Remanufacturing: Key Strategy for Sustainable Development-A Review

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Abstract

Remanufacturing enables a significant part of the value added to a product during its initial production to be retained. We cannot afford to dispose continually of strategically important materials in landfill sites or waste the energy associated with their processing. Remanufacturing is the process by which used products and assemblies are returned to their new and advanced state with minimum waste and expenditure on materials and energy. Parts that do not wear out are reused in a rebuilt product that incorporates the technological advances deemed necessary to ensure that repairs can be carried out in a timely manner and the item returned to functionality in an efficient manner. This review paper reports an overview of process of remanufacturing. Its need, contribution towards sustainability and lists the challenges in remanufacturing of products.

Scope and benefits of remanufacturing has increased where industries have embraced new technologies for the restitution of components and enabled greater material recovery and even the retention in-house of capabilities that may have previously been outsourced. Remanufacturing has a high chance of failure when used to compete in markets where price is the only basis for competition, unless a low-cost source of labor is available.

Key words: Remanufacturing, Reconditioning, Recycling, Circular economy, Sustainability.

1. Introduction

Remanufacturing describes the process of disassembling products, cleaning, repairing or replacing parts, and then reassembling them to a good working condition. In other words, it is recycling by producing products that are as good as original products in look and capability, from used items. Remanufacturing is synonymous with a number of other terms such as rebuilding and refurbishment, although 'remanufacturing' as a term has become commonly acknowledged as the generic industry term for this process. [1]

Candidate products for renewal are typically brought to a factory environment where they are disassembled. The component parts are cleaned, inspected, repaired or refurbished if useable; otherwise they are replaced. The parts are then reassembled and the product is tested to original performance specifications.

Remanufacture returns a used product to like-new condition; it is a process of recapturing the value added to the material when a product was first manufactured. Remanufacture results in reduced energy and material use, and production cost reductions. In the context of drivers such as the Landfill Directive, the revenue that remanufacture generates from 'waste' coupled with environmental advantages place the process as potentially a major contributor to Sustainable Development (SD) .

The process of remanufacture was first brought to the fore at an industrial level by tank remanufacturing in World War I; for a time after World War II, it was profitable for all car manufacturers in the UK to engage in remanufacture. However remanufacture is still generally a niche practice today. Caterpillar, Xerox and Flextronics (who remanufacture a small number of Xerox products in Europe and a majority in the USA (Cosgrove, 2007b)) are leading global remanufacturers with a high profile, but the majority of remanufacture is carried out by much smaller organizations.

The 2004 Oaken Hollins Ltd (OHL) report "Remanufacturing in the UK: a significant contributor to sustainable development?" provides a detailed evaluation of the state of the UK remanufacturing industry and identified future opportunities for remanufacture, highlighting that remanufacture can lead to a reduction in carbon emissions. This report investigates the links between designs and remanufacture and builds on elements of the OHL report and contributions to elements of analysis by OHL. Nabil Nasr and Michael Thurston's 2006 paper "Remanufacturing: A Key Enabler to Sustainable Product Systems" brings Design for Remanufacture to the discussion and suggests the full potential of remanufacture to contribute to sustainable systems through the closed-loop economy; whereas Erik Sundin's work in "Product and Process Design for Successful Remanufacturing" brings detailed design to the fore.

Remanufacturing activities are applied to a large number of products. These include: automobiles, automotive parts, electric motors, tyres, single-use cameras, personal computers, industrial equipment, office furniture photocopiers,

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toner cartridges and many more. However, remanufacturing probably has its strongest tradition and currently also its strongest representation in the automotive sector. Remanufacturing of auto-motive products accounts for two thirds of all re-manufacturing.

Different industry segments sometimes use other terms for remanufacturing. For example, 'rebuilt' is used for motor-vehicle parts and systems, and 'recharged' for imaging products such as laser and toner cartridges. Other related terms that refer to distinctly different processes include 'recycled', 'repaired', 'restored', 'reconditioned' and 'used'.

2. Conditions for Remanufacturing

The Remanufacturing Institute (TRI) asserts that whether or not a product is remanufactured depends on the process utilized. According to TRI, the following conditions must be met before a product is considered to be remanufactured:

- The principal components are reused.
- Dismantling is carried out so that it is possible to ascertain component condition, wear or deterioration.
- Each part is thoroughly cleaned and examined.
- Any broken, missing or damaged items are replaced by new parts, or reconditioned so that they are as new. It may sometimes be acceptable to incorporate used items if their functionality is not affected.
- Any necessary rectification by, for example, machining, rewinding or refinishing will be carried out to restore working condition.
- A refurbished product will operate to the same standard as a new one.

The Table1 shows the definitions of remanufacturing, reconditioning and repair and Fig.1 shows the Hierarchy of secondary market Production processes (5)

Table 1: Proposed definitions of remanufacturing, reconditioning and repair [5]

Remanufacturing: The process of returning a used product to at least OEM original performance specification from the customers' perspective and giving the resultant product a warranty that is at least equal to that of a newly manufactured equivalent
Reconditioning: The process of returning a used product to a satisfactory working condition that may be inferior to the original specification. Generally, the resultant product has a warranty that is less than that of a newly manufactured equivalent. The warranty applies to all major wearing parts
Repair: Repairing is simply the correction of specified faults in a product. When repaired products have warranties, they are less than those of newly manufactured equivalents. Also, the warranty may not cover the whole product but only the component that has been replaced

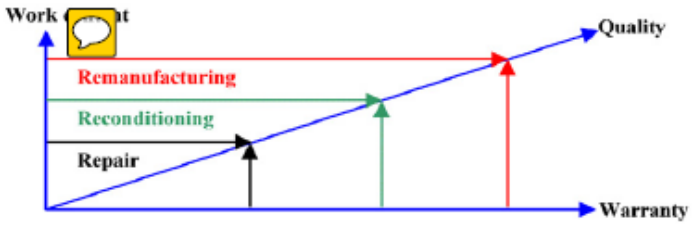

Fig1: Hierarchy of secondary market Production processes [5]

3. Need of Remanufacturing

Apart from remanufacturing, other options are also available which are repair, reconditioning and recycling. Repair is a process in which damaged parts are brought to the functional condition. Reconditioning process is similar as repair but parts and not brought to dimensional accuracy but by repainting, recoating and resurfacing process, its functionalities are brought to satisfactory level. Recycling is a process in which material is regenerated by different processes and part is maid reusable. Recycled part is ensured to have degradable properly.

Over all these options remanufacturing is better. Following different ways shows how remanufacturing is better than other options viz. repair, reconditioning and recycling.

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1. Quality: Remanufactured products are always better in quality than repair, reconditioning and recycled products. Since they involve greater work content. In case of recycled product due to quality problems, profit margin is less. Especially recycled electronics and mechanical products have less quality and performance.
2. Warranty: Warranty given on remanufactured parts are superior to the repaired and reconditioned ones. In repair, warranties are given only to the repaired parts only. While in case of remanufactured products, warranty is given on whole product.
3. Upgrades: No upgrade is present on repaired and reconditioned products while remanufactured products have one or more upgrades.
4. Recovery: In case of recycled product only material is recovered while in case of remanufactured product whole product is recovered.
5. Identity: In case of remanufactured product whole products losses its own identity while in other cases, product retains its identity.

4. History

Remanufacturing concept is practically utilized during World War II in United States and United Kingdom. There was no car or spare part production in these countries because all production facilities were dedicated to the production of war equipment. So only option remained was to remanufacture the old cars and keep those running. This is how this concept is expanded. There are 70,000 remanufacturing industries in United States creating $53 billion per annum. [9]

In today's competent world, entrepreneurs are always looking for better quality of manufacturing and quick delivery of manufactured products in cheaper rate. Technology has been developed accordingly to fulfill these needs. Due to better technological solutions availability, manufacturing techniques has improved since last decade. But during all competition, environmental aspects has ignored. Remanufacturing is a technique which is giving cheaper and environment friendly solutions. Following are the few reason why remanufacturing is incorporated.

I. Environmental Aspects: New environmental policy of government forced manufacturer to find other alternatives like reuse of end of life products. It is the big challenge to entrepreneurs to bring energy efficient option for manufacturing.
II. Profit: Cheaper cost of product is the ever demanding thing in manufacturing business. Different end of life product manufacturing option like repairing, reconditioning and recycling are available today because of cost factor. It is a great challenge to rebuild the product without affecting the functionality of it.
III. Labor: Skilled labor is the huge demand to remain competent in market. Remanufacturing requires less labor compared to conventional manufacturing process.
IV. Inventory Management: Maintaining inventory for the on time production is the biggest challenge. Remanufacturing reduces cost and time required for inventory.

5. Requirements for Remanufacturing

Remanufacturing is generally seen as the most environmentally friendly of "end of life" treatments for a retired product. If the remanufactured product can be considered a substitute for a new product, then a credit is usually claimed for the avoided resource use and emissions associated with the new product production. The biggest savings is generally from the avoided new materials production, but the difference between new manufacturing and remanufacturing can also be significant. At the same time, remanufactured products generally sell for about 50 to 80% of the new product. Hence, remanufacturing can be seen as a win win; it saves money (for the consumer), and it saves the environment

One of the primary requirements for remanufacturing is that the retired products have significant residual value at the end of life. The second is that the remanufacturing firm can effectively capture the retired product. The third is that the product can be restored to like-new condition (in terms of product function) with only a modest investment. In terms of number of remanufacturing plants, the largest remanufacturing categories in the U.S. are tires, followed by motors and generators and motor vehicle parts. The fact that a product can have significant residual value at its end of life can present a dilemma for the original equipment manufacturer (OEM). For example, if the OEM decides to not remanufacture its own products, then it might find itself competing with its own products remanufactured by another firm. To avoid being placed in this situation, an OEM might employ a variety of strategies to defeat "third party" remanufacturing. These strategies might include making spent products inoperable, rapid (minor) design changes,

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using a “prebate” system, and buying back the spent products. All of these strategies have been employed by various printer OEMs with varying success in an effort to protect their ink cartridge business.

6. Choice Between Remanufactured Vs. Refurbished Products:

These days, there is a lot of talk about global warming, sustainability, recycling and there is also a lot of confusion. Many companies have instituted sustainability programs and encourage recycling. Not just paper recycling, but also electronics. There a many ways in which the reuse of electronics can have a positive impact on the environment and the economy, but you have to choose the right solution to make it work for your business.

Remanufacturing is the rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts. It requires the repair or replacement of worn out or obsolete components and modules.

Parts subject to degradation affecting the performance or the expected life of the whole are replaced. Remanufacturing is a form of a product recovery process that differs from other recovery processes in its completeness: a remanufactured machine should match the same customer expectation as new machines.

Refurbished is the distribution of products usually electronics and electrical that have been previously returned to a manufacturer or vendor for various reasons. Refurbished products are normally tested for functionality and defects before they are sold. It is repaired from the manufacturer and resold.

The main difference between "refurbished" and "used" products is that refurbished products have been tested and verified to function properly, and are thus free of defects, while "used" products may or may not be defective.

Refurbished products may be unused customer returns that are essentially "new" items, or they may be defective products that were returned under warranty, and resold by the manufacturer after repairing the defects and ensuring proper function.

Remanufacturing is a more thorough and costly process because it is more rigorous and works toward a higher standard than refurbishing.

If the vendor cannot meet the actual definition of remanufactured (reassembling to meet or exceed the OEM specifications), then it should be considered a refurbished product.

When you choose to either replace, repair or stock electronic equipment always choose remanufacturing to ensure the highest quality and to minimize the risk of future problems.

7. Remanufacturing Towards More Sustainable Future

Remanufacturing is a concept of strategic importance that enables a significant part of the value added to a product during its initial production to be retained. Parts that do not wear out are reused in a rebuilt product that incorporates the technological advances deemed necessary to ensure that repairs can be carried out in a timely manner and the item returned to functionality in an efficient manner.

However, recycling remains limited to simple items such as drinks containers, steel products and paper goods, in part because recycling a more complex product, like a vehicle, results in a loss of up to 95% of the value added in the initial manufacture of that product. Remanufacturing, on the other hand, is the ultimate form of recycling. It protects the raw-material content, while maintaining much of the value added during the product’s manufacture. It has the potential to contribute significantly to a more sustainable future, and has already begun to increase materials efficiency by reducing emissions of greenhouse gases. 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 previously been outsourced. Among the prime benefits of remanufacturing are, of course, the ecological benefits, as it reduces the volume of materials entering the waste stream. Not only is there a reduction in the amount of product sent to be recycled, but the scrap which is sent to recycling from remanufacturers has a much better chance of avoiding contamination that degrades material quality. Further impacts on society are also discussed from both an economic viewpoint as well as the savings to be made in energy and raw materials.

8. Societal Impact of Remanufacturing

A rapidly increasing remanufacturing industry could have significant implications for the labor market. If goods do not rapidly wear out, it follows that they will not require regular replacement and hence fewer will need to be produced.

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Although this suggests that fewer employees would then be needed, this is not necessarily the case. Extractive-industry jobs would clearly be among the losers, but a shift to durability would also offer new opportunities. It can be argued that the use of better materials and their incorporation into durable, high-quality products is more in keeping with a smaller batch-manufacturing regime than with mass production. Consequently there is a need for an increased level of skilled labor. What is possibly more important, however, is a larger opportunity and incentive to maintain and repair products that can be remanufactured and reused rather than just thrown away. Remanufacturing succeeds when two basic economic conditions are present. First, the product core must permit the remanufacturer to avoid production costs that would have to be incurred in making a new product. The costs avoided must be sufficient to offset any additional costs arising in the restoration of the core. This represents value to the producer. The other requirement is that the resulting product must have marketable value, if buyers are to perceive worth in the product. The embedded value, or avoided cost, in the core must be sufficient to enable a remanufacturer to offer a product at a price that is competitive by comparison with the prices of new products.

It can be argued that society gains a considerable benefit from remanufacturing. It has an intrinsic societal impact because it uses less energy and resources than are required for new products; many existing parts are reused and therefore do not have to be remanufactured, and the effort required for refurbishment is significantly less than that associated with the production of new goods. Additionally, remanufacturing does not significantly add to the emission of greenhouse gases – a major worry in relation to global warming and climatic changes...

Challenges for Remanufacturing

In addition to the environmental and societal benefits, there are also significant indications that adopting remanufacturing techniques can lead to increasing and steady profit levels. However, despite this fact, there remain many barriers and obstacles that must be overcome in order for the full potential benefits of remanufacturing to be realized. These challenges are largely and most appropriately dealt with by the individual organization. The main ones are highlighted below.

Design engineering Product design is a vital element of profitable remanufacturing because it must in-corporate ease of dismantling for refurbishment as well as, ideally, a modular approach to the use of subassemblies that can easily and cheaply be upgraded to incorporate new developments and modifications that have been found necessary in the light of service experience. In this way it is possible to minimize obsolescence and maintain a competitive position in relation to new products.

Executive commitment The addition of remanufacturing to a corporate strategy requires commitment to it at an executive level in the company. GE is one of the best examples of how an organization implemented this philosophy at a practical level. The vision was to add value to GE capital goods in service by a combined remanufacturing and upgrade service. Substantial resources were allocated to this, and as a result it is stated that 3.5% of the company's income in 2001 came from 'other than new products' and service facilities. They provided more than 60% of profits, thus demonstrating the value

Trade groups Involvement in a trade group can be very important for any company. Trade groups have a significant impact on industry by providing a unified voice or consensus of opinion that can overcome problems or make the case for changes which would be beyond the capability of individuals. Trade bodies have made the public and government aware of many manufacturing issues and championed the case for remanufacturing as a means of saving energy and strategic materials.

Circular Economy

Original equipment manufacturers face a future of dwindling natural resources and increasing, competition from low-labor-cost countries. This, coupled with social pressure adds to the need to make best use of the materials already contained within existing end products. Historically product life cycles have been modeled on the strategy to "Take materials from the ground, manufacture, supply, dispose". In today's environment the strategy of a "**Circular Economy**" is becoming a critical part of resource utilization and profitability for many companies. Efforts to Reuse, Remanufacture and Recycle are key to a successful environmental and cost effective business model. [3]

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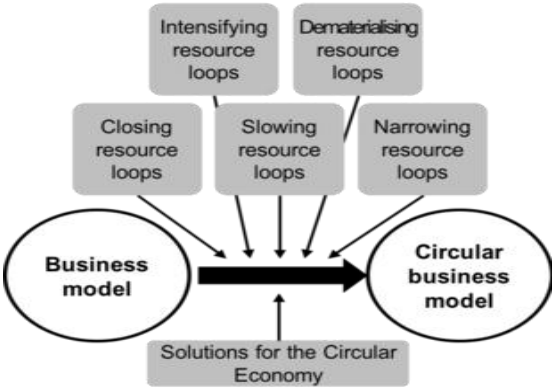

Fig2: Circular Economy

A circular economy is a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing energy and material loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and closed loops this is in contrast to a linear economy which is a 'take, make, dispose' model of production.

A major argument in favor of the circular economy approach is that achieving a sustainable world does not require changes in the quality of life of consumers, nor it requires loss of revenues or extra costs for manufacturers and other economic agents. The argument is that circular business models can be as profitable as linear models and allow consumers to keep enjoying similar products and services. The circular economy focuses on areas such as design thinking, systems thinking, product life extension, and recycling.

The circular economy includes products, infrastructure, equipment and services, and applies to every industry sector. It includes 'technical' resources (metals, minerals, fossil resources) and 'biological' resources (food, fibers, timber, etc). Some of the relevant theoretical influences are cradle to cradle, laws of ecology, looped and performance economy, regenerative design, industrial ecology, biomimicry and blue economy

Tim Jackson, in the early 1990s began to pull together the scientific basis for this new approach to industrial production published in his edited collection clean production strategies. At the time still called 'preventive environmental management', his follow-on book material concerns - pollution, profit and quality of life] synthesized these findings into a manifesto for change, moving industrial production away from an extractive linear system towards a more circular economy.

Moving away from the linear model :Linear "take, make, dispose" industrial processes and the lifestyles that feed on them deplete finite reserves to create products that end up in landfills or in incinerators.

This realization triggered the thought process of a few scientists and thinkers, including Walter R. Stahel, an architect, economist, and a founding father of industrial sustainability. Credited with having coined the expression "Cradle to Cradle" (in contrast with "Cradle to Grave", illustrating our "Resource to Waste" way of functioning), in the late 1970s, Stahel worked on developing a "closed loop" approach to production processes, co-founding the Product-Life Institute in Geneva more than 25 years ago. In the UK, Steve D. Parker researched waste as a resource in the UK agricultural sector in 1982, developing novel closed loop production systems mimicking, and integrated with, the symbiotic biological ecosystems they exploited.

Sustainability

The circular economy seems intuitively to be more sustainable than the current linear economic system. The reduction of resource inputs into, and waste and emission leakage out of, the system, reduces resource depletion and environmental pollution. However, these simple assumptions are not sufficient to deal with the involved systemic complexity and disregards potential trade-offs. For example, the social dimension of sustainability seems to be only marginally addressed in many publications on the circular economy, and there are cases that require different or additional strategies, like purchasing new, more energy efficient equipment. By reviewing the literature, a team of researchers from Cambridge and TU Delft could show that there are at least eight different relationship types between sustainability and the circular economy.

1. Conditional relation

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2. Strong conditional relation
3. Necessary but not sufficient conditional relation
4. Beneficial relationship
5. Subset relation (structured and unstructured)
6. Degree relation
7. Cost-benefit/trade-off relation
8. Selective relation

Remanufacturing Process

The typical remanufacturing process steps are represented in fig.3 and are listed as follows.

- Receipt of incoming product and identification.
- Strip - Clean - Wash if necessary.
- Assess suitability for remanufacturing
- Choose BOM parts and re-assemble as per Work Instruction
- Test/Inspect and per criteria and Work Instruction
- Identify with unique labeling
- Final pack /dispatch

Once a job is scheduled, the operators assigned to that job are responsible for every stage of the process from unpacking the unserviceable part to final pack and dispatch. This ensures full traceability and gives them total responsibility to meet customer's needs.

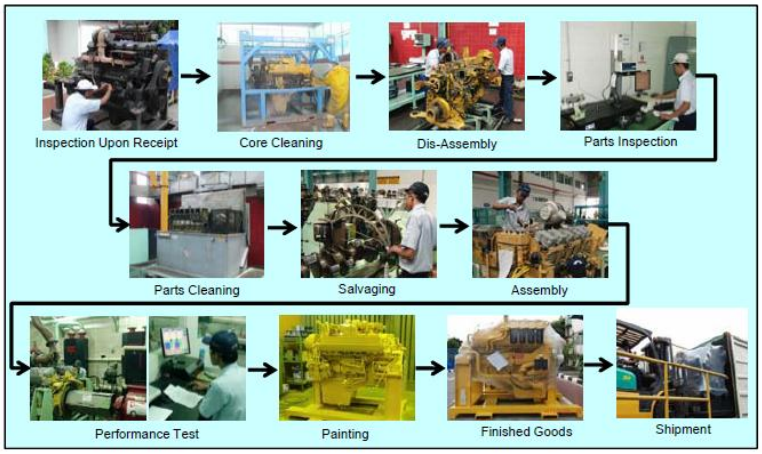

Fig3: Process Flow Diagram

Criteria for successful remanufacturing

Some product types lend themselves more naturally to remanufacturing, such as machinery and engines. Experience to date suggests that remanufacturing works best when certain criteria are met. These are that:

- Product has a high value
- Technology in question does not change quickly
- Fashion or trends in the product do not change quickly
- Product is durable
- Product is easy to disassemble
- Product is leased or delivered as a service instead of hardware. Where this occurs there are shared motives for product durability, longevity and performance

There are many examples of areas that fit these criteria but are as yet unexplored, for example wind turbines. The UK is a world leader in offshore wind energy, with many onshore wind turbines also, and there is great potential for remanufacturing in this area [10]

BENEFITS OF REMANUFACTURED PRODUCTS:

Remanufacturing is a profitable and environment friendly option for entrepreneurs. It increases the environmental image of the producer.

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- Remanufacturing gives new life to the product by consuming less energy, resources, labor, materials and disposable cost than conventional manufacturing process.
- In actual manufacturing process work environment is monotonous especially on assembly line. But in case of remanufactured product, work is interesting because every problem is new and challenging so work satisfaction is high.
- Remanufacturing industry can provide job opportunity to retired but skilled labor and in addition they can use their previous experience in disassembling, cleaning, repairing and assembling again.
- High profit margin about 20-30% is the important reason of interest for entrepreneurs in remanufacturing.
- Failure information provided during remanufacturing process will be provided to actual product design and development.
- As remanufacturing process is environment friendly, there is direct result of energy saving on green house gas emissions.
- Through remanufacturing, fewer resources are used to provide customers with same level of service.
- Remanufactured products have shorter lead time so finally it gives customer satisfaction.

Challenges in Process of Remanufacturing.

- Following are the some of challenges for remanufacturing
- Cost of remanufacturing may go down if few aspects are not considered while designing of product. Ease of disassembly and reassembly need to consider while product designs.
- Lead time in case of remanufacturing is changing product to product. Planning has to be done after the disassembly, inspection of the product.
- Skilled labor is required however existing workforce is trained as per the conventional manufacturing process. Hence skill sets need to be adopted according to the criticality of the product.
- Remanufacturing of the products are made as per the customer requirement hence strategic sales plan can't be done.
- Marketing strategy need to change for remanufactured product, especially budget on advertisement. There is need to convey customers that remanufactured products are as good as brand new products.
- Remanufactured products generally have zero depreciation value after its depreciation timeline, unlike to brand new products.
- Forecasting financial performance of remanufactured business is difficult to predict because of its irregular order from customer.[9]

9. Conclusions

Remanufacturing is gaining importance and industry is growing at a faster rate due to its inherent advantages in terns using less material, less energy and creating second and third life after the end of first life. Remanufacturing contributes to sustainable development by producing products that are as good as original products in look and capability, from used items.

Definition of remanufacturing as per the Remanufacturing Institute is as follows:

Society gains a considerable benefit from remanufacturing. It has an intrinsic societal impact because it uses less energy and resources than are required for new products; many existing parts are reused and therefore do not have to be remanufactured, and the effort required for refurbishment is significantly less than that associated with the production of new goods.

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