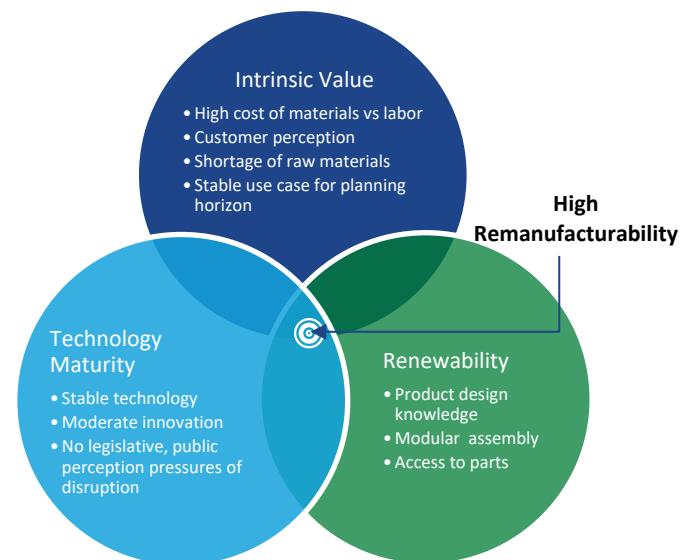


In Part I of the series, we focused on what constitutes remanufacturing along with generic steps in a remanufacturing operation. This part (Part II) will focus on remanufacturing strategy implementation, key benefits, drivers, and barriers for the manufacturers. As discussed in Part I, not every product lends itself to remanufacturing. There are three basic components of product characteristics that relate to remanufacturability. The intrinsic value is the measure of the cost and quality of usable materials remaining in the product core. If materials and sub-components are inexpensive, or most of the cost stems from labor-intensive processes, the remanufacturing case is difficult to justify. Other factors such as customer perception and brand loyalty also play a key part. The renewability of the product is determined by the access to subparts, the design, and diagnostic knowledge relating to the product core. The product's technological maturity is indicated by innovation and the frequency of disruptive change in the product architecture that renders previous generations obsolete. The variable combination of these factors validates the case for remanufacturing (Figure 1). Therefore, remanufacturing decision-making and implementation can be a complex task.

Remanufacturing has four distinct implementation scenarios in industry. It could be adopted as an internal or outsourced service or a separate business unit providing the product. Each type of implementation has its own advantages and disadvantages. Internal service can give design engineers good control and direction, but remanufactured products struggle to get the same priority. Outsourced remanufacturing gets the needed focus and priority as it is the primary function, but direct design knowledge transfer is required.



**Figure 1: Product characteristics for remanufacturing**

The success of the remanufacturing strategy depends on top management support and an integrated proposition to the customer. It also depends on the product knowledge sharing and adaptation to suit remanufacturing characteristics. A general methodology – 5-step approach for initiating remanufacturing (5AFIR) implementation proposed by *Duberg et. al.* – involves the selection of product family, review of stakeholders, iterative assessment of prerequisites and system performance, remanufacturing steps definition and industrial implementation, and validation and refinement of the assessment<sup>1</sup>.

The economic drivers for remanufacturing include reduced costs of goods sold, reduced prices to the customer, improved sales, supply risk mitigation, improved customer satisfaction, and stronger value chain relationships. The other indirect enablers for remanufacturing in the circular economy can include increased market share, brand enhancement, brand loyalty, and improved regulatory compliance. Remanufacturing also yields significant benefits in production and upstream supply chain energy use and corresponding emissions<sup>2</sup>.

<sup>1</sup> Vogt Duberg, J., Kurilova-Palisaitiene, J. & Sundin, E. 5-step approach for initiating remanufacturing (5AFIR). *Bus Strat Env* bse.3369 (2023) doi:10.1002/bse.3369.

The barriers to remanufacturing include non-conductive product design, high initial cost to change product design, reduction in new product sales, negative perception towards remanufactured products, complex remanufacturing process, non-availability of skilled and economic labor, non-availability of replacement parts, lack of infrastructure to facilitate remanufacturing, and regulation and policy. Another factor is the availability and condition of manufacturing technologies from the time when original products were made. In some cases, manufacturers of such equipment have either stopped making them or gone out of business. As a result, companies that want to remanufacture can find it difficult to find and maintain the older manufacturing process equipment needed to remanufacture products. A few of these barriers are easily resolved, but others can be systemic and difficult to change<sup>3</sup>. Reducing Embodied Energy and Emissions (REMADE) Institute and Golisano Institute of Sustainability at Rochester Institute of Technology are leading research and workforce development in remanufacturing and have developed numerous training and related resources which can be found on their websites<sup>4,5</sup>.

<sup>2</sup> Chaudhari, S. A. *et al.* Key Strategies In Industry For Circular Economy: Analysis Of Remanufacturing And Beneficial Reuse. in *Proceedings of REMADE Circular Economy Tech Summit and Conference* (Wiley Scrivener Publishing, 2023).

<sup>3</sup> Chakraborty, K., Mondal, S. & Mukherjee, K. Critical analysis of enablers and barriers in extension of useful life of automotive products through remanufacturing. *Journal of Cleaner Production* 227, 1117–1135 (2019).

<sup>4</sup> REMADE. The REMADE Institute. *The REMADE Institute* <https://remadeinstitute.org>.

<sup>5</sup> Golisano Institute for Sustainability. Center for Remanufacturing and Resource Recovery at Rochester Institute of Technology. <https://www.rit.edu/sustainabilityinstitute/center-remanufacturing-and-resource-recovery>.