TEMA-ARTIKEL

Circular Economy – what does it mean for remanufacturing operations?

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It appears that our modern society is somewhat characterised by the industrial economy of "take, make, throw-away", where raw materials are extracted, converted into products, sold and consumed by end users, and at their end-of-life, the products are disposed of. Though many of the parts of the products can be recycled, in reality much still ends up in landfill. In the midst of the emerging global economy and growing middle class, this "linear economy" model is obviously an unsustainable way forward. Mass media have recently reported ongoing discourse by politicians, non-governmental organisations, commercial organisations and academics about the emerging concept of a Circular Economy (CE).

Circular Economy and Remanufacturing

The term CE is often positioned at the opposite end to the linear economy model. Not only does the CE aim to minimise the consumption of finite resources in the manufacture of products, it also promotes reusability of products by maximising the circulation of the content of end-of-life products. CE fosters sustainability and environmental conservation *beyond recycling*; and for that reason, it has been branded by the Ellen MacArthur Foundation (EMF) as an industrial economy that is restorative and regenerative, as well as efficient.

The notion of restorative and regenerative is manifested, for instance, through the advanced product design, development of intelligent materials, design for product reuse, product-service systems, and various business models that, in the end, retains the intrinsic value of the products being recirculated between the points of use and production.

The EMF uses the 'butterfly' diagram (Figure 1) to elaborate the two routes of circulation of materials. At the spine of the diagram lies the outbound processes (i.e. forward logistics) and each side of the spine can be considered as the opposite circles (reverse logistics) of what the EMF terms as technical and biological materials. Both technical and biological materials from end-of-life products should be properly treated, so that if inevitable, these materials can safely be released into the biosphere.

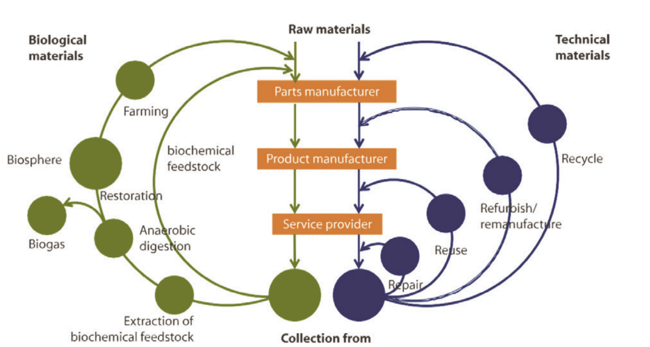

Figure 1 – Circular Economy (adapted from www.ellenmacarthurfoundation.org).

Remanufacturing is one of the functions in the technical reverse circle, which aims to transform used, worn, defective or obsolete products (also called cores), into functional products with at least the original performance of newly manufactured products. The cores are usually collected from the end users via various routes, e.g. retailers, third party collectors or authorised recyclers (Figure 2). Having been remanufactured, the products will be recirculated to the market via retailers or other third parties. Any spare parts or components post the remanufacturing process, may be sold to the after-market and unusable or unrecoverable parts may be recycled.

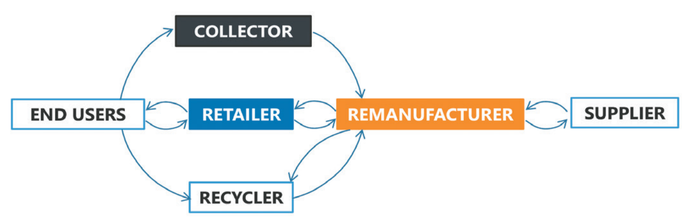

Figure 2 – A generic remanufacturing network.

A generic remanufacturing process typically involves inspection, disassembly (or dismantling), cleaning, and replacement of components, before the products are reassembled and tested (Figure 3), but, depending on the products, remanufacturing may also involve refurbishment or system upgrade and modification, i.e. to enhance appearance. As the customers expect remanufactured products to have at least the same performance as new products, the products will undergo a thorough quality check and the remanufacturers can then offer the same level of warranty as they would for new products.

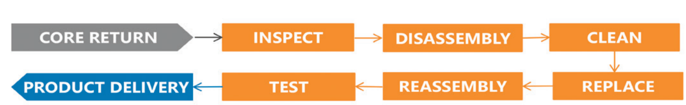

Figure 3 – A generic remanufacturing process.

Benefits of a CE and remanufacturing

The macro-economic benefits of adopting a CE have been recognised by a number of organisations. The Ellen MacArthur foundation (www.ellenmacarthurfoundation.org) suggests that over US $1 trillion a year could be generated by 2025 for the global economy and 100,000 new jobs created during the next five years if companies focus on encouraging the build-up of circular Supply Chains to increase the rate of recycling, reuse and remanufacture, which are all integral parts of a reverse logistics system. In their strategy document, closing the loop – an EUaction plan for the CE, the European Union (EU) stipulates its vision for transitioning to a CE and highlights a range of benefits including, protecting businesses against scarcity of resources, volatile prices, creating new business opportunities, improving innovation, production efficiency and conserving energy.

Positioned at the outer circle to both reuse and repair but inner to the recycling process of the EMF butterfly diagram, remanufacturing is a critical enabler of a resource-efficient manufacturing industry and has become an important component of, and clearly fits with, a CE. In the last ten years, many Original Equipment Manufacturers (OEMs), have decided to remanufacture their products, not only due to environmental pressures, but unsurprisingly for commercial reasons.

Remanufacturing has gained economic importance in many industrialised nations. The US International Trade Commission stated that the US has reached $43 billion in total production of remanufactured goods, supporting over 180,000 full-time jobs. Caterpillar Inc. alone is reported to have remanufactured over $3.5 billion worth of parts and components for diesel and turbine engines, construction and mining equipment, electric power generators, railroad locomotives, and railcars in North America. In the EU, remanufacturing is set to become increasingly important for the EU market, generating around €30 billion and employing around 190,000 people. The value-added through remanufacturing has encouraged global manufacturing companies to include the remanufacturing of used products in their offering portfolio.

While these benefits have been identified, fundamental changes throughout the value chain are required to implement a CE. This has to start from the product design and production process, through to product usage and reverse logistics processes (reuse, remanufacturing, recycling, etc.). However, considerable challenges exist between our conventional linear systems and models of circularity.

The Circular Economy values

Whilst there is an increasing awareness of the CE, there seems to be little appreciation of how it can be utilised in practice. We hereby provide the CE values, grouped into three categories: *Principles, intrinsic attributes* and *enablers*. We term principles as the essential activities or guiding rules to be followed in implementing a CE; intrinsic attributes as the natural characteristics belonging to the materials being circulated; and enablers as external entities that will support the practicality of the CE implementation. Table 1 lists the 15 CE values and their descriptions.

	Value	Description
Principle 1	Cascades orientation	Products are to be kept longer in circulation and transformed into different types of products or materials.
Principle 2	Waste elimination	Waste must be reduced and/or eliminated from the very beginning of the product design and at subsequent circulation stages.
Principle 3	Economic optimisation	Optimisation of production and consumption of products/services so that a resilient economy can be created.
Principle 4	Maximisation of retained value	Extension of values of products by creating a suitable treatment system.
Principle 5	Environmental consciousness	Preservation of environmental resources and reduction of environmental impacts.
Principle 6	Leakage minimisation	Avoidance of loss of opportunities to maximise the usage period of products that are lost.
Attribute 1	Systems thinking	The extent to which the CE is considered as a holistic system that integrates and influences one with another.
Attribute 2	Circularity	The extent to which value of products can be kept longer in circulation.
Attribute 3	Built-in resilience	The extent to which the responsiveness and robustness of a CE system can recover quickly from disturbances.
Attribute 4	Collaborative network	The extent to which stakeholders can work together within/between different industries to create materials' standards and circular information flow.
Attribute 5	Shift to renewable energy	The ability of the CE to reduce the energy usage and accelerate the shift to renewable energy.
Attribute 6	Optimisation of change	The ability of the CE to respond to changes in business environments affected by the dynamics of problems.
Enabler 1	Technology-driven	The availability of suitable and economically viable technologies to enable tracing the materials and products throughout the circulation.
Enabler 2	Market availability	The availability of a new or existing market that enables CE to create new business opportunities, thus encouraging the reusability of products.
Enabler 3	Innovation	The adoption of new, novel methods and ideas to stimulate redesign and rethink a system in CE to reach its optimum results.

Table 1 – The Circular Economy values.

For instance, with the principle of *cascades orientation* embedded into the product take-back scheme, the end-of-life product will not go straight to recycling, but will be cascaded to the next level, i.e. repair or refurbish, and then be reused. The cascading principle therefore aims to increase awareness that there are other opportunities for product recovery than simply recycling. Attributes, e.g. *collaborative networks*, are other aspects that one would possibly expect to see within the CE environment. In the context of cascades orientation, perhaps companies have horizontal collaboration networks with specialist repairers that support the remanufacturing business. Finally, the enabler, e.g. the *availability of secondary markets*, allows companies to sell remanufactured products at a higher utility.

How to apply the CE values in remanufacturing

Applying CE values into remanufacturing processes may involve the following steps:

(1) Identify the detailed remanufacturing processes involved.
(2) Map the CE values to the remanufacturing options and relevant processes.
(3) Embed the CE values in the determination or calculation of key parameters in the remanufacturing process and the relevant decisions to be taken.

Embedding CE values into remanufacturing is the systematic process by which CE principles, attributes and enablers can be evaluated and considered for adoption within remanufacturing processes. The *Disassembly* and *Replace/Recondition* in Figure 4, for example, are chosen to illustrate how CE values are embedded.

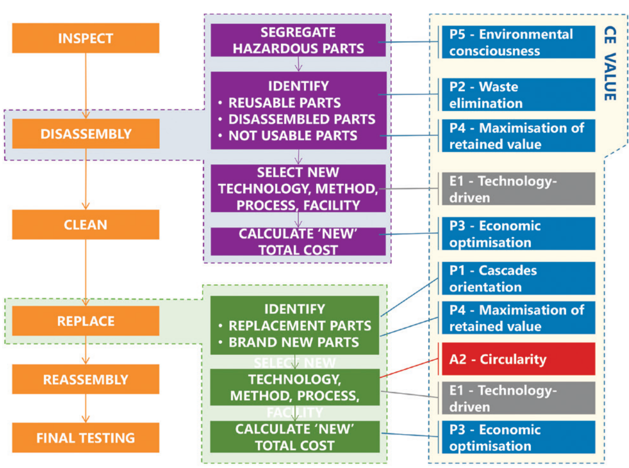

Figure 4 – Embedding CE values into remanufacturing operations.

During the disassembly, hazardous parts need to be segregated and treated appropriately and here we embed the *environmental consciousness* principle which allows any subsequent processes handling these parts to be handled in such a way that they adhere to any environmental legislation. Having removed the hazardous parts, the dismantling process can be done with a goal in mind to create a suitable treatment system so that their functional values can be prolonged and those parts that can be reused optimised. Here the *maximisation of retained value* and *waste elimination* principles are crucial to achieve the goal of optimisation. Disassembly often requires new processes and techniques, or special facilities to be built, so this will require the right enabling technology to fulfil the tasks effectively. All costs associated with the disassembly operations including material handling costs would need to be properly calculated, especially when considering the need to achieve circularity and a resilient economy at the same time, hence the *economic optimisation* principle.

Defective parts would need to be replaced with functional parts, be they brand new or used. Whichever the decision is, the replacement should carefully consider the *cascades orientation* principle to ensure that the remanufactured products are kept longer in circulation and the value of the products are maximised throughout their life cycle (*maximising retained value* principle). As with the disassembly process, part(s) replacement may need new processes and methods, thus the technology is selected not only because it is economically viable, but because it will also promote circulation in the future (the *technology-driven* principle), e.g. the use of track and trace technologies to monitor the condition of the products, which further cultivates the intrinsic attribute of *circularity* of the remanufactured products. As with the disassembly, total costs need to be carefully accounted for to ensure the economic resilience of the remanufacturing operations.

Concluding remarks

Remanufacturing continues to be seen as a business opportunity venture, a means of economic growth and job creation. As a key enabler of sustainable production and consumption, remanufacturing operations clearly uphold the *restorative* and *regenerative* notions in a CE. The meaning of the CE to remanufacturing operations, and thus the interpretation of its benefits, may vary from one industry sector to another, but a better understanding of the values of the CE would help players, stakeholders and practitioners in the remanufacturing industry to appreciate what it takes to transform existing remanufacturing operations into a more circular one.

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