Remanufacturing: The next great opportunity for boosting US productivity

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While many remarkable labor and material initiatives have received considerable attention over the past century, a golden opportunity has remained relatively hidden, limited primarily to a handful of industries, such as capital goods, automotive parts, and the Department of Defense. Today, remanufacturing represents perhaps the largest untapped resource for productivity improvement in American industry. The reasons for its limited use are varied, but they can all be attributed ultimately to a lack of awareness of the potential benefits—and challenges—involved. The solutions offered here can aid companies in reaping those benefits and overcoming those challenges.

What does it mean in industry to be productive? Economists define productivity as the ratio of an output—units manufactured, tons excavated, passenger miles traveled, and so on—to its associated input(s). Becoming more productive involves simply "doing more with less" or "getting more bang for the buck." Increases in manufacturing productivity come from the two primary inputs to the production process: labor and materials. Labor productivity has been the main focus of American business over the past century, with automation, technology, science, and management techniques all playing varying roles. The results have been staggering: Manufacturing productivity has increased by more than 300 percent over the past 50 years, largely due to these initiatives in labor.

Material productivity initiatives, though a much newer concept than their labor counterparts, have also begun to influence the American economy. *Material substitution* has substantially reduced the material input and weight of goods, often improving their technology and performance as well. *Recycling* has become almost a way of life in the US, continuing to gain momentum through legislative and public awareness efforts. However, the lion's share of its impact has been limited to simple items such as beverage containers, steel products, and paper goods. This is because recycling a more complex product, like a car, results in a loss of up to 95 percent of the value-added content.

Remanufacturing, by contrast, is the ultimate form of recycling. It conserves not only the raw material content but also much of the value added during the processes required to manufacture new products. And it may represent the largest untapped opportunity for improving productivity in American industry.

Just what are the benefits of remanufacturing? And what challenges await those companies attempting to use it? Here we describe the remanufacturing environment, report the primary obstacles limiting its wide-scale use, and offer advice to businesses in how to jump over those obstacles on the way to becoming more productive.

The ultimate form of recycling

Remanufacturing begins with the reclamation of used durable products. Typically called "cores," these products are then disassembled into parts, which are cleaned, inspected, and tested to determine whether they meet acceptable quality standards to be reused. Some parts become waste. Others that do not meet standards can be repaired or reconfigured. These used parts and some new ones are then combined to reassemble the original core from which they were reclaimed, or to build a product with a new identity. Remanufactured products typically have the same or similar performance characteristics and quality standards as new units.

The types of products being remanufactured vary, generally falling into two classes: capital goods and consumer durable goods. *Capital goods* can be anything from complex military weapon systems to manufacturing, mining, and agricultural equipment to vending machines. They constitute the majority of remanufacturing expenditures in the United States. Capital goods remanufacturing is also the more mature of the two types, having existed in one form or another for much of the twentieth century. In the case of *consumer durable goods*, process costs can often exceed the price of a new product, which has limited their use in many industries. Large-scale remanufacturing of products outside the domain of capital goods is still in its infancy, and time will tell how this opportunity will yet be exploited. There are, however, some prominent examples of successful remanufacturing of consumer durable goods—automotive parts, computers, laser toner cartridges, and single-use cameras are a few.

Of all the material productivity initiatives mentioned so far, capital goods remanufacturing provides the greatest profit opportunity for US businesses. Estimates of the current scope of remanufacturing activity vary, but two comprehensive studies shed light on its impact on the economy. The first, published in 1996 by Robert T. Lund of Boston University and funded by a grant from the Argonne National Laboratory, is summarized in **Table 1**. Lund's remanufacturing database, comprising more than 11,000 trade group members, provided a thorough first look at the US remanufacturing industry. His results may be surprising to many. In terms of employment and economic impact, the "industry" rivals such giants as household consumer durable goods, steel mill products, computers and peripherals, and pharmaceuticals (**Table 2**).

A more recent study by the OEM Product-Services Institute (OPI) used a slightly different perspective and method in an attempt to fill in some of the gaps in the Lund study. It used the current replacement value (CRV) of products currently in use as the basis for its estimate of remanufacturing expenditures. Experts in each industry then estimated the scope of remanufacturing costs as a percentage of the CRV. Though more reliant on estimates by industry experts than the Lund study, which made extensive use of real data, the OPI study was able to include a much broader range of industries, many of which have no formal trade organizations. The results of the OPI study are summarized in **Figure 1**.

Although the estimates differ somewhat, the conclusion is clear. Remanufacturing offers tremendous untapped opportunities for American business. According to OPI, the US spends an estimated $47 billion a year on it. Yet although this dollar figure is far from trivial, it represents only 0.4 percent of GDP, compared to 10 percent for new product manufacturing.

The benefits

There are many beneficiaries of remanufacturing. Here we focus on the four most prominent of those: business enterprises, the workforce, consumers, and society.

Business enterprises

The argument for an enterprise to enter the business of remanufacturing products or distributing remanufactured ones is compelling. Original equipment manufacturers (OEMs) like General Electric, Boeing, Caterpillar, Deere,

Table 1
Size and scope of remanufacturing activity in the US

Total number of firms	73,000
Total annual industry sales	$53 billion
Total direct employment	480,000
Average annual company sales	$2.9 million
Average company employment	24
Number of product areas	Over 46 major categories

Source: Lund (1996)

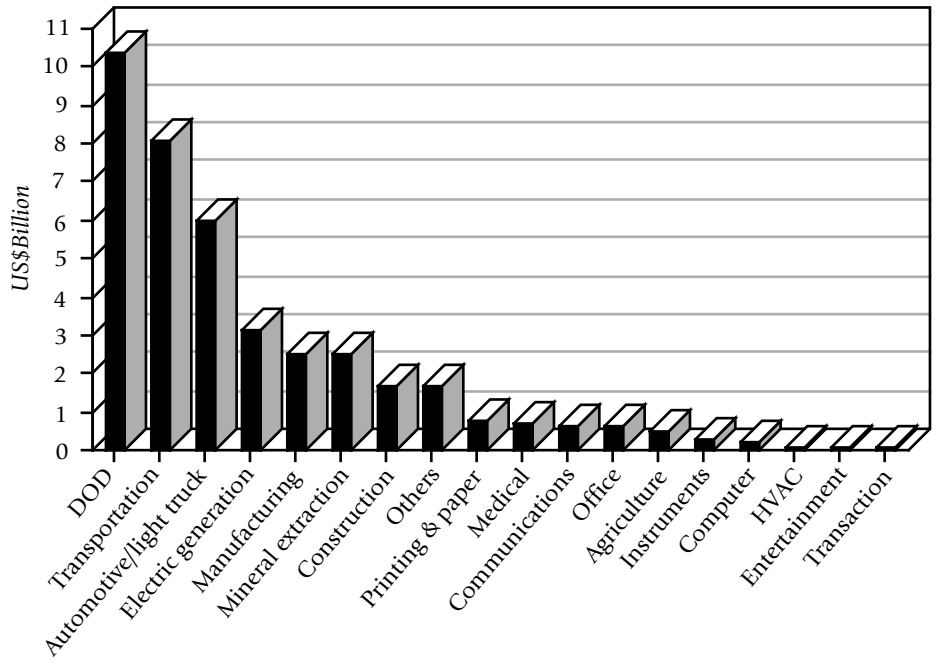
Table 2
Relative size of remanufacturing activity in the US

Industry sector	*Employment*	*Shipment value*
Remanufacturing	480,000	$53 billion
Household consumer durables	495,000	$51 billion
Steel mill products	241,000	$56 billion
Computers & peripherals	200,000	$56 billion
Pharmaceuticals	194,000	$68 billion

Source: Lund (1996)

Navistar, Xerox, and Pitney Bowes have created business models in which capital goods remanufacturing is an integral part. They currently lease, remanufacture, and remarket an estimated $130 billion of assets. In the consumer durable goods case, most automotive OEMs, directly or indirectly, engage in some level of remanufacturing, with the used parts generally sold through the same distributor network used for new ones. Eastman Kodak and Fuji Photo Film have revolutionized photography with their single-use cameras, but most consumers are unaware that the cameras are remanufactured up to 10 times after being returned for film processing. As far back as the 1930s, when Henry Ford began remanufacturing automobile engines after the Great Depression brought new car sales to a standstill, companies with an eye to the future have recognized and capitalized on this untapped opportunity.

Figure 1
Remanufacturing expenditures by industry



Source: OPI study (Giuntini 2001)

Many enterprises are stakeholders in the successful expansion of remanufacturing. The list below, though by no means all-inclusive, gives some examples:

- firms that use remanufactured products, enabling them to reduce their capital investment expenditures
- OEMs, which can use the remanufacturing process and the remarketing of the resulting products as a business strategy to increase profits
- manufacturers of specialized equipment used in the process, such as cleaning and test equipment, optical gauges, and so on
- OEM stockholders, who would likely see greater growth and stability in their investments (GE may be the best example of the possibilities that exist when remanufacturing is incorporated into an OEM's strategic vision)
- information technology suppliers, who would help build the IT infrastructure to support remanufacturing and distribution process activities
- management consultants, who would assist new-condition product manufacturers in incorporating remanufacturing into their business models
- design engineering software suppliers, who would develop design optimization tools for the remanufacturing processes of disassembly and reassembly
- financial service firms, which would finance the capital investment needed for companies to enter the remanufacturing sector
- third-party logistics suppliers, which would experience a large increase in reverse logistics activity

The workforce

A quick read of Ben Hamper's 1991 bestseller *Rivethead* or a similar chronicle of life on the factory floor casts light on the monotony faced by the direct labor workforce. Remanufacturing, by comparison, is a much more dynamic and varied production environment. Blue-collar workers require more initial training and skills, with the long-term benefit of a broader skill set and higher work satisfaction. In addition, retired and laid-off factory workers would be in high demand, providing the experience in disassembling and reassembling products that they helped build years before.

Consumers

Remanufacturing brings lower prices to the consumer, typically on the order of 30 to 40 percent less than similar new products. It also means more consumer choice, espe-

cially for discontinued products that are still available in mint condition, which is currently the case in such industries as retail auto parts.

Society

Society is arguably the greatest beneficiary of remanufacturing. As a material productivity initiative, the process has an intrinsic societal benefit in that it reduces the volume of energy and natural resources required to produce the goods we value. Remanufactured products incur costs that are typically 40 to 65 percent less than those incurred in the delivery of new products. This is because most of the raw materials already exist in their final form and thus require only a fraction of the material processing required of new products. In terms of energy consumption, remanufacturing a product requires only about 15 percent of the energy used to make the product from scratch. The estimated worldwide energy savings of current remanufacturing in lieu of building new products is an incredible 400 trillion BTUs of energy annually. To put that figure into perspective, it is the equivalent of about 16 million barrels of crude oil (about 350 tankers), or enough gasoline to run 6 million cars for a year.

The estimated savings in raw materials is equally compelling—the materials saved would fill 155,000 railway cars in a train spanning 1,100 miles.

As a direct result of the energy savings, remanufacturing is also extremely effective in reducing greenhouse gas emissions. A weighted average of 140 pounds of CO_2 is emitted for every million BTUs of energy consumed (burning coal is higher, hydroelectric and nuclear lower). Based on its estimated savings of 400 trillion BTUs per year, remanufacturing avoids the generation of about 28 million tons of CO_2 annually, roughly the output of ten 500-megawatt coal-burning electrical plants.

The estimated savings in raw materials is equally compelling—the materials saved would fill 155,000 railway cars in a train spanning 1,100 miles. While recycling has a similar effect in terms of conserving natural resources, it requires that the parts be returned to their raw state (which requires energy), at which point the manufacturing process must be repeated just as if virgin raw materials were used (which also requires energy).

All these energy savings are only the tip of the iceberg. OPI has estimated that if capital goods OEMs and automakers delivered 20 and 10 percent of their product output, respectively, in a remanufactured rather than new condition, remanufacturing activity in the United States would increase by 200 percent. That equates to an estimated 5 to 10 percent drop in waste and energy consumption throughout the entire US manufacturing supply chain.

Government officials have already begun to recognize and favor remanufacturing's environmental benefits, and are pursuing the legislative means to encourage it, albeit cautiously. Their counterparts in Europe have taken a more aggressive stance. As of 2002, for example, no more than 15 percent of a scrap vehicle can be discarded in Europe, with that percentage dropping to 5 percent by 2015, coupled with the mandate that a percentage of automobiles sold each year must be remanufactured. The German Packaging Order and the German Recycling and Waste Control Act are models of how to establish green legislation to drive remanufacturing.

Recent executive and legislative efforts indicate that the US is moving in the same direction. In May 1998, the Federal Trade Commission formally began allowing remanufacturers to label their products as "recycled" and "remanufactured in the USA." Although seemingly semantic, the FTC's ruling will raise the public awareness of remanufacturing to the level that recycling has attained in the past 30 years.

State governments have begun to follow suit. New York passed a remanufacturing bill in June 1998 (by a vote of 146–1) mandating that purchase requests for durable equipment consider remade goods first. It also mandates that "products purchased by the commissioner or other state agencies shall be recycled or remanufactured products…provided the cost…does not exceed a cost premium of ten percent." Finally, it prohibits state agencies from purchasing commodities from OEMs that place restrictions on remanufacturing, such as Lexmark with its "Prebate" program. The following year, Texas, Connecticut, and California passed similar laws. In 2000, New York added to its landmark legislation by passing a tax credit to benefit remanufacturing firms.

Since 2000, Congress has been considering a 20 percent tax credit for businesses on the purchase of remanufacturing and recycling equipment. The bill has enjoyed enormous support, with nearly 60 co-sponsors in Congress. Although the legislation became moot when Congress passed changes to the tax law providing 20 percent tax breaks for investment in all forms of capital equipment, the number of co-sponsors was a strong indication of the level of support that such legislation will likely receive in the future. Efforts by remanufacturing proponents like William Gager, President and CEO of the Automotive Parts Rebuilders Association (APRA), will ensure that remanufacturing remains of interest to Congress. As *Busi-*

ness Week's Janet Ginsburg (2001) suggests, "If US companies want to stay competitive, they may want to start thinking green sooner rather than later."

Why remanufacturing's modest success?

Given the size, potential, and benefits of remanufacturing in the US, one would expect firms to be embracing this concept with reckless abandon. But with remanufacturing activities accounting for only 0.4 percent of GDP, this is clearly not the case. What are the various reasons for this poor showing?

Design

When products are designed to be easily disassembled and reassembled, as has traditionally been the case in the defense industry, the remanufacturing process can be both efficient and profitable. Unfortunately, this has not been the case in most manufacturing industries, resulting in high operational costs or high scrap rates, or both, during the process. Such lack of focus creates market conditions in which remanufactured products often do not have a significant price advantage over new-condition products, resulting in relatively low demand for them.

Sales

Salespeople are generally not given incentives to handle the sale of remanufactured products as alternative solutions for customers. Historically, they have been programmed to sell new-condition products, viewing remanufactured ones as a threat to their commissions.

Marketing

Product marketing managers do not usually incorporate remanufactured products into their strategic selling plan. On a tactical basis, remanufacturing is often addressed only in response to individual customer requests. In some cases, OEMs enter into the remanufacturing business only to control the perceived damage incurred to their brand name due to the poor quality of remanufacturing performed by small, independent, unauthorized enterprises.

Production and inventory management

In a traditional manufacturing environment, the exact parts requirements are known for each unit to be assembled. Assembly is generally a straightforward matter as well, since the new parts have already been manufactured to the required tolerance. For remanufacturing, however, the new parts requirements are not known because the used cores are the primary source of supply for parts. The number of usable parts from cores, unfortunately, is not usually known until after the core is disassembled, inspected, and tested. Moreover, the disassembly, test, inspection, and, to a lesser degree, reassembly processes require different skills and equipment than their manufacturing counterparts. These challenges make operationalizing remanufacturing activities difficult.

Workforce skill levels

The historical focus on mass production skills in the work force has resulted in worker specialization, rather than the broader technical skills required of the remanufacturing process. Even with the recent trend toward cellular manufacturing and its associated increase in worker skill sets, there are many skills unique to remanufacturing that are not widely available in the workforce. This often creates shortages of skilled technicians.

Metrics

New product business metrics are often designed to recognize revenue growth, not profit growth. The sale of remanufactured products generates lower revenues, but in absolute terms and as a percentage of sales, profits are often greater. Manufacturing performance metrics are driven by new-condition product labor productivity, even if managers are responsible for the remanufacturing process as well. Thus, little attention is given to reducing remanufacturing process costs. As the saying goes, "You do what you measure," and currently the measure is of new products.

Tax credits

Tax credits for capital equipment purchases have historically focused only on new-condition products. This trend is reversing, however, as discussed previously.

Advertising

Product advertising emphasizes obtaining access to the latest or greatest new technology and throwing out the old. "America today remains a throwaway society, and economic motivations are at the root of that pervasive mentality," explains Dr. Nabil Nasr, Director of the National Center for Remanufacturing and Resource Recovery (NCR^3) at the Rochester Institute of Technology. "However, I believe that we can help change that attitude. The market for remanufactured products can flourish once customers are educated that remanufactured can be as good as new" (Judge 2002). Advertising is the key to that end.

Depreciation

Tax depreciation time lines for capital goods are briefer than the physical life of the product, resulting in 40 percent of such balance sheet assets having a zero book value. Financial management often perceives that these assets also have a zero economic value, so expenditures to extend their lives through remanufacturing are often not given budgeting priority, despite the potential avoidance of capital investment in new equipment.

Accounting

Managerial accounting techniques are in a primitive state when it comes to reporting remanufacturing process activities. The result is often poorly configured balance sheets and income statements for remanufacturers, giving top managers an inaccurate perception of financial performance. As for financial accounting, the FASB has been silent on remanufacturing, providing no guidance in this area.

Overcoming the obstacles

The evidence is convincing that remanufacturing can be a strong, stable source of profit for product manufacturers. Its societal benefits are also clear. However, many obstacles must still be overcome in order to realize the benefits. The good news is that, with few exceptions, those obstacles fall under the direct control of the individual enterprise. They are the result of internal policies and incentives that can easily be changed with appropriate management commitment.

Executive-level commitment

As with any change in a company's focus, adding remanufacturing to the corporate strategic vision requires a commitment from the top first. Remanufacturing cannot simply be a sidebar appended to an existing department; it must be woven into the very thread of the firm. In a letter to shareholders, employees, and customers, Jack Welch summed up the vision of GE's service activities, a significant portion of which comprise remanufacturing, repair, and overhaul. His letter provides an excellent example of how a top-level commitment can spawn a completely new—and profitable—business paradigm (Welch 1999):

> With this initiative, as with globalization, we are broadening our definition of services—from the traditional activities of parts replacement, overhauling, and reconditioning…to a larger and bolder vision. We have the engineering, the R&D, the product knowledge, the resources, and the management commitment to make the series of hundred-million-dollar investments that will allow us to truly change the performance of our installed base, and by doing so, upgrade the competitiveness and profitability of our customers.

Welch articulated a vision that went far beyond simply offering overhauled and remanufactured products. His vision included *adding value* to GE capital goods already in use through a combination of remanufacturing and upgrades. He committed all resources, including engineering and R&D, to achieving this high level of customer value. As a result, about 35 percent of GE Capital's 2001 revenues came from other-than-new product and service activities, accounting for more than 60 percent of profits. This performance was the direct result of Welch's top-level commitment to remanufacturing and overhaul.

Design engineering

For corporate vision to work, it must be operationalized into its processes from start to finish. Beginning with the earliest stages of a product's life cycle, engineering plays a pivotal role. The product's design is a critical element in enabling profitable remanufacturing, since 70–80 percent of its costs are incurred after production. Designing products in a modular fashion therefore becomes the key to being able to disassemble and reassemble efficiently. Modular design allows technological upgrades to be infused easily during the remanufacturing process, reducing obsolescence and maintaining the competitive positioning of the resulting products vis-à-vis new ones.

Marketing, sales, and advertising

The marketing and advertising focus must include revising metrics and incentives in order to develop and maintain a customer base that is interested in remanufactured products. Equal billing must be shared with new product sales. Moreover, savvy marketing departments will realize that remanufactured parts offer the capability to segment the market, meeting diverse customer needs with a broader range of offerings without straying from the company's core business. For the sales force, which generally operates in response to financial incentives, a similar shift of attitude must occur, with a focus on solutions that deliver products regardless of whether they are new or not.

Production, material management, and reverse logistics

The remanufacturing process is more complicated than that of new product manufacturing. Production engineers, most notably Nabil Nasr of NCR[3], have spent most of the last decade studying the processes of disassembling, cleaning, inspecting, and testing used parts. NCR[3] has also been involved in product design and other areas of engineering directly related to successful remanufacturing. An expansion of such efforts will create a body of knowledge that enables enterprises to improve their remanufacturing process productivity, creating an even more compelling story for lower costs and improved quality.

Material management poses its own set of challenges. Conditions and configuration classifications must be established in order to plan, acquire, store, issue, distribute, and return materials involved in the remanufacturing process. New manufacturing assumes that all materials are in a new condition and have a single configuration, an assumption that does not hold for remanufacturing.

Reverse logistics is the process by which used cores are collected and returned to the remanufacturer for processing. On the surface, it may appear that this is simply an

extension of forward logistics, but in practice it is much more complex. Ferrer and Whybark (2000) offer an excellent discussion of the unique issues involved, including transportation, storage, handling, packaging, and sorting decisions that are critical to remanufacturing success.

Accounting

Some of the greatest challenges faced by remanufacturing companies today lie in the accounting field. Several of these challenges are internal, such as educating accountants on the cost and revenue structure of remanufacturing. Others, such as tax credits, are unfortunately beyond the scope of a firm. The following paragraphs discuss a few of the major accounting challenges and offer suggestions on how to cope with them.

Depreciation versus expense. In the case of capital equipment, the system for depreciation and its interrelationship with remanufacturing must be thoroughly understood. The legal precedent of expensing rather than capitalizing the remanufacturing process came in October 2000 from the case of *Ingram Industries, Inc.& Subsidiaries v. Commissioner of Internal Revenue*, when Judge Joel Gerber of the US Tax Court held that Ingram's marine engine overhaul outlays were indeed expenses required to realize the expected life of the equipment. Because they did not appreciably extend that life, they could be written off as preventive maintenance expenses for tax purposes. Many tax, GAAP, and managerial accounting issues must be scrutinized to ensure that a firm chooses the most favorable way of reporting the impact of remanufacturing on its income statement and balance sheet.

Material valuation. There are a wide variety of ways to valuate remanufactured materials, with differences in tax, GAAP, and managerial accounting approaches. Many expenses are out of period with revenues, requiring income statement and balance sheet accrual accounts. Unfortunately, most financial accountants are ill-equipped to handle these transaction streams effectively because they are primarily educated in new-condition material valuation. For remanufacturing to grow, the FASB and the Federal Tax Court must create a comprehensive body of knowledge and rulings, respectively, to provide guidance for remanufacturers. A recent example of tax court rulings clarifying material valuations came in the case of *Consolidated Manufacturing, Inc. v Commissioner of Internal Revenue* (2002). The US Court of Appeals for the Tenth Circuit stepped in and ruled against the IRS, which traditionally viewed the book value of cores in inventory as the remanufactured product exchange price, and held that the appropriate book value of used cores should be the fair market value of used cores in the marketplace. Accountants can thus use independent broker prices to determine a "fair market price" regardless of the exchange price surcharge. This means that the actual profitability of remanufacturing will now be visible, where previously it was often grossly understated. It also means the asset values on the balance sheet will be reduced.

Trade groups

Active involvement in trade groups is one of the best ways a firm can help itself. These groups can have a tremendous impact on an industry by helping to remove external obstacles that fall beyond the control of individual firms. Recent efforts to pool the resources of government agencies, academic institutions, and segmented trade organizations have succeeded in bringing remanufacturing issues to the attention of the public and its elected representatives. One such effort, which has already had a big impact, was the formation of the Remanufacturing Industries Council International (RICI) in 1995 and its sister organization The Remanufacturing Institute (TRI). Created to pool the concerns and resources of the many trade groups already active in remanufacturing, RICI includes interested representatives from government and academia. Its original stated purpose was to "foster cooperation among remanufacturing industries in areas of common interest, promote the use of remanufactured products, and increase public awareness of remanufacturing's contributions to the economy and the environment." That purpose, and the council's strategic vision, are well articulated at www.reman.org. Participants in RICI are diverse and span most of the major remanufacturing activities in the US. **Figure 2** lists the charter participants from the original meetings in 1995.

Figure 2
RICI charter members

- American Retreaders Association
- Argonne National Laboratory
- Automatic Transmission Rebuilders
- Automotive Engine Rebuilders Association
- Automotive Parts Rebuilders Association
- Boston University
- Business Products Industry Association
- Diamond Research Corp
- Electrical Apparatus Service Association
- Environmental Protection Agency
- Environmental Protection Agency, Office of Solid Waste
- International Compressor Remanufacturers Assoc
- Martin Marietta Energy Systems, Inc
- National Engine Parts Association
- National Tire Dealers and Retreaders Association
- North American Valve Rebuilders Association
- Production Engine Remanufacturers Association
- Professional Cartridge Remanufacturers Institute
- Remanufacturing Consulting Group
- Rochester Institute of Technology
- US Dept of Energy, Office of Industrial Technologies
- US EPA, Pollution Prevention
- United Laser Toner Recyclers Association
- Valve Remanufacturers Council

The United States has enjoyed the benefits of enormous labor productivity gains over the past century. Now it has begun to tap into the potential of material productivity as well. Of the different types of initiatives mentioned in this article, material substitution is the most mature and has yielded the most impressive results to date, in terms of both material reduction and technological improvement. Recycling has also become almost a way of life in the US over the past 25 years, adding to the gains of material substitution and further increasing material productivity. Remanufacturing remains the least mature initiative, and as such presents the largest potential for productivity improvements.

The benefits of remanufacturing, though not widely understood, are extremely attractive. Businesses that incorporate it into their strategic plans, as GE and many others have done, can reap a stable source of long-term growth. The workforce benefits from additional training and a more varied workplace. Consumers have a broader range of products to choose from in meeting their needs, along with a corresponding broader range of prices. Society arguably benefits the most, with an 85 percent energy savings over the production of new products and an associated reduction in the use of scarce natural resources.

Progress will not be without its challenges, but it can be achieved. It takes serious strategic planning by manufacturing firms; rethinking product design; experimentation with new organizational structures; reengineering or creation of new business processes; reconfiguration of reward and compensation systems to align with desired business outcomes; implementation of support infrastructures; and training or hiring of qualified people. Most important, it takes the commitment, courage, and willfulness of the executive management team to implement and sustain the type of environment needed to support a business model in which new-condition and remanufactured products are both incorporated into one strategic enterprise focus. With a little bit of effort, everyone wins, regardless of perspective. ❍

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