensive (replacing individual colour components replacing tri-colour tanks) and of smaller capacity. This has focused consumer attention on running costs, and stimulated a market in refills and home refill kits.

This market is supplied by a well organised network of remanufacturers and cartridge collection agencies operating at both the national and local level. Although the materials under consideration are not technologically complex, the contribution to waste volume reduction is clear, pragmatic and worthy.

Cartridge refilling as remanufacturing

The use of the term remanufacturing in this case is justified by the performance expectations of the product in use, and the care taken to achieve that. Companies that have a reputation for poor product are soon dropped from supplier lists, and may not achieve UKCRA registration. Top class refilling also entails the replacement of key wearing components, drive wheels and wiper blades, which are known to deteriorate in use. Quality control regimes also require batch tests using a variety of printer makes.

Industry dimensions

It is estimated by the main body representing remanufacturers (UKCRA), our detailed interview candidate (Mercia Laser, 2002) and campaigner David Connett of The Recycler trade magazine, that 12-13 million toner and inkjet cartridges were used in the UK in 2001.

To put this in perspective, uncrushed, such a waste volume would be in excess of 70,000 m^3. With an average sales price of £50, this indicates an industry with a value of over £600m in the UK alone. This figure is quite realistic; it is known that nearly half of HP's global sales are attributable to these products – a figure of $2.3b – and with a profit margin of over 30% (Guerrera et al., 2002). HP is the largest manufacturer, with Lexmark, Canon and Epson close behind.

Remanufacturing dimensions

UKCRA consists of around 150 companies employing 1000-1500 people, ranging from 5-6 large operations operating internationally and handling 15-40,000 toner cartridges per month, through intermediate operations of around 10 people handling 2,000 units pcm, to one-man bands. These companies are spread throughout the UK, and generally locally to the sources of supply/demand, the exception to this being the international operators.

It is estimated that around 20% of all cartridges are recovered – mostly by the remanufacturers. The majority of product returned directly to OEMs is exported to

countries such as China, where it is shredded for other recycling operations; a minor component may be remanufactured.

The remaining 80% is sent to landfill. Turnover associated with processing remanufactured goods in the UK is €220m (£140m).

It should be noted that the UK cartridge remanufacturing industry is the largest and most advanced in Europe, to the extent that further growth is now hampered by the availability of suitable core product. Typically, empty cartridges are retrieved through formal and informal networks of collection agencies, mostly charitable, that receive a donation for each unit delivered. Cost is an issue for industry, so this low price channel is most welcome. Professional recovery agents usually collect from medium to large companies thus achieving economies of scale.

Benefits of remanufacturing

The Recycler magazine estimates the industry to be recovering around 2500 te of raw materials per year. These are high grade engineering plastics, copper and significant amounts of aluminium. The latter is a highly refined metal with significant embedded energy. In addition, cartridges also contain residual and unknown quantities of toner, whose long-term effects in land-fill cannot currently be ascertained; the process of remanufacture requires the extraction and safe disposal of such materials.

Cartridges that are not fit for remanufacture are generally disassembled and sent directly to materials recovery facilities.

Significantly, although OEMs have recycling programmes in place, little if any of their product is remanufactured; in contravention of rules requiring recycling in the country of origin, most recovered material is exported, largely to developing countries.

Potential of remanufacturing

From the current level of 20% recovery, it should be practical to double this to 40%. In theory, properly serviced cartridges could be reused four or five times, implying a recovery rate of 80%. UKCRA estimates that projected demand could absorb 70% of cartridges that end up in landfill sites. At this level about 9,000 tpa of direct waste could be avoided.

Barriers to increased remanufacturing

There is a clear demand for remanufactured products in this sector. In satisfying this demand, the most immediate problem is the availability of the cores, namely cartridges.

With recovery rates at only 20%, including recycling, most cores appear to be going directly.

Recently, there have been moves by such OEMs as HP and Lexmark to introduce anti-reuse technologies into their products. For example, these may incorporate chips that disable further use of a cartridge once removed from a machine unless replaced by an OEM, or may destroy print heads of inkjet cartridges upon withdrawal. Such moves might reasonably be construed as anti-competitive, and indeed form the basis of evidence now being placed before EU legislative and anti-competition bodies.

To some extent, development of the industry is hampered by performance standards of remanufactured products.

These fall into two camps, namely:

* agreement of mechanical items to be replaced
* agreement of comparable tests between different print engines

The first of these has been the historic cause of concern within the industry, since significant cost savings can be made by not replacing components. At the point of remanufacture the component may still be within specification, but will deteriorate within the next cycle of use, adversely affecting print quality. In general, such shortcuts have driven the customer perception of remanufacture being a low grade substitute for new product.

The second concern has been a source of obfuscation, since it is intimately associated with printer software. Different printers formulate characters in different ways, requiring varying amounts of ink, suggesting the same cartridge appears to perform differently. This has been used as a means of confusing comparisons. Inkjets work on different principles, and it is more appropriate to set standards based on the number of print-head firings.

Moves by bodies such as UKCRA are consolidating the approach to remanufacture with codes of practice on both these issues – a charter for remanufacturers, and a strict definition based on 100% black coverage, for example.

Inkjet standards are still evolving. The emergence of large operators of such size that they can create their own brands, has aided stability.

Enabling features

The toner cartridge remanufacturing representation is, relatively, an extremely well organised and co-ordinated industry body. (Internationally, there is uniformity amongst bodies around quality standards.) It is well tuned to the impact of forthcoming EU WEEE legislation, the counter-measures being devised by OEMs and has a very active lobbying agent who has demonstrably affected the course of EU policy (Davies et al., 2002). It is clear that had such action not been instigated, legislation now in progress could, potentially, have stifled – if not outlawed – remanufacturing activity across industry broadly.

For historical reasons, cartridge remanufacture has been a straightforward operation, demanding skills no more onerous than manual dexterity, cleanliness, quality control, access to channels of supply and distribution, and a source of replacement parts.

Remanufacture has been considerably assisted by the co-operation and foresight of industry founders – Canon – particularly in their design for ease of dis/assembly and their failure to place barriers to the practice, including free access to design and assembly drawings, and support of replacement component manufacturers.

In addition to the design features, the technological evolution of laser print engines and their feed systems has halted. New cartridge products are reformulations of known principles, and even toner formulations are converging.

Laser printers are now differentiated by their software systems and drivers, which allow more sophisticated manipulation of document formats at the point of production, and for businesses, by remote diagnostic, accounting and control features linking the product to suppliers.

To a large extent, the industry is maintained by the high prices charged by OEMs for new, own-brand consumables. This has allowed adequate room for lower price, dedicated remanufacturers. The prevalence of large retailers participating in used cartridge take-back schemes, and a well developed collection industry has greatly assisted economies of scale in reverse logistics.

Actions

The key actions for the increase in remanufacture are:

* public and institutional purchasers should source from reputable branded wholesalers. Generally, these will be distributing on behalf of validated remanufacturers
* consider legislation to ban cartridges from landfill waste. (Toner could be described as a potentially hazardous waste.) In particular, apply pressure to OEMs to disclose the fate of their returned cartridges, and justify
* remanufacturing industry and local authorities to promote to businesses and individuals existing mechanisms to recycle, for example, via charities and registered core brokers
* local Authorities should consider cartridge collection to be included in municipal segregated waste collection schemes. Suitably handled, this would form a valuable revenue-generating and easily segregated recoverable stream, perhaps handled in concert with local brokers
* support and vigilance from trading standards organisations in detecting and prosecuting anti-competitive features in products

Tyre retreading

Retreading is one of the most publicly visible examples of remanufacturing commonly occurring in society today.

It is therefore a great pity that retreads (remoulds) are so poorly perceived, limply promoted and generally unrecognised as an accessible contributor to resource reduction and domestic waste management.

In the UK, approximately 40 million tyres are discarded per year, a number roughly in balance with replacement.

This market breaks down into three main sectors:

* cars (and light trucks)
* trucks (freight lorries and specialist machinery)
* aeronautical

Of these, the car market forms by far the largest volume sector, and aeronautical the least.

However, this is completely inverse to the level of retreading within each sector.

Retreading as remanufacturing

The purchase of a remould tyre is commonly perceived as a cut-price means to obtain a lower quality, lower performance tyre. Certainly this would be justified from the examination of the historical roots of the practice in the 1930s, where new treads were casually bonded to worn tyre carcasses. Despite this the industry expanded through being a cost-competitive alternative to relatively expensive new products.

From the 1970s onwards, British and European Standards targeting road safety have ensured a much more rigorous approach to the science and engineering of the remould process, and define acceptability criteria for key elements of the operation. Currently, remoulds are so highly regulated that they cannot effectively be discerned from new tyres. Indeed, effectively all new tyres are obliged to be capable of remould at least once. Recent comparisons by the OEMs have attempted to differentiate performance by rolling resistance - and by implication, fuel economy - but these comparisons have not been made on a like-for-like basis, as is likely to be confirmed by an imminent independent audit by AEA Technology.

From a technical standpoint, retreading is feasible and acceptable if properly monitored and controlled. Leading operators report that around 20% of car tyres that they receive are suitable for remoulding, which indicates both the degree of tyre abuse by the domestic user, and the rigour of the inspection process. Each remould tyre is obliged to undergo a series of performance test prior to re-release. As a result, we believe that it is correct to consider this product as a true remanufactured item.

Benefits of retreading

A number of life-cycle analyses of retreaded tyres have been conducted. Generally, the independent assessments have favoured the retreaded tyre over the newly manufactured. Tyre industry assessments have found the opposite claiming that rolling resistance of retreads is higher, the in-use benefits thus negating the production savings. This is disputed and subject to independent assessment as noted previously. In any event, simple material and energy balances reveal that a remould tyre will typically consume 18 litres or so less of oil-equivalent compared to the manufacture of a new passenger car tyre.

However, it is significant to note that the Used Tyre Working Group, on which the Tyre Industry Council and the Retread Manufacturers' Association are both represented, has identified retreading as the best practical environmental option.

On the basis of the figure of 18 litres of oil (Oliver, 2002), and assuming conservatively that truck tyres save 90 litres of oil (attracting economies of scale in processing), then remoulding is benefiting the environment by over 1 million tonnes of oil, or 3 million tonnes of CO_2 equivalent per year. Alternatively, 85 kte of crumbed tyre waste would occupy a volume of around 150,000 m^3, or over 300,000 m^3 uncrumbed. The derivation of these values is shown in Appendix 3.

However, although used tyres have recently formed a high-profile waste nuisance, it is important to place the disposal issue in the context of product life cycle. The pollution and resource use effects of a tyre in use dominate the overall carbon burden of the product.

Even minor improvements in rolling resistance and tyre longevity reap benefits that dwarf these disposal issues. Therefore, measures that address the in-use performance of tyres may represent sound environmental policies. In addition, if such measures force the development of a technologically more advanced product, this is likely to further encourage UK remanufacturing activity, and more responsible product ownership.

Industry dimensions

Statistics for this industry are hard to assemble. However, TRL Ltd has recently completed a Biffaward project (Hird et al, 2001) to estimate the input-output balance for the sector. This has necessarily involved significant

guesstimation, but the general figures are compatible with the anecdotal evidence of our interviewees. The sector does form one of the more easily bounded economic activities within the economy.

As described previously, the tyre market breaks down into passenger cars, trucks and machinery/aerospace. Of these, aerospace is the smallest and least documented market, albeit with the highest level of remanufacture due to the cost and duty of the product. In addition, there is a significant market associated with heavy earth-moving equipment; both these account for about 15% (6 million units) of domestic production, and are well serviced by the OEMs and independent remanufacturers alike. We can speculate on the value of such premium level activity compared to road use.
Of the remaining 85%, 75% by mass (95% by number) is attributable to passenger cars. The residual is attributable to truck tyres, also a premium remanufacturing market captive to OEMs.

According to TRL, there are over 130 companies worldwide manufacturing more than one billion tyres per year, but the industry is dominated by a few majors, most of which are represented in the UK. New tyre production is dominated by the USA, Japan, China, Korea and the EU. The UK accounts for about 4% of global production, centred on 10 locations in the West Midlands, North-West, North and Scotland. (The only indigenous producer is Avon-Cooper near Bath.)

In 1998, the UK produced 479 kte of tyres, including the retread component of around 72 kte. Of this, 391 kte was exported, and the balance of UK needs was satisfied by the import of 432 kte. (As a result, there was a small accumulation of tyres and tyre waste within the UK.)

Remanufacturing dimensions

As noted above, the amount of remanufactured tyre was around 72 kte at point of remanufacture, and 85 kte post remanufacture. Essentially this satisfied the captive market only, being barely competitive with the lowest priced imports. Reputedly, by conversation with retreaders, the number of tyres handled by them is around 1 million per year, but that the percentage of replacement tyres attributable to passenger cars in by remoulds is only a couple of percent. This number should be placed in the context of a market decline which has seen a fall from around three million units (cars) in the last decade. (This replicates the decline seen in the USA).

On the basis of TRL's estimates of disposal rates, we estimate that around 1,200,000 remoulds enter circulation per year. Assuming that car tyres weigh about 6.6 kg each, then this would account for only about 8 kte of the recycle. Therefore, truck and special tyres, which weigh over 50 kg, must form the majority of retreads by mass, and of the same order number as passenger cars. This is in line with the knowledge that OEMs do not retread passenger tyres, but are active in the high end markets of truck tyres.

On this basis, and reconciling TRL's figures, we estimate that around 1.3 million truck tyres are remanufactured by all operators, the majority perhaps by OEMs. This appears to give a remanufacture percentage of over 60% compared to new tyres, a figure which is not out of line with industry operator claims that tyres can be remoulded 3, 4 or 5 times.

The approximate turnover of the passenger car tyre remanufacturing industry is about £24m, assuming a transfer price of around £20 for the recovery, sorting and processing of each tyre. An equivalent figure for the truck tyre market at £100 per tyre would be a much healthier £130 million. Specialist construction and quarrying equipment attracts premium prices and could boost this figure significantly. Overall, the sector may be generating over £150m turnover. Amongst the independents, this activity is concentrated into 39 UK retreaders, most of whom are affiliated to the Retread Manufacturers Association (List in Appendix 5).

Potential of remanufacturing

In theory, most tyres may be remanufactured at least once by law. In practice, because of other tyre failures, only around 20% of tyres may actually be reused as bases for remould. Potentially, therefore, of the 40 million passenger tyres per year, 8 million may be remoulded under current legislation (given the correct construction). This represents an 8-fold expansion of the industry, and an extra saving of over 100 kte oil equivalent (300 kte CO_2 equivalent).

Further savings are possible if tyre constructions similar to trucks and other performance applications are incorporated. However, these would probably require changes to legislation to address concerns over verification of the history and inspection records for individual tyres. The potential to expand the truck tyre remould market appears is possible through increased penetration, and

changes to the current practice of place brand new tyres onto steering axles (Terry, 2002). Growth into Europe, and Eastern Europe in particular, offers opportunities.

Barriers to increased remanufacturing

The barriers to remanufacturing amongst independents are unanimously expressed by all representatives of the RMA and even the TIC. In short, although the retread product now conforms to as-new performance standards, through BS AU 144f:1988 and EU marking, in the public's mind remoulds are a second-grade substitute for a new tyre. Certainly in the past the industry has been tarnished by poor quality products, but concerted moves by the RMA and BSI have virtually eliminated the rogue elements. However, this alone has not prevented the decline in the number of remanufacturers from 90 less than a decade ago to only 39 today.

In conjunction with this, there has been a huge expansion in the number of overseas manufacturers, particularly in China and Korea. Typically, the cheaper labour in these locations has enabled a flood of low-price imports into Western economies. These products are now marginally more expensive than UK remoulds, such that purchasers will buy new tyres in preference despite the unknown provenance of many of the sources. This has driven down the cost of UK remoulds forcing the exit of many operators.

If it is considered that remanufacturing is desirable, then current regulations that allow only a single cycle of remould must be changed. If levels of remanufacturing similar to the truck and heavy equipment market are desirable, then some changes in the construction and manufacture of tyres may be required, for example, a thicker tread that may be re-grooved as well as remoulded.

This may imply a more expensive new tyre, but an expansion of replacement options (new, re-groove or retread). Such moves will also mean education of the public in better care of tyres (significant numbers of used tyres are rejected because of side-wall damage), and possibly a system for tracking the history of individual tyres.

We note that Bandvulc, through its Total Tyre Management programme, has recently instituted a web-based system for its truck customers to track the life-cycle of its products. This is an excellent example of moves to underpin public confidence in the product.

Actions

The key actions for the increase in remanufacture are:

* concerted efforts by the RMA, UTWG, TIC and distributors to advertise the quality and reliability of remanufactured product. This should be in conjunction with a clear description of labelling, and sourcing from accredited manufacturers (as in the US), coupled with a system for full traceability on products.
* public and institutional purchasers should institute a policy of using remanufactured tyres, except where this is excluded by other criteria; we note, for example, that Italian public bodies are obliged to obtain a certain percentage of goods in this way.
* legislative bodies should consider introduction of standards that force or encourage tyre longevity and efficiency. This will require added product complexity, and could enhance life-cycle management - including remanufacture - of tyres.

Other industrial groups

Standard SICs often span a variety of end products, and manufacturers often produce products under a number of SICs (although only recorded under one). It is therefore hard to unambiguously ascribe products or activities neatly into a single category. In the course of this work, we have come across evidence, documented, anecdotal or other, which permits us to make a qualitative assessment of remanufacturing level and trends in Priority 2/3 sectors, some of which show emergent applications.

SIC 17.50: Other textiles (apart from apparel)

The item of specific interest here is carpeting textiles. Coverings generally fall into the categories of domestic (broad loom) and industrial (generally polymer backed tiles), of which carpet tile forms 35-40% by area of the total market. UK installed carpet base is around 85 million m^2, and at 12 million m^2 per year is replaced roughly every seven years.

Two companies have recently started marketing eco-carpets: Interface and Milliken. The former has been piloting a carpet leasing arrangement, with periodic refurbishment of the stock; this has had limited uptake. Milliken has been operating a less radical model whereby

suitable product can be exchanged for a remanufactured carpet tile, from stock.

Carpet tiles are candidates for remanufacture because the pile – usually nylon – is virtually indestructible. Suitable cleaning, texturing and reprinting can restore appearance to as new. However, most of the installed carpeting, based on bitumen and PVC is not suitable for this treatment, and only modern carpets based on PU can take these treatments.

It may therefore be some years before significant levels of remanufactured carpet are available for direct swap. Remanufacturing activity in the broad looms is non-existent. Accordingly, the current levels of activity are adjudged low, and confined to the tile segment. We estimate that remanufacturing is saving less than 100,000 m^2 of carpet per year, or around 3,800 barrels of oil[8], or 500 te per year, or 1,610 te CO_{2e} (a new carpet tile consumes five barrels of oil per 100 m2, whereas a remanufactured carpet consumes 1.2 barrels, including cost of transport). The potential could be tens of times higher.

SIC 28.10: Structural & metal products

Negligible activity. Requires improved demolition and recovery techniques. An important step in the life-cycle analysis of new and reclaimed components has been taken in the BedZed construction project (Lazarus, 2002). To what extent remanufacturing has a role in this sector is not clear.

SIC 28.20: Tanks, vessels and central heating radiators

The bulk of this sector is concerned with the manufacture of tanks and vessels. These are largely static items which have a finite useful life – possibly with repair – followed by scrapping. Central heating radiators are rarely remanufactured, and account for a minor turnover. Remanufacturing is assessed to be low, and with low potential.

SIC 28.30: Steam generators

These are significant capital items ranging from portable domestic equipment, to multi-megawatt power station installations. Equipment at the top end is likely to undergo several cycles of reconditioning, probably involving re-tubing, upgraded burner controls, improved heat transfer surfaces etc. Significant remanufacturing is anticipated at this level.

However, the overall market size of these goods is low.

SIC 28.40: Forging and pressing of metal; powder metallurgy

These techniques currently present a minor contribution to remanufacturing, comprising rather basic mechanical processing operations. However, powder metallurgy is one of the fastest growing new techniques in the metals industry, and is at the forefront of metallurgical science. We believe that it could have a significant future role in remediation and restitution of otherwise unrecoverable mechanical components. Research and development in this field should be encouraged.

Currently, activity is assessed as low, but with high potential to contribute to manufacturing techniques at the most fundamental level.

SIC 28.50: Treatment & coating of metals; general mechanical engineering

As for SIC 28.40, this group also encompasses some basic remediation technologies. Treatments and coatings, such as metal spraying and plasma coating, have a high potential to facilitate remanufacture, and are already being applied to military and power systems goods. This is particularly so in consideration of the aesthetic components of domestic goods, where perception of quality is strongly related to surface finish. Further development of low cost restitutive techniques is required. We judge that the sector currently has a low impact on remanufacturing, but has the potential to be a significant enabler of restitution of metal and plastic components.

SIC 28.60: Cutlery, tools and hardware

Activity in this sector is low, and concentrated towards specific tooling and hardware. Although a great many tools undergo maintenance and repair, this is unlikely to be as rigorous as remanufacture.

However, a number of novel businesses are emerging in contravention of the traditional make and sell model. For example, tooling (drill bits etc.) for precision machinery are now being supplied on a pay-per-use basis, being guaranteed for a number of operations, and then being returned for restitution, surface treatment and sharpening. Such models could grow if applied

more widely in consideration of total lifetime cost of equipment, especially in industrial application. Logistical considerations of many dispersed items could be a barrier.

SIC 29.22: Lifting & handling equipment

This is a large market of around £3 billion domestic consumption, and with significant import/export activity, which appears amenable to remanufacture. However, like other machinery sectors, this too suffers to some extent from the effect of foreign imports.

In the personal and goods lift segments, the significant changes have been towards lower quality goods that last only 10-20 years, instead of the 50+ years from indigenous manufacturers. There is also relatively little classical remanufacture in this area, although regular repair, maintenance and testing – as a result of safety regulations that appear to prohibit removal and re-use. Estimate total activity as low, perhaps £50m.

SIC 31.30: Insulated wire & cable

These items are generally long-lived, and once installed the act of removal causes irreparable damage. Hence, most domestic cabling is unsuitable for remanufacture.

However, certain types of heavy duty, power and sub-sea cable is intrinsically valuable and durable enough to sustain remanufacture, and there are some companies offering this service. On the whole this is, and is likely to remain, a niche market of low overall value.

SIC 31.40: Accumulators, cells & batteries

Products in this category are largely chemical-based and suffer extreme degradation during use. Recycling to smelters and refiners is a common fate. Possibilities exist for larger products, such as automotive and UPS lead-acid batteries, to exploit construction modularity for remanufacture. However, this industry is generally coping with a legacy of toxic and hazardous constituents in a highly dispersed user base.

Future prospects for this group will be linked to the emergent fuel cell industry; these hold the promise of cleaner construction almost certainly coupled with design for extensibility. Given the alleged economic potential of these devices, it would be prudent to consider design for remanufacture at an early stage.

SIC 31.50: Lighting & lamps

The main barrier to remanufacture of lamps is a construction that is not amenable to disassembly. Incandescent lighting is made from tungsten filaments captured inside fused blown glass bulbs; fluorescent lighting is made from electrodes captured inside fused, phosphor-coated quartz tubes and associated external electronics.

Remanufacture is impossible without destruction of the integrity of major components. We are aware of one major manufacturer that is researching a new design of bulb that will permit modular reassembly.

SIC 32.10: Electronic valves, tubes and other electronics components

There is insignificant remanufacture of these components because:

* vacuum valves make up an increasingly small proportion of the electronics components market
* electronics components are generally packaged in a way that does not make them amenable to reuse, let alone remanufacture

There is limited remanufacture of highly specialised, high power components such as klystron tubes (microwave tubes) for application in industrial reaction and drying units, and military radar and weaponry. The contribution of these industries is low, however.

We believe the current electronics component paradigm may be a barrier to remanufacture of electronics assemblies. It is known that the generic issue of fixing PCBs and other assemblies into casings to

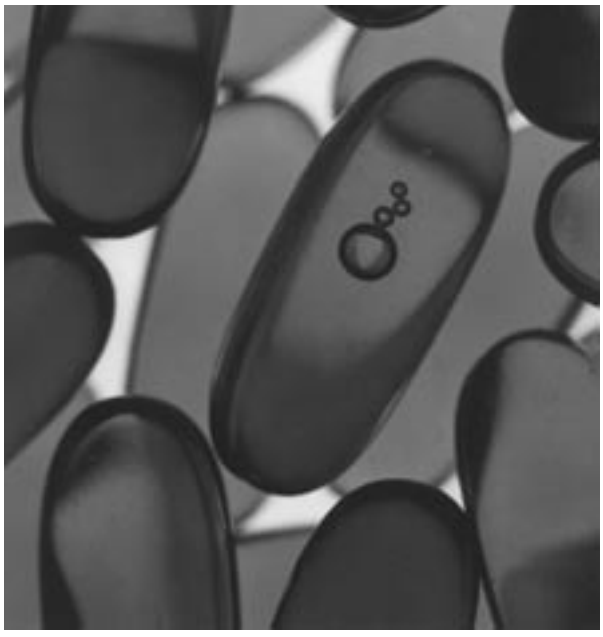
assist disassembly is important, and that redesign has significantly reduced demanufacturing time. A 1997 report by Van Amstel on recycling schemes in Holland notes the cost and time reduction in this operation for various brown and white goods by a factor of more than two for old and new generation products.

It is likely that current component assembly techniques, involving the practically irreversible soldering onto PCBs, is detrimental to mass component reuse, or to cost-effective selective component replacement. We would suggest that this area deserves more investigation, with the possible outcome of research programmes into novel jointing technologies.

SIC 32.20: TV and radio transmitters and line telephony apparatus

SIC 32.20/1 relates to exchanges, handsets, faxes and telexes etc. As identified previously, the only component known to remanufactured to a significant extent in this category is exchange equipment. Even so, this is estimated as low to moderate. It is known that the other type of apparatus is sold on price, and is replaced even when fully functioning to the extent that around 80% of telephone handsets are working at disposal (ICER, 2000). SIC 32.20/2 relates to radios, mobile phones, broadcasting, TVs and decoders.

This market has lately been dominated by mobile phone sales, an area of high innovation, miniaturisation and



subject to fashion. Around 15 million phones are sold each year in the UK.

Pressure in advance of the WEEE directive is now forcing moves to handle the end-of-life legacy of precious and toxic metals that arises: A recent move by a consortium of service providers, the Dixons Group and Shields environmental– Fonebak – is providing a service to recover and recycle these devices. A high proportion of these – perhaps 70% - will be refurbished and exported to developing countries and Eastern Europe. The target for the first year is around 1.5 million phones remanufactured, with full warranty, saving around 100 te of waste per year, perhaps 200 te CO_{2e}.

The main competitor to Fonebak is XS tronix (ENDS, 2002a). They are handling around 660,000 phones a year, of which 45% can be refurbished.

ICER reports that the lifetime of a television is around ten years. A significant fraction are replaced in working condition to upgrade functionality e.g. NICAM, teletext, digital, flat-screen, wide-screen, or integrated with VCR or DVD. This trend is unlikely to stop. These devices are not remanufactured in the UK, but notoriously may be exported for "reclamation" abroad.

SIC 33.20: Instruments for measuring, checking, testing and navigating

Information gleaned from the aerospace sector suggests that much low-end instrumentation in this category, like general electronic goods, will not be remanufactured. Mid to high end electronic and mechanical metering systems, for example, laboratory instruments, radar, electricity meters, etc. will be amenable to remanufacture.

We have identified at least one company that is remanufacturing meters as part of a total service package. ECS, a subsidiary of LE Group, itself part of Electricité de France, located in Bexleyheath, is accredited by Ofgem for metering UK grid supplies (Anon, 2002). ECS's Measurement & Calibration service also offers the facility to repair, recondition and certify all makes of instrument.

It can therefore offer total lifecycle management of the metering task, not only for the electricity market. A number of other metering companies are Ofgem regulated (Appendix 5), but their status as remanufacturers is uncertain; they are well distributed around the country.

Such instruments are ideally suited to remanufacture in the sense there is clarity about the performance standard required of the item, and technology is unlikely to evolve rapidly. They may therefore attract good prices, particularly since they are likely to be remanufactured by OEMs.

This sector also includes laboratory and other scientific analysis and measurement equipment. These items too seem suited to remanufacture, being highly componentized, increasingly software driven and of known quality. There are a number of American companies trading in refurbished equipment eg Sciquip, but operators on this scale are not apparent in the UK.

Contact with a number of operators, world-scale and otherwise, indicates that in fact technical advances in this sector are so rapid that end-of-life equipment has little resale value. Top flight users who replace before end of life may cascade used goods to less discriminating users such as universities.

Remanufacturing therefore plays only a small role in this sector in the UK, but may be forming a significant export market to developing countries.

Industrial and process instrumentation also falls into this category. This is increasingly sophisticated either through greater mechanical precision or electronics including remote telemetry, diagnostics and on-board data processing.

Also, there is a trend to non-intrusive measurements, which may mean equipment is more generally transportable from one application to another. These types should, therefore, be amenable to remanufacture. In practice, much instrumentation is still dedicated to relatively basic duties measuring flows, pressures, temperatures and levels of gases, water and steam. Meters in these duties are unlikely to be remanufactured.

SIC 33.30: Manufacture of industrial process control equipment

Personal experience of working in the process industries suggests that there is little remanufacture of process control instrumentation (field instruments, panels, DCSes or MISes). This equipment has generally lasted the life of the plant, although undergoing significant in-use repair and refurbishment. High value control valves may undergo refurbishment as described elsewhere in this document.
Recently, pneumatic systems are being replaced by electrically actuated fly-by-wire or wireless systems.

The modularity of such systems may make them amenable to upgrade in the same manner as other valuable electromechanical systems, such as automotive.

Our overall assessment of the level of remanufacturing in this sector is low, but with moderate potential commensurate with increasing electrical and electronic content.

SIC 33.40: Manufacture of optical and photographic equipment

This class includes spectacles, microscopes and telescopes, and photographic equipment.
Few examples have been found of companies undertaking these activities. In general, they are likely to be restricted to precision optics for laboratory and scientific use, or commercial photographic and reproduction machinery (photo-booths and film processing).

SIC 33.5: Manufacture of watches and clocks

This class ranges from wristwatches to longcase clocks to industrial timers. Although there is a thriving business in repair and maintenance, there is unlikely to be a significant market for remanufactured items. High value items are generally preserved for their historic or personal value rather than for a utilitarian purpose.

Our overall assessment of the level of remanufacturing in this sector is low.

REMANUFACTURING IMPACTS IN THE UK

The examination of the activity in individual manufacturing sectors has been synthesised according to the proposed methodology to determine an estimate for its impact in terms of:

* turnover: £5 billion
* carbon equivalent, expressed as CO_{2e}: 800 kte
* employment: 50,000 people

Appendix 3 contains an examination by sector of the estimated activities and impacts across sectors, and provides a number of explanatory notes to justify or caveat the numbers.

Are the numbers realistic?

The value for the turnover is £5 billion. This should be regarded in the context of several factors.

Total UK engineering activity

According to government statistics, the total value of engineering activity from SICs 17 through 36 is £400 billion. It therefore represents a fraction of 1¼ % of total activity. This does not appear extraordinarily high, and is probably around the lowest level of activity in any of the sectors examined; true activity may well be higher.

Employment figures are derived by pro-rating the total number of employees per sector as recorded in Trade Statistics 2001 based on prorated turnover. This is likely to underestimate employment because:

* some engineering activities have not been determined for contribution, or ignored as insignificant. However, their employees and contributions have been used in the prorating exercise, which will dilute the remanufacturing effect
* we know definitively that remanufacturing activities are, almost by definition, labour intensive compared to primary manufacturing. Simple pro-rating will therefore underestimate activity
* further, much remanufacturing takes place in micro-businesses, which again tend to have lower turnover per employee

Comparison with parallel activities

Critical comparisons here will be made with the recycling and waste management industries. According to engineering turnover statistics, as reported in Table 4, the basic engineering activities of these groups are around £1.3 billion and £3.3 billion respectively and employing a total of 50,000 people. Of course, secondary handlers and other processors will be recorded elsewhere under service-related SICs. For example, landfill operations accounted for a turnover of over £4 billion and employed around 35,000, and catering for around 80 million tonnes of waste in 1999 (Biffa, 2002, pp:38). This compares to an estimated recycling rate of 9 million tonnes.

Comparison with USA remanufacturing activity assessed by Lund

Lund's survey estimated a USA remanufacturing sector of at least $53 billion in 1996. Allowing for general growth in US output, this could now be nearer $60 billion, or approximately £37 billion. We know that US GDP outstrips UK GDP by a factor of 6-7, so assuming a pro-rated remanufacturing activity level, then our estimated figure is not surprising. In fact, given the scale advantages of the USA, it is surprisingly high. This could be attributable to these factors:

* a strong UK standing in the higher value technology aerospace, military and power turbine sectors, and rather gross attempts to value the activity
* very high UK population density, which may offset transport costs and encourage remanufacturing at a local level
* under-reporting of critical activities in the American study

A fuller consideration of the comparison with the USA statistics is provided below.

Are the numbers significant?

Again, simple comparisons suggest that remanufacturing has an economic value in excess of raw recovered materials, although it does represent a lower tonnage.

This demonstrates extremely well the main thrust of remanufacturing, which is to preserve the value of materials converted into products. These margins over the raw materials pricing typical of recycling are hard won by a sequence of value adding operations. As a result, remanufactured goods command between 40 and 70% of new goods prices.

In this study, the sparseness of basic data has only allowed us to estimate engineering turnover at the engineering stage; we have not been able to decompose across sectors the value added.

However, we can say that, in most of the growth sectors that we have investigated, and where operators were bullish about future prospects, there were anecdotal reports that margins on remanufactured goods significantly exceeded those on new sales. An examination of our interview reports will give greater insight into the climate of various sectors.

With regard to materials savings, we have simplistically chosen to relate these to carbon equivalents as defined by the Carbon Trust. In general, most remanufactured products are composed of metals and primarily steel.

This is an eminently recyclable material. Our purpose in presenting instead as CO_{2e} is that this is a topical measure of environmental impact, and may assist various industries in exploiting financial mechanisms aimed at reducing energy impact.

Our estimate of remanufacturing carbon impact is a figure of around 800 kte per annum. This compares to an approximate CO_{2e} figure for the entire steel industry of 37 M te CO_{2e} per year (Parker, 2002) assuming 14 M te of strip steel production. Alternatively compare to an approximate national energy expenditure of around 2 Gte CO_{2e}, based on coal-fired power stations. Our estimates of manpower are simplistically based on pro-rated sector turnovers. As described previously, we believe that these will seriously under-estimate employee numbers, which may be double quoted numbers in reality.

Comparison to US Experience

Results

As stated above, a simple comparison of the findings would indicate that the UK and USA remanufacturing may be occurring at a similar level. This would not be surprising considering the similarity of economic models, and a historic grounding in a military-industrial complex.

On the other hand we would expect the scale of USA operations to have some bearing, as well as its more adventurous nature in exploring novel product/service models. Accordingly, we should be aware of possible sources of difference in the two estimates.

In his study, Lund does make it clear that:

* he has, generally, canvassed only those businesses which
* he has not considered the wider remanufacturing industry, such as sub-contractors, component suppliers, logistics agencies etc
* he has avoided double-counting ie is considering only value-added during the remanufacturing operation, not sub-assembly repair and additional for assembly and retail etc

Exclusion of aerospace and military

We have attempted to remain true to these principles. However, the state of many sectors is such that many businesses cannot classify themselves as pure OEMs or pure remanufacturers, except where extra-ordinary OEM barriers exist (as in toner and inkjet cartridges). This has made allocation of turnover extremely hard to dis-aggregate. In any case, it is probably more relevant to consider the general feel of the proportion of goods being remanufactured as an indicator of the "sustainability" of the product or industry. Lund may also be missing a proportion of businesses that operate as both OEMs and remanufacturers, thus under-counting.

On the other hand, like Lund, we consider that, besides the "official" remanufacturing market, there is a significant "grey" market of second grade goods that are being refurbished at a local and regional level. One class

of these is through charitable initiatives. Although these may not record large economic values, their social worth as employers of otherwise wasted human and physical resources is highly valuable. Another class is a plethora of specialist owner-managers servicing niche markets, mostly locally, probably not being picked up on industry statistics.

An significant area of exception in Lund's study is that of military and aerospace remanufacture. This is all the more extraordinary given that modern day remanufacturing has its roots in these functions. If the allowance is made in the American study as has been observed in the UK, and biased by the proportionate size of the US military, it is not hard to imagine remanufacturing being 50-100% higher than Lund has recorded.

Taking these points into consideration, the value which we have ascribed to the activity could be judged as rational and reasonable. We recognise that the view is based on fragmentary and sometimes contradictory opinions, and is in a dynamic state. The true extent could vary by +/- 50%.

Survey

Given our level of time and resources, it has not been possible to replicate the full methodology of the Lund investigation. We note that Lund had three co-workers engaged over two years. In addition, the industrial climate and geography is well aligned to manufacturing, and the remanufacturing groupings well established with knowledgeable representative bodies keen to share membership lists.

Similarly we have rejected a suggested methodology from the University of Plymouth survey unit. Their technique requires a geographical segmentation of typical target areas followed by detailed investigation of all activity in that region.

In our view, there are no typical regions – a limited survey would produce a large bias to the local industrial cluster. For example, a survey based on Birmingham would imply the UK is dominated by machine tool and automotive component industries.

In our experience, there are few sectors where remanufacturing is organised to the extent of the USA, and with representative organisations geared to understanding the extent and state of the practice in their industry, especially in comparison to new build activity.

As a result, we have had to rely extensively on relatively crude canvassing of semi-randomly selected members of sector, and on the opinions of observers of the sectors, such as consultants, trade journals and advertising media.

Differences

The USA has an almost unique global economy in that its single geographical market, demography and resource base can support virtually every form of industry. By extrapolation, and combined with abundant entrepreneurial spirit, remanufacturing appears similarly widespread. Other countries with the capacity to achieve this distinction would be Russia and China.

In contrast, the UK cannot achieve a critical mass across all sectors, with the result that some industries and remanufacturing sectors are poorly represented. On the other hand, the UK has historic strengths in certain advanced technology areas, notably aerospace and power sectors, military applications, certain automotive activities and precision machinery, the legacy of manufacturing past.

We have already noted the generally lower overall activity in the UK, some of which may be attributable to more discriminating definition, but the remainder of which is undoubtedly due to more extensive penetration.

As expected, the USA has an extremely active automotive remanufacturing sector riding on the world's largest

manufacturing capacity and car-buying public. In parallel, most freight is carried internally by heavy-duty haulage, employing custom drive units fitted with market-leading engine brands, such as Caterpillar.

A competitive, efficient and well organised infrastructure exists to service the needs of these fleets. In general this is not replicated in Europe where truck and engine suppliers are the same company. A by-product of this capacity is a more vibrant tyre remoulding industry, for example.

This feature is replicated across much of US manufacturing, although we can speculate that it is not immune from the threat of cheaper foreign imports. Historically, America has been more patriotic in its purchasing, both domestically and industrially, and particularly in the self-sufficient internal markets where dealer network toeholds are hard to establish.

Undoubtedly the USA will continue to rely on this, the economies of scale, low internal transport and energy costs and a certain continental isolation to justify significant levels of remanufacturing.

However, it is also true to say that the US has been creative in redefining goods and services, and harnessing the power of logistics and reverse logistics.

One area where the USA may be lagging Europe is in the handling of certain classes of electronic goods, particularly PCs. It is notable that major domestic suppliers do not have high-profile take-back campaigns for reclamation or refurbishment, which is in contrast with the office equipment manufacturers, such as Xerox.

Learning

In summary, what are the factors which we believe make the USA a comparatively stronger base for remanufacturing activity?

As usual, culture plays a strong role, and the factors are:

* entrepreneurial, learning culture adept at occupying market niches
* geography and demography supportive of a self-sufficient market
* strong belief in home-made products, and a vigorous buying public
* strong capability for networking, promoting, branding and lobbying
* a regulatory framework that enshrines freedom of information and competitive environments, thus helping to reduce artificial barriers to competition
* fiscal measures that encourage remanufacture as a desirable environmental option by offering tax breaks to practitioners (proposed)

DISCUSSION OF THE FINDINGS

The part of this survey that has dealt with quantifying the contribution of remanufacturing to the economy and to resource utilisation was necessary in order to baseline the significance of the activity. A more important aspect is to articulate points related to the climate of the industry, and the practice of remanufacturing businesses. As a result, it is possible to suggest routes forward to encourage remanufacturing, if appropriate.

Key findings that are addressed in this section are:

* identifying remanufacturable goods
* emergent themes
* areas of growth and decline
* issues & opportunities for the UK

Identifying remanufacturable goods

Our initial scoping interviews were extremely productive in identifying the types of goods that might be amenable to remanufacture. This has enabled us to define a number of indicators that point to reasonable business segments.

Figure 9 is a simple graphical representation of such business segments – which we have called the feasible operating space – constructed on three axes.

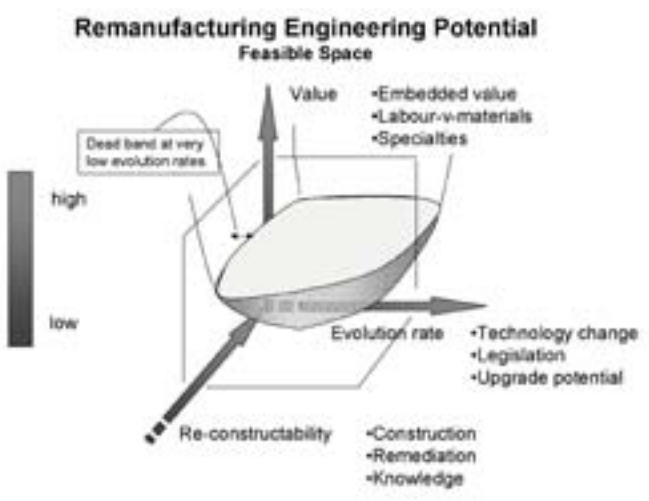
The vertical axis is termed Intrinsic Value

Essentially, this implies that more expensive items will naturally lend themselves to remanufacture because of the invested time and resource to achieve.

However, this must be moderated by consideration of other factors:

* equipment may be expensive, yet capital expenditure may be low relative to the cost in use (such as is the case with tyres where the bulk of expenditure of the user is petrol cost)
* the customer may not value durability where this is beyond his planning horizon (such as is the case with many engineering machines and electromechanical systems)
* the uniqueness of the product (and the advantages that it confers) in relation to alternatives, or perhaps displacers of the function or service can affect decisions to renewIn this respect we should also consider goods which have been converted into services, essentially embedding them – perhaps invisibly – into more valuable activities (such as is the case with photocopiers and pumps for the water industry, both outsourced)
* the balance of labour and materials content prevailing – from a remanufacturer's perspective very high labour costs will negate effects of reclaiming materials
* lack of market competition through strong incumbents can generate profitable spaces for remanufacturers; for example, toner and inkjet cartridges are a high margin business for OEMs that is protected by the diversity of designs and machines on offer. A highly profitable segment provides possibilities for those able to undercut despite the need for replacement components, extra labour and logistics
* products amenable of upgrade will attract capable remanufacturers
* legal frameworks can work both positively and negatively. For example, the safety restrictions on aircraft require regular overhaul (rotables) of critical components such as engines. Disassembly and reassembly to exacting standards constitutes an enforced remanufacture, and a profitable opportunity for OEMs and third parties. In some industries such legalities expressly forbid reuse: lifting gear, lifts and in the US, safety valves are examples. This cannot be explained solely as being due to lower cost of simple items; it is likely also that a poor remanufacturing and safety reputation can adversely and indelibly

Figure 9. The feasible operating space



taint an industry, and force the hand of legislators. Additionally, for complex assemblies of goods (relevant to products such as cars), trade description laws prohibit the inclusion of remanufactured (reused) components in new products

* customer perception is critical in consumer and personal goods. There is a strong association of status and self-worth associated with many utility items in today's economy: cars, furniture and furnishings, apparel, white and brown goods may be capable of remanufacture to a greater or lesser extent, yet activity is marginal. Issues of branding, trust, liability and warranty can unlock such markets
* impending threats to the business environment may motivate change in perceived intrinsic value. For example, a shortage of a raw material (temporary or permanent), or a penalty on end-of-life disposal could cause a shift to maintaining or increasing the value of a core, and biasing towards its recovery or reuse. WEEE legislation may affect high value goods in this way

The first horizontal axis relates to issues of Re-constructability

Again this is a bundle of characteristics that may prevent or assist the physical remanufacturing task:

* access to used goods – cores – is critical to remanufacturing. Some industries, because of the set up of the official channels to customers, find it very difficult to source these raw materials. This is typical of mainstream automotive where dealerships intermediate between users and suppliers, and are subject to pressure from BVAs to both use own-brand parts (sometimes remanufactured), and to return broken parts through official channels to approved remanufacturers. Independents are then forced to cater for niche markets, and source through grey channels and breakers. At other times, cores are widely distributed and users do not appreciate the return value; brokers may not exist to identify, locate and collect such cores
* the majority of remanufacturing operations are unlike the initial manufacturing processes. The major difference is in the variability of the raw materials, whilst still being subject to the quality constraint on the finished product

Personnel employed in these operations require both an orientation to hands-on engineering skills, and a facility in problem solving. Several interviewees report that, within mixed primary and remanufacturing organisations, these jobs are seen as more rewarding than straight production. Industries which have automated and mechanised remanufacturing into standard procedures do not report such differences. Overall, however, the decline in attractiveness of engineering compared to softer sectors endangers the health of the sector

* once available, the item must be capable of disassembly, diagnosis and reassembly in a reasonable time and whilst maintaining the essential integrity of the piece. An excellent example of such design is the toner cartridge whose inventor, Canon, targeted ease of construction to stimulate reuse. Xerox and Océ photocopiers are examples of products that have been re-engineered by designers and users for maintenance, reuse of components and upgrade capability. Some electronics and white and brown goods are not amenable to remanufacture because of the complex joining technologies employed
* given that items can be disassembled, the materials of construction must be amenable to repair – if that is the chosen route – or replacement. Currently plastic components are not generally cost effective to repair, so joints cannot be relied upon, and surface finish is often an issue with consumers. On the other hand, several techniques for rebuilding metal components have been developed including metal spraying, impregnation, sputtering, anodising, powder metallurgy and metal screwing to name but a few
* given that techniques and materials are available, knowledge of product design specification is essential. Without such knowledge, critical engineering components built to incorrect tolerances can fail prematurely to the detriment of users, and discrediting remanufacturers. Truly independent remanufacturers have commonly built reverse engineering teams to infer design specifications, often at great cost. Such operators will struggle to keep pace in environments of high product innovation, such as automotive and electronics. We have identified knowledge barriers as a universal block to remanufacture,

which will require government to introduce freedom of information acts to counteract, in the style of the US

* given that items may be successfully remanufactured, it is necessary that they are then compatible with co-dependent equipment. There are examples of OEMs including features that bar unauthorised items from functioning when placed as spares in equipment. The best hard-system example is in printer cartridges, where microchips prevent reintroduction of once-used pieces. Such practices will open OEMs to prosecution once the European WEEE directive comes into force

The third axis is that of Evolution Rate

Primarily this relates to the change in functionality or capability of goods, features, size, weight, power, economy, emissions, longevity, being typical.

* very high rate sectors will not be amenable to remanufacture at low value or low reconstructability. However, even these systems can justify remanufacture at high value, primarily because they are composed of subsystems that can be individually reconstructed and/or upgraded
* sectors of zero or very low technological change can also be unattractive. Generally, the products have achieved maturity, and manufacturing costs have been minimised. Products can be long-lived, meaning that refurbishments are few and far between, and in volumes incapable of supporting a vibrant remanufacturing industry. Ways to break out are through service (and software) change, as in the case of photocopiers, or by supporting of an incumbent base of mission-critical equipment, eg military goods
* the middle ground provides fertile areas for remanufacturers. This is especially so if complex products can be modularised so that elements have a longevity beyond a single product; and if they can be designed to be amenable to upgrade – not always foreseeable or achievable

In some sense, remanufacturing may provide a bridge between the classical views of the technology maturation model, and the newer concepts of disruptive innovation provided by Christianson (1997).

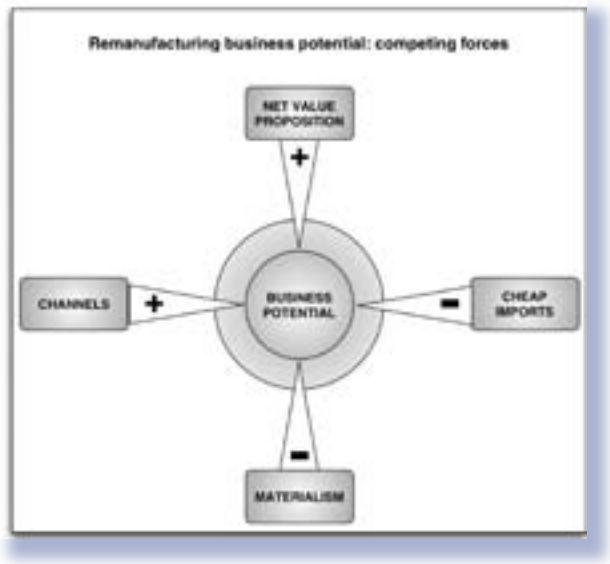
Christianson's model exemplifies waves of new technology addressing the emergent needs of select customers, initially at low volume and high price, but gradually intruding into the mass market and displacing older technologies that have become bloated and over-specified.

On the one hand remanufacturing has the effect of extending product life, and perhaps re-energising sales through novel features or service combinations. However, this may be to the detriment of new sales, a feature that may be seen positively or negatively by various antagonists:

* OEM remanufacturers can extend a technology, and maintain or extend profit margins as traditional markets saturate, thus defending their positions. This is the case for power turbines
* contracted remanufacturers can offload non-core activities from OEMs, and support end-of-life lines, thus freeing OEM facilities for new products. This is the case for automotive markets
* independent remanufacturers can parasitise wherever skills and knowledge are available, and where OEMs are not threatened. They may also profitably exploit maintenance activity emerging technologies where OEMs are heavily engaged in building new markets. This is the case in electronics for Electroversal, which has developed techniques for remediating the growing LCD market

Remanufacturing may therefore play a role in bolstering the introduction of new technologies, and managing the

Figure 10. Remanufacturing business potential



extension and ultimate decline of old ones.

Establishing the engineering potential is not sufficient to ensure a viable business proposition. Figure 10 shows that other business factors will influence the business potential.

In particular, the declining relative cost of newer models or imported goods acts negatively; consumer materialism, preference for new rather than renovated items and distrust of warranty or reliability related to reconditioning also detract; on the other hand, good reverse logistics channels giving access to a stock of core goods is a significant enabler of remanufacturing.

These factors are explored within the following section.

Remanufacturing themes

This section summaries the key themes that have emerged from interviews. Many of these are common across sectors, but clearly there is variation in each one.

Skills & practices

The nature of remanufacturing work typically demands people with a mechanical and manual orientation but, critically, ability to diagnose, isolate and rectify malfunctions, and a concern for standards.

This is because remanufacturing, unlike manufacturing, works on raw materials of unknown quality that must be disassembled and assessed for viability and future worth.

Many respondents highlighted an inability to obtain personnel of the correct skill base. This was more pronounced in the engineering-based organisations, and particularly those in smaller, less-glamorous companies and crafts.

Companies engaged in more routine remanufacturing operations did not express such concerns. However, in most cases, it was clear that the UK's high wage economy would always place it at a disadvantage compared to imports in cost-conscious sectors.

Where companies did have adequate access to skilled personnel, they were generally working with local TECs, colleges and RDAs to nurture candidates, in conjunction with internal experience rotation plans.

Larger companies were more alert and supportive of these possibilities. It is well known that the numbers of entrants into engineering disciplines is in decline compared to "cleaner" sectors such as IT, retail and media.

However, operators in the more creative remanufacturing practices, where the task was formulated as a personal project, largely owned and effected by the individual, did appear to have higher job satisfaction. In at least one company, the remanufacturing unit was perceived as the goal to escape less interesting work elsewhere.

To a large extent, it also seems that the quality – tidiness, cleanliness, comfort, ambience, procedures – of the workplace set an undertone for the perceived status of the work.

At a managerial and procedural level we also saw a number of competencies and behaviours conducive to good business. Some of these would also be applicable to general business practice.

* a large number of operators were operating to a Quality Standard
* many of them had adopted lean manufacturing techniques, particularly cellular, workflow, SPC and kanban methods
* the issues of warranty forced many to implement inventory control and full component traceability measures. The electronics operators were particularly advanced, but we note that at least one tyre remoulder is now instituting such a system
* managers were attuned to local networks of suppliers and remanufacturers to and from whom they could source core materials or outsource sub-components for remanufacture outside their own competence. This was a feature of the automotive and other electromechanical sectors, where units are complex amalgamations of parts
* independent manufacturers are often hampered by inability to obtain information regarding design specifications for cores from OEMs; in such cases, they need networks to glean such information from deregulated markets, such as the USA, or explicitly create reverse engineering cells to deconstruct cores. The time and expense of conducting this analysis on a significant number of units should not be estimated, particularly in markets where product marques are deployed at high frequency

Basis of Competition

Our research indicates that remanufacturing is in decline where products, despite probable technical superiority, are competing solely on price. Unfortunately, this includes a large swathe of manufacturing industry, particularly in machines and standard engineering equipment and utility items.

On the other hand, the greatest success is observed in those industries that address highly engineered and costly items, for which technical or service enhancements can be added.

These two areas are not mutually exclusive. We believe that it is possible for even relatively simple industries to support a thriving remanufacturing industry.

Shifting the basis of competition requires modification of attitude by both the seller and the buyer. The previous examples have illustrated how the seller's offering can interest a purchaser. However, it is also necessary for the purchaser to be motivated and receptive to new models.

Our research seems to indicate that many parts of UK industry may not be viewing its environment in the same way as users of pumps. For example, purchasers of industrial machines are content to buy cheaper imported machines, even though they have limited life compared to those that can be remanufactured in the UK. This may be related to:

* an inability to look beyond a five year horizon – perhaps symptomatic of general economic uncertainty, perhaps simply poor management
* poor purchasing decisions which do not consider the lifetime cost of ownership
* purchasing decisions devolved to finance departments that whose purchase criteria are not geared to lifetime cost, and who ignore the opinions of users and maintainers of equipment
* poor attempts by OEMs and/or remanufacturers to sell benefits of remanufacture, and to incorporate novel elements, technological or service-related

A large part of the blockage may therefore be through external factors characteristic of British industry; attention could therefore be well spent in improving the internal management processes of companies, and removing internal barriers to effective purchasing.

Legislation

Legislation can have a significant impact on the environment for remanufacturing. We believe that this is an area in which government may have a significant impact without the distortion of fiscal measures.

Case study - the pump industry

Ostensibly, pumps are a relatively simple piece of machinery with limited number of rotating parts; the technology is well understood. Indeed, pumps are subject to intense price competition at high quality from global imports, and this route does absorb a high proportion of low-end devices, say less than £1000. However, all major pump manufacturers have realised that there business is not in selling pumps, but rather in selling pumping solutions. This manifests itself at the extreme as customers outsourcing the running of pumping facilities to the pump company, who are reimbursed with a revenue stream. They are therefore motivated to install and maintain durable equipment and, to address evolving demands, introduce upgrades and improvements.

Responses such as this help retain value within the OEM, and are hard to displace by imports because they typically require local presence to support. This does not mean that these OEMs are not global players, only that they are aware of the individual service required of, for example, water companies. Other industries, such as chemicals, are more reluctant to outsource pumping functions, since they are highly integrated into the chemical processes. However, they are still sensitive to the cost of pumps, and will remanufacture complex and exotic material devices. According to industry sources, in some cases up to 50% of revenue could be attributable to maintenance and remanufacturing operations.

The change in the basis of business appears to have opened a new competitive front for operators in this sector: Sales literature is replete with references to and calculations of the lifetime cost of ownership, and to aftermarket and post-purchase support services. This sector may then provide pointers for other sectors.

Case Study - grinding machinery manufacturer

Jones & Shipman is an East-Midlands-based manufacturer of grinding machinery, now part of the US Renolds Group. It is perhaps the most recognised and imitated company in the sector with a long history in the UK, its fortunes mirroring those of industry in general. J&S products are renowned for their longevity, and there has been a thriving market in their remanufacture by independents, some units being 50 years old.

Other sectors of the machine industry, such as cutting and lathes, have seen severe decline due to the influx of cheaper, computer-controlled machinery from the Far East. Such machinery is allegedly not open to remanufacture due to the durability of materials employed. Few imports can match the quality required in the grinding sector, but its numbers are growing and, combined with parasitism of remanufacturers, J&S recently fell into loss.

In response, J&S has instituted a full-blown remanufacturing service. It has dabbled in such activity previously, but has tended to lapse in economic up-cycles. J&S's experience, trading on its clear brand awareness, is that remanufacturing can buffer against the externalities, and offer significantly greater profit margins over the strained new sale market. Remanufacture also allows the retrofitting of OEM-approved modern computer controls demanded by today's customers.

The greatest, most repeated complaint expressed was that related to access to information pertinent to design specifications. This data is commonly closely guarded by OEMs, and often only released to contracted agents. Absence of design data adds significant effort and cost to determining the standards to which cores must be renovated, since cores themselves are usually worn and exceed manufacturing tolerances. Independents are thus forced to estimate based on common practice, or institute dedicated reverse engineering teams (see above).

At first sight the release of design information appears to advocate the loss of a fundamental competitive advantage. However, it could easily be argued that the retention of that knowledge, in a remanufacturing economy, is anti-competitive.

This is because protective measures embed OEM stagnation, preventing exploration of service innovations until forced. On the other hand, early access to such information would allow smaller niche players to explore novel service options, which would place an onus on OEMs to do the same, with benefits to consumers. In a climate of producer responsibility, such moves could rapidly accelerate environmentally beneficial businesses.

Clearly such moves could have repercussions for warranty and liability, which may need greater definition and policing. However, we note that such freedom of information is enshrined in US business law, and already forms a backdoor route to product knowledge in Europe. Explicit legitimisation is therefore only sensible.

We also note that legislation also prevents the reuse of components in certain industrial applications such as lifting equipment. This seems out of place compared to the extremely high prevalence of remanufacturing in say, the aerospace industry, where safety is critical. Perhaps this is a legacy, like much industrial safety law, of a cavalier history of operations and a lax attitude to safety standards.

However, harmonisation of such legislation could also open other areas for remanufacture. The third major area of product legislation concerns the banning in new goods of anything other than new components as an act of misrepresentation. Relevant legislation here is probably the Trade Descriptions Act (1968), and possibly Trademarks & Copyrights Act (1992).

This also bars a significant opportunity for increasing remanufactured content. The most significant example of this is in automotive remanufacture, where operators

Case Study - photocopiers

Objections to impending WEEE legislation were raised recently by UKCRA, and other EU operators, in response to moves by certain photocopier manufacturers to include chips and other devices into cartridges that deactivated them on removal from the host printer.

After concerted lobbying by MEP Chris Davies, WEEE legislation has been modified to outlaw such practices except where they confer extraordinary consumer benefit.

also cite the public acceptance of "used" goods as a significant barrier in this respect. However, it is the basis of remanufacture that the products are as good as new, indistinguishable from new, and carrying the same warranty.

Given such a description, what is the functional and legal difference between the items if liability still rests with a known party?

A fourth area of concern, which has already received some attention in the European Parliament, is around OEM inclusion of measures to prevent reuse of remanufactured components other than those routed through nominated channels.

A more general application of these principles would assist remanufacturers elsewhere, but especially in the knowledge-based economies.

If the three pillars of access to design specification, open field to remanufacture (given adequate standards), and remanufactured goods substitution can be put in place, then typical OEM warranty get-out clauses regarding non OEM components can be removed, with benefits to the consumer.

Considering business legislation more widely, many operators were concerned by the burden of regulations governing job definition and control in engineering, with its supposed benefits to health and safety. These complaints were not exclusively made by small operators.

There were repeated statements about the inequality of standards applied in the manufacture of goods manufactured abroad, particularly in respect of SHE and social costs.

Case Study - white goods and electronics

Only relatively recently in white goods, have major operators such as COMET teamed with refurbishers such as Remploy to establish reverse logistics channels. We note however, that this is still not a true remanufacturing operation.

Still more recently mobile electronics has seen its first large scale return-to-remanufacture channel, Fonebak, established by alliance of manufacturers and network operators with a waste management company, Shields environmental.

Core Broking

Remanufacture is contingent upon being able to obtain the raw materials – cores – on which to operate. In many sectors, through reputation or perseverance, operators have engaged sourcing routes:

* in the automotive sector, dealer networks provide a bona fide route to contracted agents; independents must operate through grey markets, from vehicle breakers, or direct from independent garages
* in the cartridge refilling industry, there is a host of intermediate core brokers comprising charities and commercial operators who amass many thousands of units
* in other sectors, the reputation of individual agents makes them a point of direct contact for customers

However, other high profile sectors are not as well developed, or are only now emerging.

Expansion of remanufacturing into new areas is likely to be held back by the absence of such channels. This will be particularly significant if there is to be an impact on other widely dispersed products, such as consumer electronics, which will certainly require coordinated and cost-effective collection schemes, if only as a compliance measure for impending WEEE legislation.

There is likely to be opportunity for waste management agencies, haulage agencies or postal agencies to engage in the reverse logistics activity. However, it is probable that such agencies will require preliminary sorting in order that only reasonable quality goods are sent for refurbishment.

Design for remanufacture

Aspects of design have a large effect on ability to remanufacture. In tandem, the emergence of new engineering techniques can improve viability and materials efficiency of these processes.

These examples illustrate the range of attitudes and effects to design and assembly. It is clear that some materials and techniques are beneficial to remanufacture, but that other design considerations, such as cost and weight, have over-ridden these in many products. In particular, we can point to the use of materials that are

Case Studies - machine tools, engines and photocopiers

The common use of standard engineering construction techniques has (unintentionally) presented no barrier to remanufacture. On the other hand, there are examples in automotive engine remanufacture, of OEM component manufacturers designing pieces that cannot be re-machined without damage or catastrophic failure.

Meanwhile, at the opposite extreme, photocopier manufacturer Canon, in designing the first toner cartridges, ensured they were assembled using simple screw joints, with serviceable components – a measure designed to boost growth of the industry through its complementary assets.

not amenable to remediation, such as most plastics; or not amenable to disassembly because of fusion, welding gluing or other irreversible jointing techniques; or the complex interweaving of components such as foam fillers and insulation, that are not simply removed. These considerations are likely to limit the remanufacturing potential of most white goods.

The concerns of the electronics industry with regard to disassembly in anticipation of WEEE directives are well known. This has implications for brown goods and other electronics. Some attention has been given to the toxicity aspects of solders, and to component fixing systems within equipment carcasses to address speed of release.

However, it may be that there is a greater problem with the current electronics construction paradigm, which makes component reuse uneconomic in many cases. Given the volume of electronics in society, this area could form an area of profitable research.

Such research should not be restricted to electronics. Significant advances have been made in remediation in the metals area already. This should also be extended to plastics, and especially high quality surface finishes required for automotive and other consumer goods. In addition, further research into lubrication and wear to extend product life would benefit longevity.

General attention to minimisation of the number of parts, component standardisation, and enclosure standardisation can all assist.

These are not materials issues: They are management issues. Successful companies have integrated product design, uses and de-manufacture by good management of teams representing different stages of the life-cycle, as in the photocopier industry. There are lessons here to be learnt by all OEMs considering the benefits of remanufacture, and which can cause such ventures to under-perform if not enacted well.

Public image

Perhaps the greatest barrier to widespread, recognisable and acceptable remanufacture is the public perception of quality of remanufactured goods. If the term is understood at all, it is generally taken to imply second-best.

To a large extent this is the result of historic malpractice within all sectors of industry; such reputation is now largely undeserved because of the emergence of:

* informal self-policing of industry groups, although trade associations dedicated to remanufacture alone are rare - tyres
* imposed quality standards through legal requirements cascaded through vigilant

intelligent purchasers - aeronautical

* imposed quality standards through close working relationships with the OEMs (e.g. Tier 1 status, OEM branding) - automotive
* proxy branding through large, reputable distributors who buffer remanufacturers from the end user - cartridges

However, the level of ignorance of remanufacturing within traditional trade associations is remarkable, and a cause for concern. This is not unsurprising given commerce's record in, for example, defining sustainability strategies for their sector.

We note in October 2002 Warmer Bulletin (pp9) that in the DTI's target group only five sectors have so far submitted sustainability plans.

For these sectors, remanufacturing may be an opportunity going begging, and a chance to recast themselves in a more favourable light. For many of the companies we have met, remanufacturing is a profitable meeting point of economic and sustainability issues, and meeting customer needs. Active endorsement, validation and policing by authoritative and representative bodies could invigorate their own sectors and establish the credibility of remanufacturing more widely in the public's mind.

We cannot help contrast this with the activity level in the USA where remanufacturing institutes and associations are widely advertised on the internet, and where the field is an active topic of debate in the legislature.

The impact of negative public perception cannot be underestimated. It is likely to persist as long as the economy is obviously oriented towards single use. Some of this appears to be a self-reinforcing cycle in which second-user goods have negligible trade-in value compared to new, such that incentive to buy remanufacture is minimal. In many cases we must accept that use of remanufactured goods will not be feasible or desirable, for example, where technology or fashion evolves quickly, and unit price is low.

However, it is possible that servicization of goods, even in consumer markets, is possible, and creates incentives for remanufacture. Such a system has been instituted by Electrolux with fridges in Sweden.

Other European countries have experimented with communal car and facility ownership schemes, and there will be lessons for the UK here.

KEY UK ISSUES & OPPORTUNITIES

Potential

The potential for remanufacturing must be judged carefully from a number of perspectives. Primarily, we have conducted this work as an evaluation of the contribution of remanufacturing to "sustainability" and "resource efficiency" in broad terms. Considering the overall level of remanufacturing it is tempting to say that, from a materials standpoint, the potential for further increase is large.

However, it is also true that remanufacturing is not driven explicitly by altruistic concerns for the environment. Operators that we have spoken to have judged that remanufacturing is a business opportunity to be exploited, and competitive judged by the balance of costs of core parts, replacement materials and additional labour, and risk of product failure.

Where remanufacturing is being squeezed, and being perceived as offering low potential, goods are generally being supplied on a lowest cost replacement basis. Conversely, the most bullish operators are working in sectors of higher added value, often knowledge related, and breaking down traditional notions of manufactured products.

Therefore, to a large extent and given no external macro-economic measures to bias towards remanufacturing, the activity can flourish in relation to higher value goods offering customer solutions in a diversity of options, and likely as part of a supply, maintain and upgrade package. In these circumstances, there is more incentive to design robust, long-lived, maintainable products, which almost certainly embody material resource efficiency benefits.

"Sustainability" benefits thus accrue as a result of appropriately structured markets.

The challenge for regulators and managers is how to encourage the evolution of such markets.

Development agencies will be interested in remanufacturing for its potential to generate regional employment.

In large-scale manufacturing, companies tend to source components from limited disparate sources, often from abroad. In contrast, in remanufacturing, large companies tend to concentrate on the core elements and sub-contract locally to trusted affiliates who can refurbish other sub-assemblies. Remanufacturing hubs can thus seed diverse local companies.

In this country, even where primary goods are made abroad, UK service operations may be upgraded to remanufacturing sites to the benefit of local economies.

Areas of low exploitation

IT, specifically home computing systems

As previously described, the IT industry is subject to rapid evolution of performance, specification and protocols. To a large extent this is driven by a synergy between software and hardware suppliers, targeting the needs of a minority of demanding domestic customers, and squeezed by commoditisation of ostensibly high technology components.

Thus the expectation of limited lifetime and enforced redundancy fuels a slim margin market with little incentive to design for anything beyond three years.

Large corporate users, on the other hand, have increasingly out-sourced their IT demands, and require a value-for-money service. This has incentivised the suppliers or intermediaries to consider longevity of the systems, including cascaded use of machines within clients, and engaging reputable remanufacturers to manage maintenance and warranty issues. Remanufacturers may, to some extent, manage the inventory of goods, sub-assemblies and components.

Whilst there appears to be a large amount of refurbishment in the PC market, there is very little true remanufacturing

capability. From the customer's perspective, this would require provision of one or more of the following elements:

* a reasonable length warranty, at least one year
* support line
* upgrade to keep pace with evolving standards and protocols

Reclaimers are generally caught in a cycle of low margins being unable to justify significant effort investment, followed by low price tolerance of the purchaser. Low cost operators offering the above service, perhaps as an integrated repair and upgrade service may find a more willing public.

White goods

Not likely to be remanufactured whilst the emphasis is on cost of manufacture rather than longevity, no reputable remanufacture exists, and aesthetic factors sway purchasing decisions.

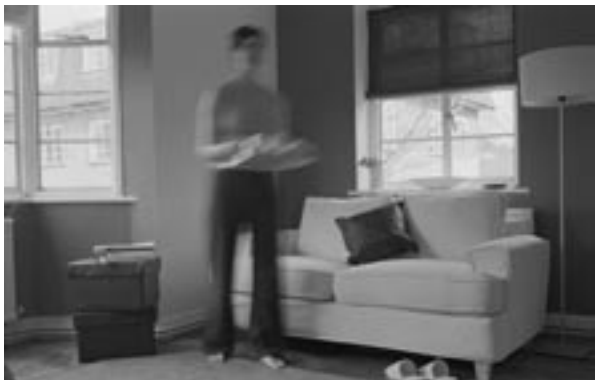
There are example initiatives in, for example, Scandinavia where washing machines have been leased to householders who then pay per use. An extreme case would be a return to laundrette and laundry services, but this seems unlikely given consumer attitudes to convenience.

Furniture

This is a sector of large economic importance in the UK even just at the manufacturing level. A large part of this activity is directed at domestic use, of which virtually none is remanufactured. A small amount of furniture is leased, and may undergo minor refurbishment such as recovering.

However, furniture is largely regarded as an intensely personal good, reflecting status, achievement and indulgence. It is therefore unlikely to appeal to second users unless embodying particular qualities of age, provenance or extreme craftsmanship. We have found no evidence of significant remanufacture, or any moves which could enable modular component reuse.

Given that manufacture in home goods is a manual process, the comparative advantage for remanufacture should be relatively high. However, remanufacture is likely to require complete teardown to components that are essentially quite cheap, so the intrinsic value is biased



towards the labour element – which does not persist after first purchase.

Having said that, there are examples of furniture remanufacturing initiatives on the continent: the ecomöbel project in Germany is a case in point.

Industrial machinery (selectively)

Industrial machinery has seen a great decline in domestic primary manufacture due to competition from low-cost imports. In many areas, the quality of these matches indigenous goods, but not exclusively.

However, most manufacturers do not appear to have embraced the service principle as enthusiastically as other sectors, even similar ones such as pumps. We must consider that they are attempting to sell the wrong products, in the wrong manner, to the wrong people.

Non-commercial maritime

Whilst remanufacturing plays a role in commercial and military maritime, it does not extend into the pleasure sector. This probably reflects the fact that this activity is generally for hobbyists who relish their own maintenance activities, and who feed a vibrant resale market.

Equipment is generally budget versions of commercial equipment, and subject to the commercial pressures of other retail, white and brown goods. There has been a marked erosion in the cost of sophisticated electronics – navigation, communication, automation etc. – which does not support remanufacture. Engines and other power equipment is amenable to remanufacture, but in a fragmented manner.

Remanufacture is therefore unlikely to play a large role in this sector.

CONCLUSIONS

Our survey has revealed a large area of activity based on the return of goods to as-new condition with warranty. In our estimate, the GNP of remanufacturing (at the point of remanufacture) is around £5 billion per year in the UK.

This compares to a published value of £1 billion for the waste metal recycling industry, and £3.3 billion for refuse disposal.

Remanufacturing has a long history in the UK, and continues to be practised across the whole range of industrial sectors, some in ascendancy, some in decline.

A number of factors that promote and mitigate against remanufacturing have been identified including:

Factors in favour of remanufacturing

* high intrinsic value
* essentially durable items
* low to moderate technology evolution
* cores readily available
* integration of sales/service/upgrade etc
* design information available

Factors against remanufacturing

* poor design for assembly/disassembly
* proliferation of materials in construction
* status-dependent, fashionable items
* poor perception of standards/branding
* low price (new) goods
* craft skill shortage

Additionally, the materials savings, amount to at least the equivalent of 270 kte of steel per year. This translates into an equivalent carbon saving of 800 kte CO_{2e}

Also, employment related to remanufacturing is estimated to be at least 50,000.

Our survey suggests that remanufacturing can satisfy the joint objectives of economic and resource sustainability in a normal market economy.

Frequently, remanufacturing activities are more profitable than new sales, since they are presented on the basis of service rather than materials.

In all cases except for charity schemes, remanufacturing activities were driven by economic motives and a sense of business opportunity. Therefore, remanufacturing does form a practical response to the developmental and environmental objectives of government and regional development agencies.

Many operators are being squeezed by the cost of new goods from abroad, and by the burden of UK social operating costs and legislation.

However, we would not recommend taking fiscal measures to artificially skew the competitive field. In time, it is likely that rapid acceleration of foreign economies will bring their cost base more in line with the UK, and remanufacture will be invigorated.

In addition, multilateral moves to include the cost of externalities are likely to provide further incentives for remanufacture, as is a general improvement in the productivity of UK industry.

We note from DTI document "The Government's Manufacturing Strategy" (DTI, 2002) that UK productivity remains around 75% of that of US, German and French competitors.

Instead, we believe that it is more advantageous to address the barriers to remanufacture which have been discussed more fully above, and which are included in our recommendations to various bodies below.

In short we suggest the following:

* removal of legal impediments to remanufacture
* establish freedom of information in product knowledge
* support research into materials remediation, recovery, assembly and disassembly techniques
* public support of remanufacturing through purchasing policies
* education and dissemination in concepts of servicization
* greater efforts by companies to sell benefits of remanufacture by quantitative assessment of cost and materials savings, and life-cycle analyses
* coordinate efforts by existing (or new) trade organisations to set standards or codes for remanufacture, collate relevant statistics and use these to promote the activity
* government and RDAs support efforts by charities to attack marginal areas where conventional businesses cannot profitably operate

RECOMMENDATIONS

Recommendations for Legislators and Development Agencies

Some or all of the following recommendations could assist in boosting remanufacturing, given an explicit objective of increasing material efficiency. The desirability of these measures, taken unilaterally, is a matter for debate. Some of these measures are being addressed at the European level, for example, restrictive design practices.

* discouragement of practices which lock in users to OEM products. This includes such practices as keeping design specifications unavailable (black box products, such as car control systems). Encouragement of open standards as in the USA
* removal of legislation that prevents reuse of components in new goods, where that component can be shown to be indistinguishable from new, and with producer liability to match
* removal of legislation that prevents reuse of components in certain industrial applications (eg lifting & hoisting) where that component can be shown to be indistinguishable from new, and with producer liability to match
* promote greater use of labelling for materials of construction and history
* establish advertisement and accounting channels for businesses with remanufacture elements
* tax credits for the purchasers of second-hand or remanufactured items
* promotion at an international level of metrics which value resource effectiveness and efficiency as a total systems measure of activity
* compulsory extended warranty periods to encourage durable build; links to capital relief for guaranteed life
* proper consideration for public purchasing of remanufactured goods, where standards are equivalent to as new, and prices lower; move to leasing, pay-per-use and part-exchange/upgrade contracts
* remove barriers which would prevent the re-export of used goods, such as classified waste streams, to be remanufactured abroad, particularly if they could then be re-imported
* demand for longevity and design for remanufacture in public purchase
* sponsorship of profile-raising events
* pursue multilateral efforts to factor in externalities

Recommendations for sponsors of R&D

Place greater emphasis on research and development of techniques that can assist in the remanufacturing process. These may include material processes, mechanical operations, or design considerations

Design Considerations

Our study has shown that remanufacturing is significantly enhanced by designs which are conducive to remanufacture. These include minimisation of the number of parts, ease of disassembly and assembly - including lack of welded joints and embedded moulded parts, component standardisation, enclosure standardisation. Absence of OEM lock-in features is important for non-take-back markets.

These classic elements are illustrated particularly well in the design of toner cartridges, where initial open standards from technology owners ensured the ease of construction of the items in question.

On the other hand, makers of mechanical equipment have successfully obstructed remanufacture by mechanical construction to design standards (threads, bores, clearances, tolerances etc.) that are non-standard. These hamper the process of reverse engineering that many un-allied remanufacturers are forced to conduct.

Material & mechanical processes

In the past, component parts may have been discarded simply because techniques did not exist whereby original form or composition could be restored.

For example, wearing components - bearings, shafts, collars, mating surfaces - would have been discarded once pitted, scarred or otherwise degraded. Recently, technologies such as metal spraying have allowed surfaces to be built up sufficiently to allow machine back to as-new condition to take place. Such activities are common in the remanufacture of military equipment.

Management processes

Technical capabilities alone have not been able to account for the remarkable difference in performance of practitioners of remanufacturing. The comparative

experiences of Xerox and Pitney Bowes have been described. These differences have been ascribed more to the management attitude and commitment to reengineering established company processes and communication channels to achieve an efficient and effective product/service.

Like conventional manufacturing developments of the past – production line, cellular manufacturing, total quality, lean manufacturing – remanufacturing design and operations practice may therefore form a reach field of study for social scientists and business schools.

Recommendations for industry associations

* ensure members are aware of the full implications of impending producer responsibility legislation
* establish forums to define the meaning of sustainability in the context of their industry, and with proper consideration of remanufacturing benefits
* be more proactive in defining the role of recycling and remanufacture and the impact of design for these
* seek opportunities to promote sustainability metrics for the sector, including proper assessment of mass balance, materials benefits and economic value of activities
* create channels to assist members in establishing foreign remanufacturing bases, where these could create markets for goods not viable in UK markets, or as bases for re-import of remanufactured goods

Recommendations for companies

* press industry associations for concerted efforts in presenting a coherent message for remanufacturing in their sector
* benchmark and identify best practices within and without the sector
* seek opportunities to tie in to OEMs or to accredited brokers and distribution channels for added credibility
* identify novel service/product combinations, particularly those that combine purchase, maintenance and upgrade capabilities

Possible actions & opportunities for businesses

Low labour cost operations move into remanufacturing

Key points:

* in direct competition with low cost imports, only organised, low cost organizations will be able to engage head to head
* reputation, warranties, relationship with OEMs, and excellent bi-directional logistics will be major competitive issues for local contenders

This implies that only large, well organised and reputable operators, perhaps already possessing logistics capability and a low cost base will be able to compete in "standard" markets.

Typically, the competition will be from low-cost imports (developing countries), or higher productivity units in Europe.

Therefore, UK companies can compete through cost base, investment in productivity, or customer service (JIT, flexibility etc). Such operations may be of interest to established operators such as Remploy, or diversifying outfits, such as ABRO.

Modify basis of competition:

* do not compete on price: provide complete supply and maintenance and refurbishment service to reclaim value chain directly
* back-integrate into customers operation to in-source the aspect of operation related to use of the equipment
* ally with service providers, eg logistics agents, where the above service is beyond the scope of knowledge, or is at another business interface
* become local maintenance and remanufacturing arm of a reputable foreign importer, particularly if they have no presence in the UK; consider profit share or equity stake of OEM in business
* insurance and warranty companies promote uptake of remanufactured
* ally, for example in trade associations, to lobby for changes to legislation that are unfairly hampering competition

These points suggest a number of approaches to changing the basis of competition. Some of them are already successfully tactics for the companies that we have seen in markets as diverse as office equipment and power turbines.

They will usually require the acquisition of new skills, frequently a more sophisticated approach to marketing and selling to fully exploit the expansion of the product-service opportunities that remanufacturing can provide.

Also, partnership with other organisations will require excellence in control of internal operations before management of a new interface is attempted.

Seek alternative markets:

* do not remanufacture for primary home, European or other western markets, but rather secondary markets
* relocate or create subsidiaries in developing markets to take advantage of local cost structures; this creates a foreign remanufacturing operation at point of high demand, but also capability to re-import cost-effectively into the developed world

We have seen few specific examples of these tactics employed as a sole means of operation. However, some operators are clearly considering establishing equivalent operations abroad as their home markets saturate, and to exploit globally their already strong relationships with OEMs.

This is particularly true of the automotive sector. Moving abroad in this way may then place such companies in a good position to exploit local economies either by acquisition of those industries that appear currently to offer import threats, or even as bases for low cost remanufacture and export.

There also appear to be significant numbers of products, particularly related to the science of technology development, that have a poor second user market in the UK. Scientific instrumentation and medical electronics are areas where rapid advancement promotes replacement over repair.

However, there are almost certainly developing markets where such reasonably priced equipment could be remarketed. Remanufacturing firms may need assistance from companies experienced in export and accreditation to exploit these opportunities, for whom remanufacturing may therefore also offer potential.

Create new businesses

* consider opportunities in logistics and brokering of core components using existing skills, and leveraging economies of scale

It is clear from interviews that obtaining core materials and transporting them to the point of remanufacture can be a major factor in business viability. It is also a fact that there will be increasing pressure to manage end-of-life issues associated with an expanding range of goods.

We speculate that opportunities will exist for companies that can cost-effectively collect, sort, broker and distribute materials of diverse types.

Such organisations may evolve from current waste operators, logistics organisations or even waste reclaimers. Undoubtedly, however, the management, scheduling and tracking processes associated with this will be orders of magnitude more sophisticated than currently.

Recommendations for investors

Investors may wish to apply our Remanufacturing Potential model as a guide to the basic attractiveness of any particular good.

Institutional investors will be especially interested in companies positioned to exploit remanufacturing capabilities as a route to more profitable growth, or in defence of their markets.

In the first category are those companies who have embarked on remanufacturing and have found it to be more profitable than manufacturing. Remanufacturing appears to be more profitable than manufacturing on a like for like basis where the goods have a relatively high intrinsic value.

This will tend to bias investors towards industries involving large industrial machinery or performing complex processing tasks, and high technical content industries such as power turbines and aerospace. Included in this will be certain automotive applications related to transport and specialised loading equipment.

Emergent electronics markets can provide opportunities to exploit repair techniques, as are now appearing in the LCD market. However, these may be transient due to the high rate of background technology change.

Other facets of attractiveness are related to the structure of the particular market. For example, companies applying disruptive business models that break down traditional "make and sell" customer relationships are more likely to find value-adding opportunities in remanufacturing.

In the second category, investors will be scanning for possible disruptors in the business environment, such as caused by legislation.

The major class of legislation currently being imposed in Europe is that related to producer responsibility. Companies that are well positioned to cope with this responsibility, either as OEMs or as contract agents, may find favour with investors.

Investors' confidence in the ability of ventures to flourish is largely based on management competence, track record and access to complementary skills.

In respect of remanufacturing companies, it is important to highlight structural features of some companies that have successfully engaged a remanufacturing capability, and which could be indicators of a commitment to the activity. In particular, electronics operators have succeeded where they have "Joined-up" design and maintenance teams ie the requirements at end-of-life are fed back to alter the product design.

Similarly, sales and marketing teams need to be aware of the portfolio of options that remanufactured products offer to the product mix: new, swap-outs, upgrades etc, often at higher value than new sales.

These considerations apply largely, but not exclusively, to OEMs. Independent remanufacturers typically face a different problem in that they do not have access to OEM design information: A core capability in these companies will be ability to access such information either through networks, or dedicated reverse engineering teams.

Public sector investors may have more complex motives. In this respect, they may also wish to consider a range of other benefits associated with stimulating or supporting remanufacturing:

* effect on local employment and defence of traditional sectors
* existing skill base, its development and stimulation of new capabilities
* requirement to affect resource re-use and recovery
* position as an exemplar to the community
* potential synergies of local companies
* opportunities to stimulate the research and academic base
* reduction of its own costs through intelligent purchasing

Development agencies will be interested in remanufacturing for its potential to generate regional employment. In large-scale manufacturing, companies tend to source components from limited disparate sources, often from abroad. In contrast, in remanufacturing, large companies tend to concentrate on the core elements and sub-contract locally to trusted affiliates who can refurbish other sub-assemblies. Remanufacturing hubs can thus seed diverse local companies.

In this country, even where primary goods are made abroad, UK service operations may be upgraded to remanufacturing sites to the benefit of local economies.

FURTHER WORK

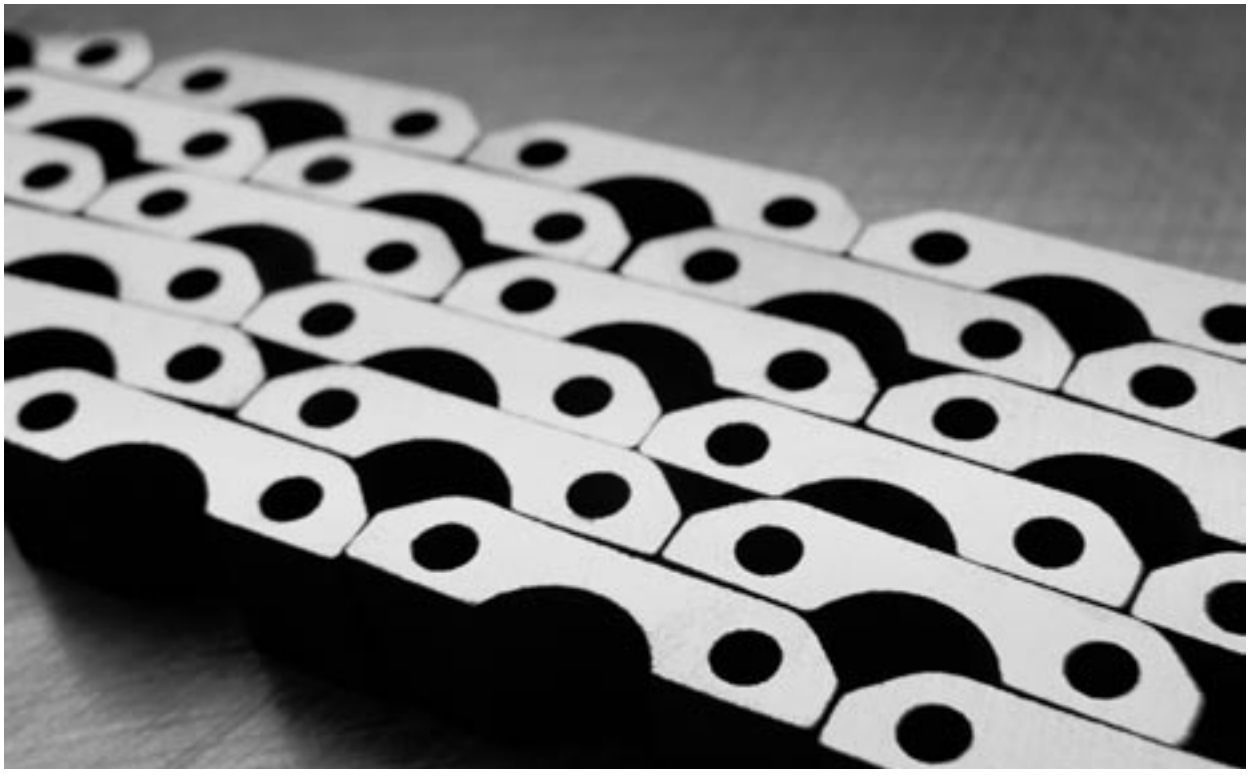
This report has provided a brief overview of the issues, value and opportunities in remanufacturing, and leaves many detailed questions unanswered. Typically such questions are dependent on each sector. It therefore goes without saying that persons with a particular interest in a sector may require a more detailed analysis than is presented here.

We have found that remanufacturing occurs practically everywhere it would be expected, to a greater or lesser extent considering the complexity of some industries.

Specific recommendations for individual products and sectors are therefore difficult to formulate.

However, as an aid to understanding the background, we believe that the following research would be useful, correctly targeted:

* detailed analysis of potential in promising sectors; understand segmentation and value chains. Using our standard categories for determining remanufacturing tendency, a fuller investigation of the goods/service chain is required to determine whether novel service combinations exist. This is particularly true in examining industries which appear to be locked into price-based competition
* investigation of rationalization with industries, and shifts in balance of OEM and independent remanufacturers. This may indicate anti-competitive behaviours, or merely illustrate sensible responses to external business environmental pressures
* investigate potential for export into secondary or developing markets. As an interim measure, export can improve global resource efficiency whilst preserving traditional supply chains in the home markets. A fuller investigation of
* determine where such export might run foul of hazardous export legislation, and identify modifications to such legislation
* examine reverse logistics and integration with forward logistics to enable closed-loop producer responsibility
* examination by product class of the sort of design and remediation techniques required to facilitate cost-effective remanufacture; such research will examine common failure modes and barriers to rectification, with recommendation to government on profitable areas to place research funding



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TABLES

Table 1: Group Categorisations

Priority	Number of Groups (SICs)	Data Extraction Process
Higher	12 (init. est.)	Determine whether Groups must be sub-divided into a number of eg product manufacturers. Contact trade associations, industry bodies and trade journals to establish: significance of remanufacturing in the sub-sector, background data, quantitative data - if available - further references and sources of knowledge, major operators in the sector. Meet these contacts if appropriate. Identify selection of companies (10-15) to engage in substantive telephone interview. Capture large companies to judge impact of large operators. Small companies to assess “tail” and business pressures. Mail to pre-warn, interview and assimilate data. Synthesise raw data, project value and impact, postulate potential level.
Lower	14 (init. est.)	Determine whether Group must be subdivided to into a number of eg product manufacturers. Contact trade associations, industry bodies and trade journals to establish: significance of remanufacturing in the sub-sector, background data, quantitative data - if available - further references and sources of knowledge, major operators in the sector. Meet these contacts if appropriate. Identify small selection of compa nies (4-8) to engage in substantive telephone interview. Capture large companies to judge impact of large operators. Small companies to assess “tail” and business pressures. Interview and assimilate data. Synthesise raw data, project value and impact, postulate potential level.
Extrapolated	<10	Find comparable sectors based on value and complexity of equipment, user relationship etc. Take average of comparable sectors and impose on sector value. Where possible, spot-phone to gauge typical unit embedded resource ie mass, material. Convert to carbon equivalent.
Excluded	Balance	Ignore.

In this context, Excluded covers only the SICs concerned with manufacturing (28-36); services are excluded by default.

Table 2: Sectoral Remanufacturing Contributions

GROUP	SUBGROUP	UK t/o [£M]	Reman t/o [£M]	Material te	CO2e te	Emp'yee	
175 Manufacture of other textiles	1751 carpets & rugs 1752 cordage 1753 non-wovens, except apparel 1754 other textiles	2,632	0.5	500	1,000	0	
251 Manufacture of rubber products	2511 tyres & tubes 2512 retreading 2513 other rubber	3,717	150	80,000	350,000	1,200	
281 Manufacture of structural metal products	2511 tyres & tubes 2512 retreading 2513 other rubber	6,962	0	0	0	0	
282 Manufacture of tanks, containers of metal, and central heating radiators	2821 tanks, boilers etc. 2822 central heating radiators	1,111	0	0	0	0	
283 Manufacture of steam generators, except central heating hot water boilers	2830 >>	493	50	730	1,679	1,000	pro-rate to industrial macjhinery
291 Manufacture of machinery for the production and use of mechanical power	2911 engines except aircraft, autos... 2912 pumps & compressors 2913 taps & valves 2914 bearings & gears	8,321	530	35,000	80,500	5,700	pro-rate to automotive
292 Manufacture of other general purpose machinery	2921 furnaces 2922 lifting & handling 2923 ind'l ventillation 2924 other general	10,082	70	3,900	8,970	800	pro-rate to machine tools
293 Manufacture of agricultural and forestry machinery	2931 tractors 2932 other ag. & forestry	2,405	0	0	0	0	include in automotive
294 Manufacture of machine tools	2940 >>	2,129	270	15,000	34,500	2,900	include in automotive

Calculated | Extrapolated

Table 2: Sectoral Remanufacturing Contributions (continued)

GROUP	SUBGROUP	UK t/o [£M]	Reman t/o [£M]	Material te	CO2e te	Emp'yee	
295 Manufacture of other special purpose machinery	2951 metallurgy machines 2952 mining & quarrying *** 2953 food, beverage, tobacco...* 2954 textiles * 2955 paper etc. * 2956 special purpose ***	6,996	see above				
296 Manufacture of weapons and ammunition	2960 >>	1,775	200	13,300	30,590	2,200	across all supporting industries
297 Manufacture of domestic appliances not elsewhere classified	2971 electrical domestic 2972 non-electrical domestic	2,663	0	0	0	0	
300 Manufacture of office machinery and computers	3001 office machinery *** 3002 computers & processors etc.***	20,118	430				based on £20,000 per te
311 Manufacture of electric motors, generators and transformers	3110 >>	3,142	250	6,000	13,000	2,500	
312 Manufacture of electricity distribution and control apparatus	3120 >>	5,041	100	2,400	5,200	1,000	pro-rate to electric motors
322 Manufacture of television and radio transmitters and telephone apparatus	3220 >>	13,712	40	116	232	140	mobile phones only. Fax etc. included in office equipment
323 Manufacture of television and radio receivers and recording apparatus	3230 >>	7,898	niche				only in broadcasting?
331 Manufacture of medical and surgical equipment & orthopaedic appliances	3310 >>	2,388	niche				
332 Manufacture of instruments for measuring, checking and other purposes	3320 >>	6,531	unknown				

Calculated Extrapolated

Table 2: Sectoral Remanufacturing Contributions (continued)

GROUP	SUBGROUP	UK t/o [£M]	Reman t/o [£M]	Material te	CO2e te	Emp'yee	
333 Manufacture of industrial process control equipment	3330 >>	635	niche				
341 Manufacture of motor vehicles	3410 >>	37,771	530	35,000	80,500	6,000	includes parts and coachwork and ag. machinery
351 Building and repairing of ships and boats	3511 ships 3512 sports & pleasure craft **	2,993	100	20,000	46,000	1,300	estimate of hull building only, save a moderate cargo ship per year
352 Manufacture of railway and tramway locomotives and rolling stock	3520 >>	1,209	200	13,333	30,667	1,400	
353 Manufacture of aircraft and spacecraft	3530 >> ****	16,138	2,000	20,000	46,000	17,000	
361 Manufacture of furniture	3611 chairs * 3612 office & shop * 3613 kitchens 3614 other * 3615 matresses	8,997	25	10,000	22,000	300	
Comaparative Economic Activities							
371 Recycling of metal waste and scrap		988					
372 Recycling of non-metal waste and scrap		345					
501 Sale of motor vehicles		79.027					
502 Maintenance and repair of motor vehicles		10,582					
503 Sale of motor vehicle parts and accessories		14,593					
504 Sale, maintenance and repair of motorcycles, parts and accessories		1,945					
527 Repair of personal and household goods		1,244					
725 Maintenance and repair of office, accounting and computer machinery		1,233					
731 Research and experimental development on natural sciences/engineering		2,851					
900 Sewage and refuse disposal		3,308					
			t/o £m	**Mass te**	**CO2e te**	**Employees**	
SUMMARY STATISTICS			**4,950**	**270,000**	**800,000**	**50,000**	

Calculated | Extrapolated

Table 3: UK Tyre Balance (approx)

	Cars	Trucks	
Stock of Tyres on Road			
Number of vehicles (x 10^6)	23.5	1.5	TRL figures
Tyres per vehicle	5	8	
Tyre mass (kg, used basis)	6.5	51	
Total mass (tonnes x 10^6)	0.764	0.612	
Total mass (tonnes x 10^6)	**1.376**		

	Cars	Trucks	
Estimated Remanufacture			
Number of tyres into remanufacture (x 10^6)	1.2	1.3	TRL figures
Used tyre mass (kg, used basis)	6.5	51	
Total mass used tyres (tonnes)	7,800	66,300	
Total mass (tonnes)	**74,100**		
Mass after remanufacture (tonnes)	**8,914**	**75,771**	
Total mass after remanufacture (t)	**84,686**		

	Cars	Trucks	
Total manufacture (collated by TRL)			
Mass of all tyres manufactured (t)	391,000		TRL figures
Mass fraction attributable (%)	76	24	
Mass in category (tonnes)	297,160	93,840	
Churn (turnover of inventory pa)	0.39	0.15	
Mass after remanufacture (tonnes)	8,914	75,771	
Number of tyres	38,097,400	1,533,300	
Total number of tyres	**39,600,000**		

	Cars	Trucks	
Tyre disposal (collated by TRL)			
Number of tyres	39,811,000	1,9000,000	TRL figures
Total number of tyres	41,711,000		
Tyre mass (kg)	6.5	51	
Total tyre mass (tonnes)	258,772	96,900	
Total tyre mass (tonnes)	355,672		
Churn (per year)	0.39	0.16	
Remanufacture (% of disposal)	3.0	68.4	

Table 4: Comparative Economic Activities				
SIC	**Description**	**Companies**	**Employees**	**T/O £m**
371	Recycling of metal waste and scrap	420	7	988
372	Recycling of non-metal waste and scrap	455	4	345
900	Sewage and refuse disposal	1,260	38	3,308
527	Repair of personal and household goods	4,120	22	1,244
501	Sale of motor vehicles	13,100	243	79,027
502	Maintenance and repair of motor vehicles	20,665	143	10,582
504	Sale, maintenance and repair of motorcycles, parts and accessories	2,040	11	1,945
725	Maintenance and repair of office, accounting and computer machinery	1,350	16	1,233
731	Research and experimental development on natural sciences/engineering	1,320	37	2,851
	Landfill operations* (number of facilities)	2,134	35	4,200
**Figures taken from "Future Perfect: An analysis of Britain's waste production and disposal account...", published by Biffa, 2002*				

FIGURES

Figure 1. Hierarchy of waste recovery techniques

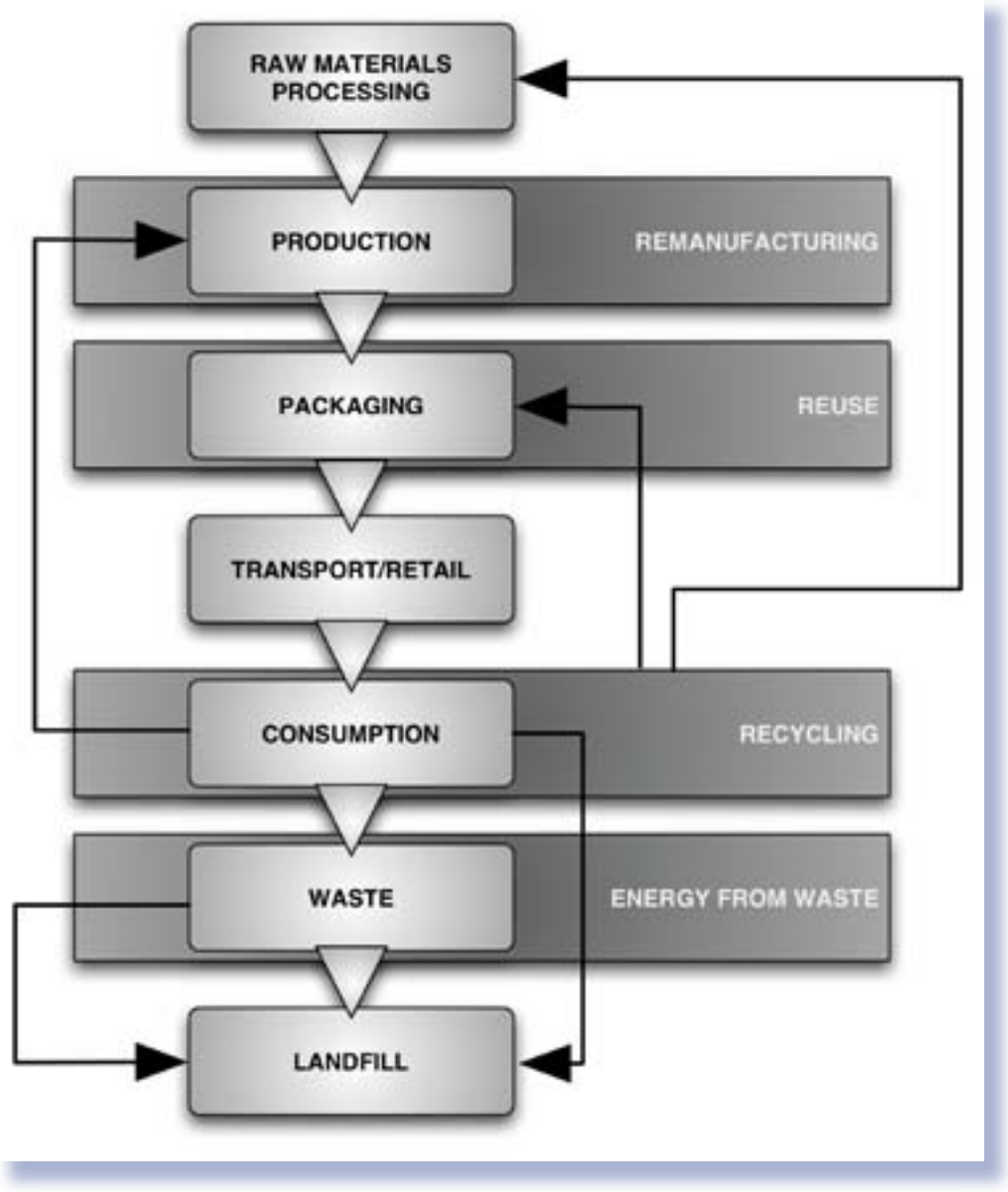


Figure 2. Remanufacturing economic value by sector (£ M)

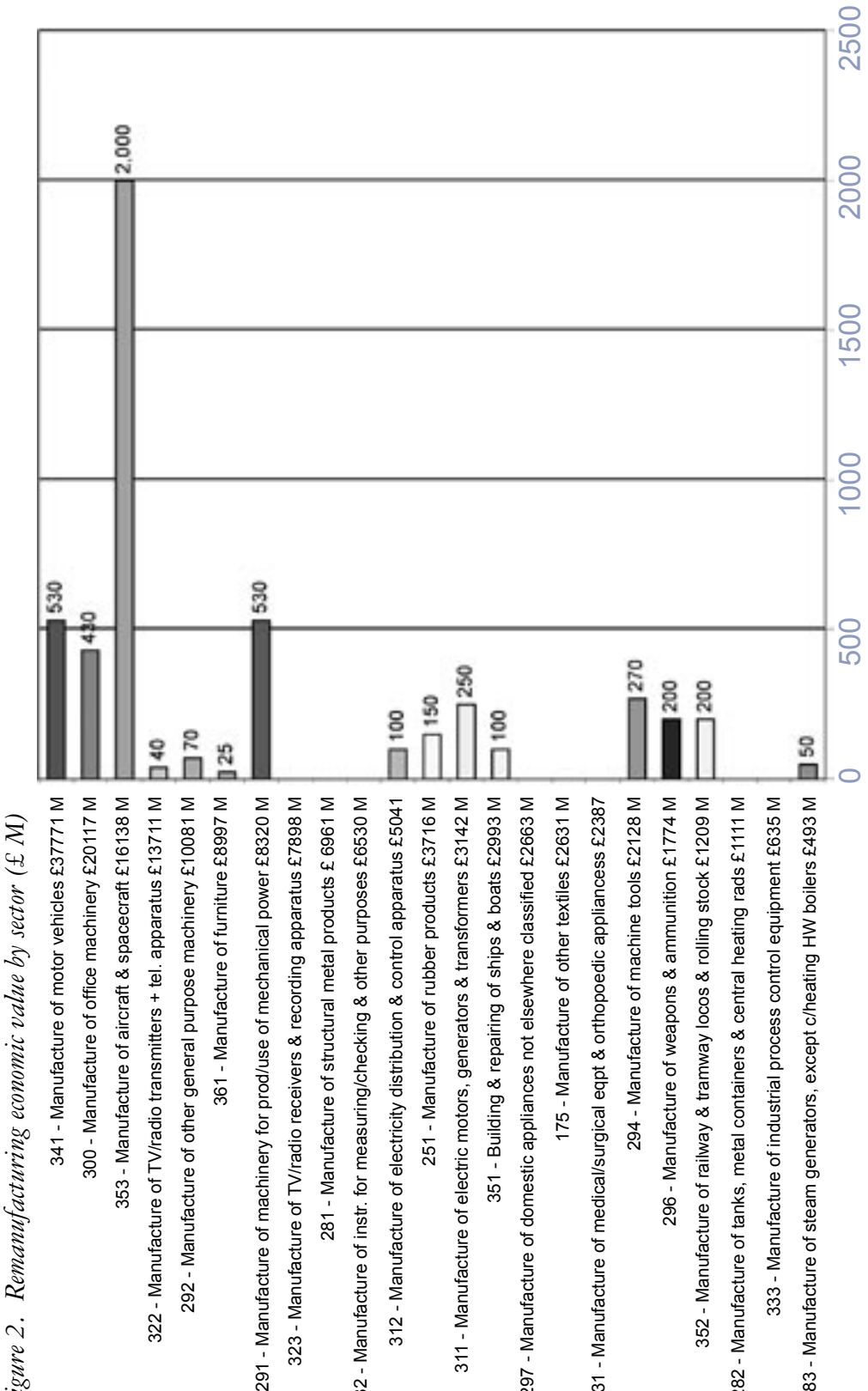


Figure 3. Remanufacturing materials saving (tonnes steel equivalent) by sector

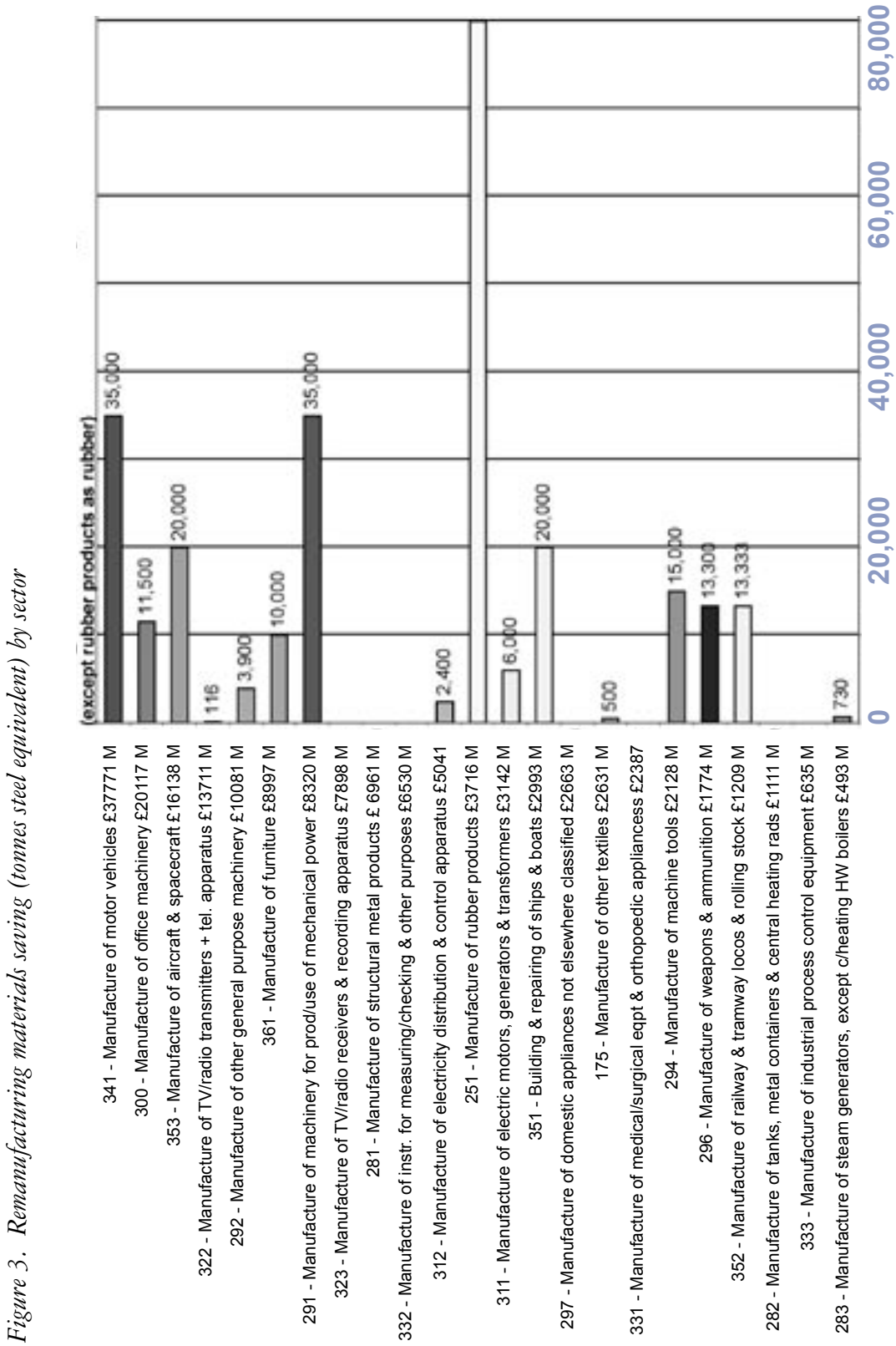


Figure 4. Remanufacturing tonnes CO_{2e} saving by sector

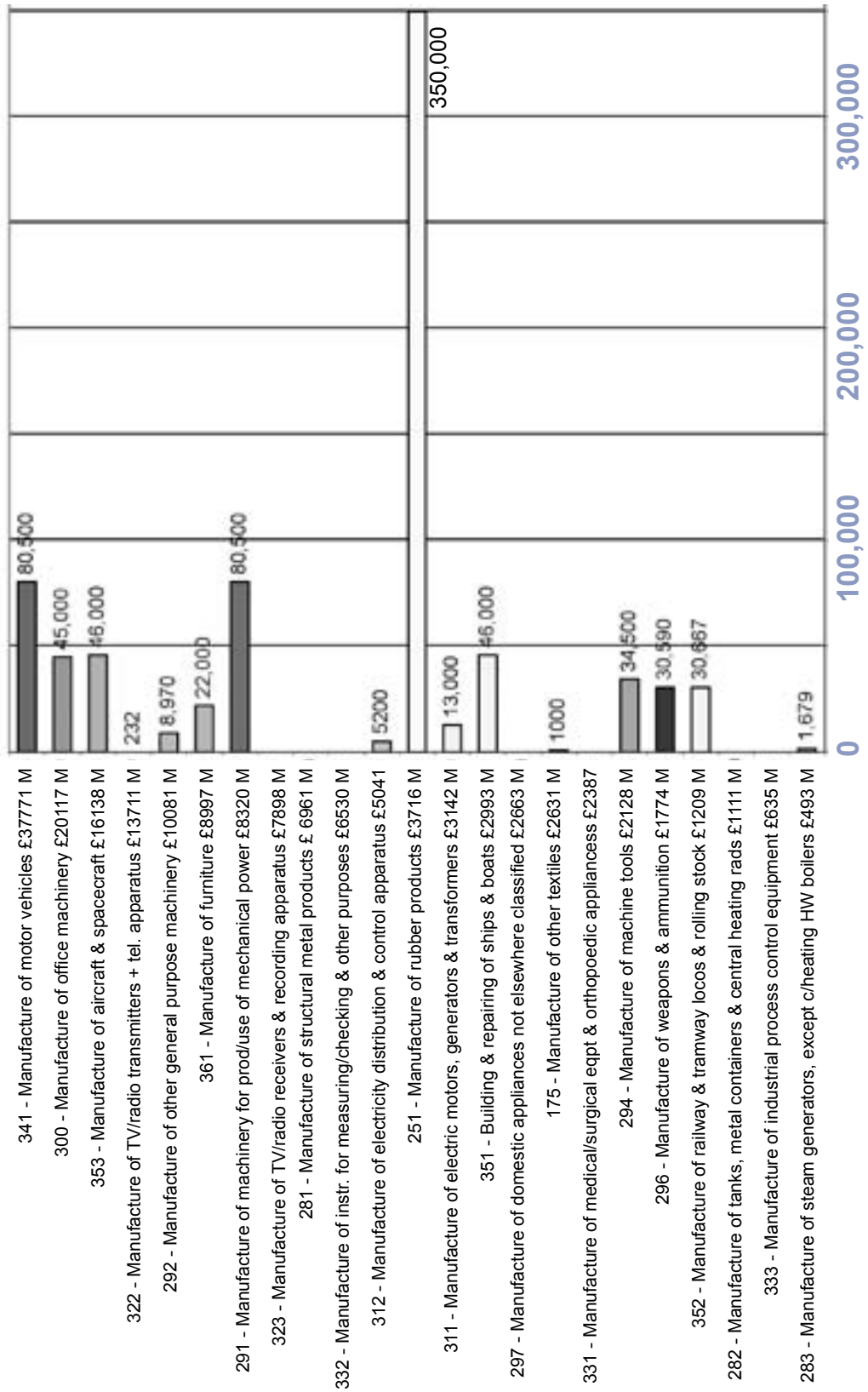


Figure 5. Overview of economic assessment process

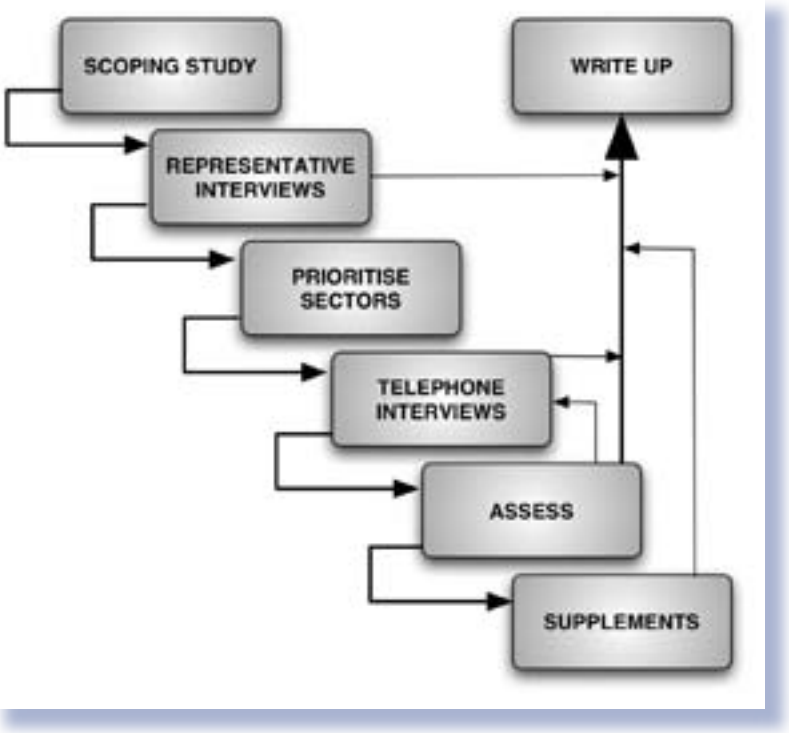


Figure 6. Relative depreciation rates of planes & cars

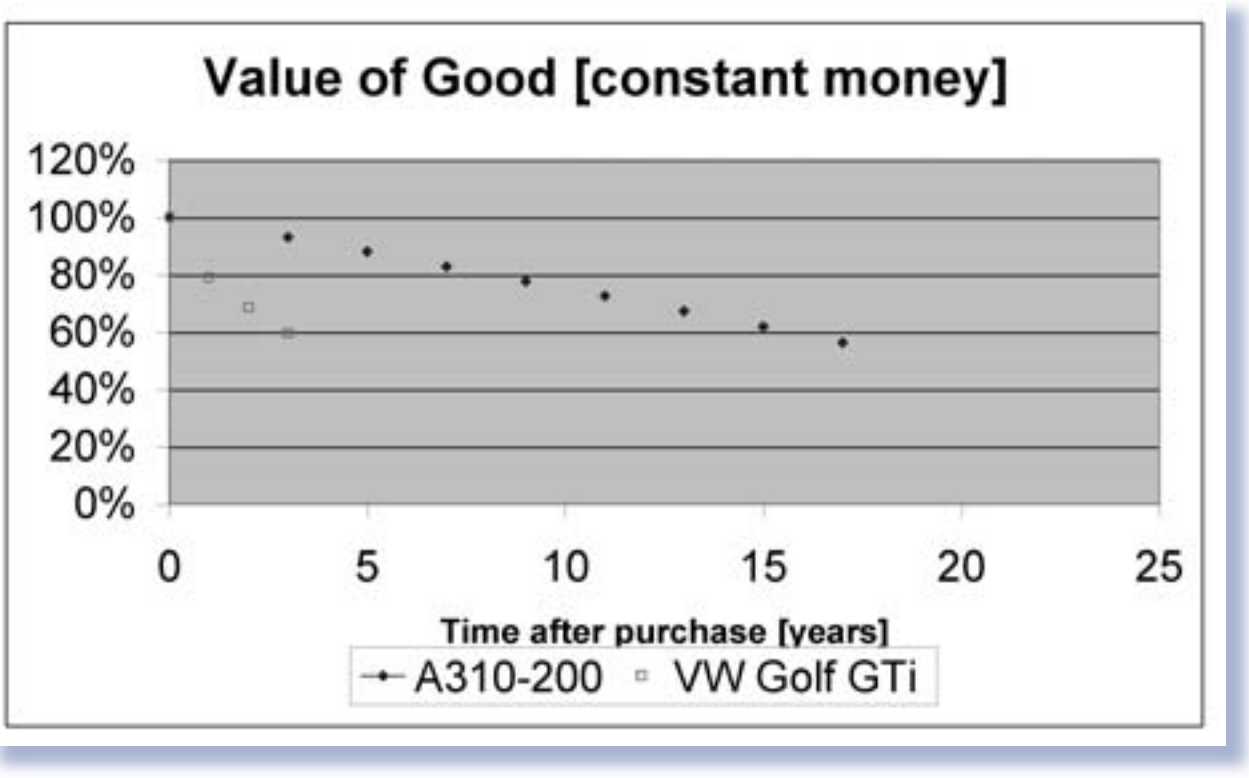


Figure 7. Industrial composition of South Yorkshire

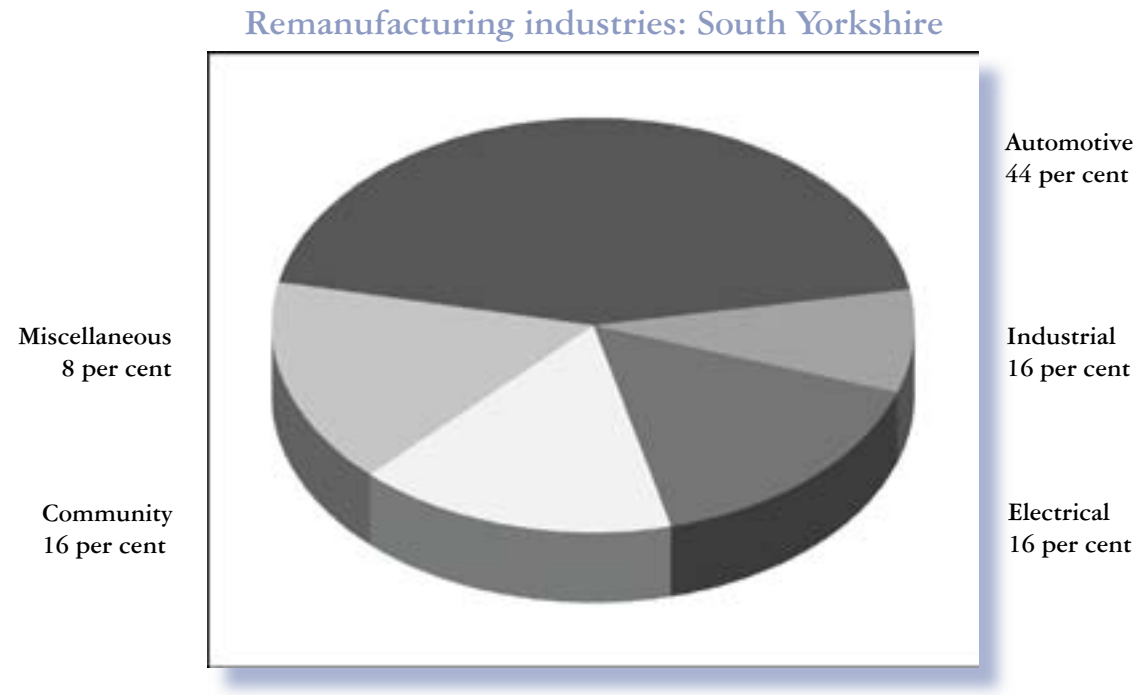


Figure 8. South Yorkshire automotive remanufacturer status

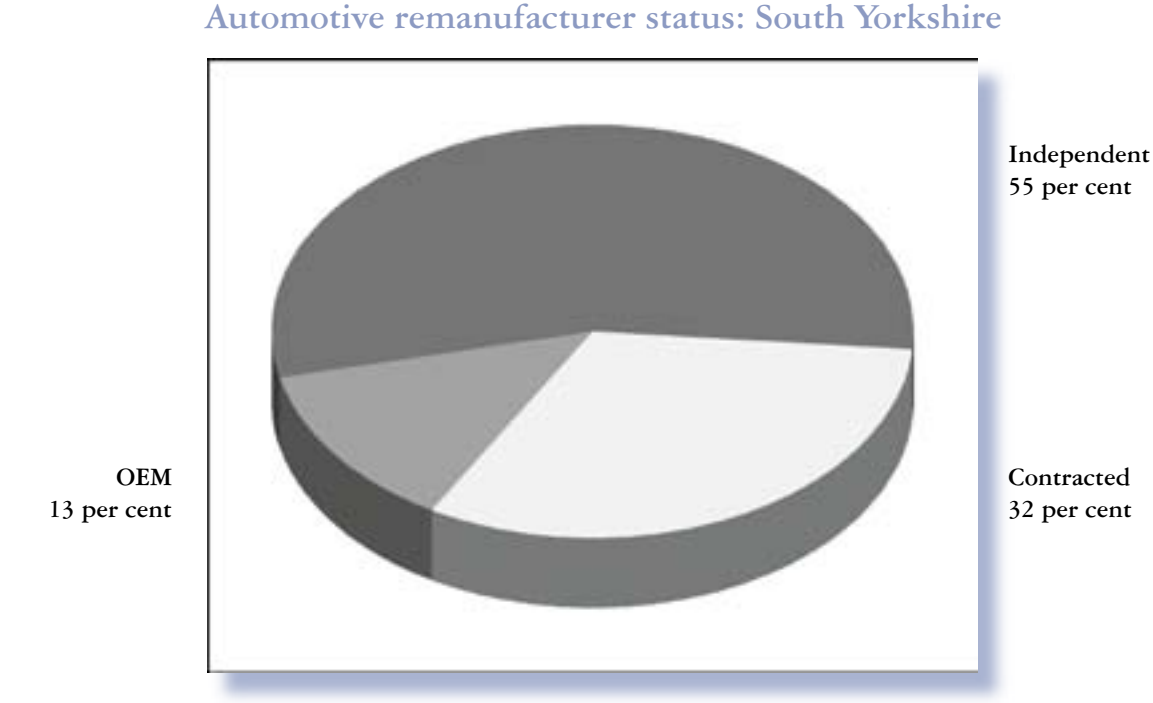


Figure 9. The feasible operating space

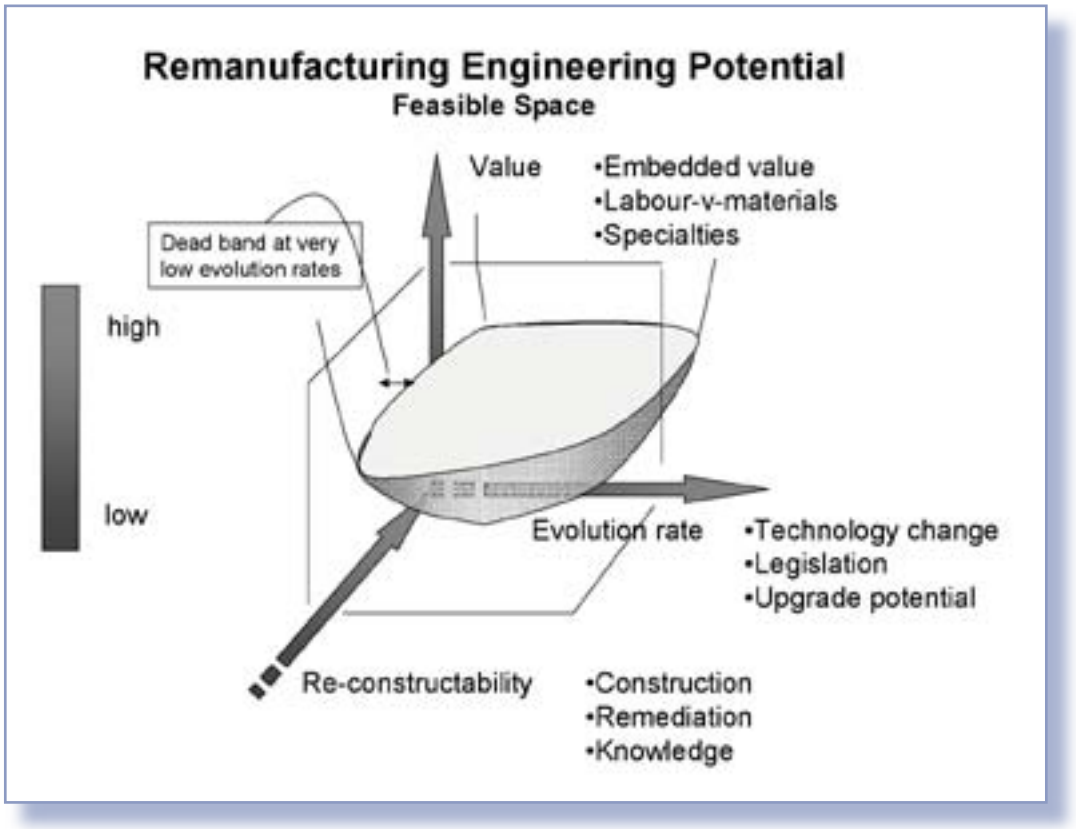
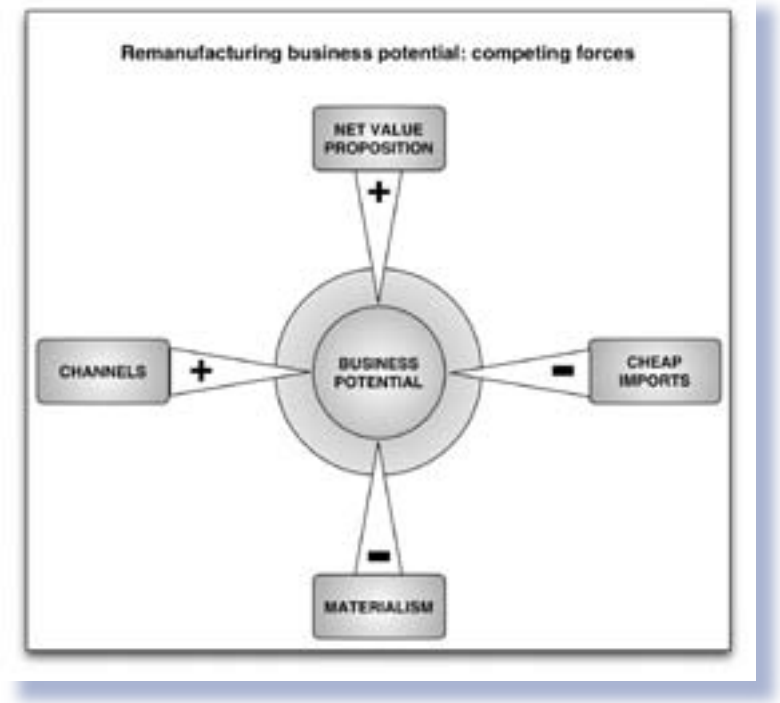


Figure 10. Remanufacturing business potential

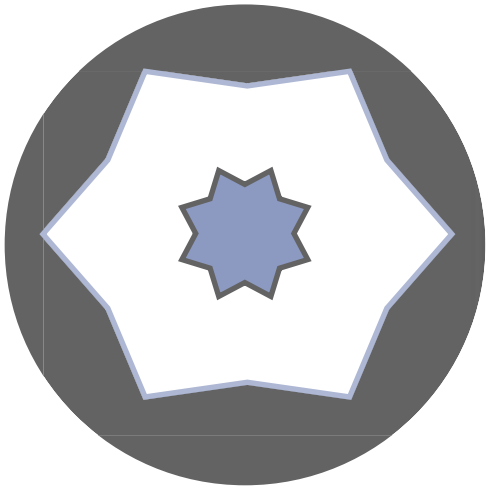


APPENDICES

THE APPENDICES LISTED BELOW ARE AVAILABLE IN ELECTRONIC FORMAT ONLY - THE CD VERSION OF THIS PUBLICATION.

APPENDIX 1:	Sub-class Analysis for Remanufacturing Potential
APPENDIX 2:	Telephone Interview Question Proforma
APPENDIX 3:	Supporting Data:
APPENDIX 4:	Acknowledgments (sponsors only)
APPENDIX 5:	Remanufacturer Lists
APPENDIX 6:	Profiling Interviews
APPENDIX 7:	Profiling Questionnaire

THIS CD CONTAINS THE FULL REPORT, COMPRISING THIS PRINTED SECTION AND THE EXTENSIVE APPENDICES



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