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Products as service carriers: should we kill the messenger – or send it back?

by
Robert Ayres

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PRODUCTS AS SERVICE CARRIERS: SHOULD WE KILL THE MESSENGER -- OR SEND IT BACK?

Robert U. Ayres

Center for the Management of Environmental Resources
INSEAD
Fontainebleau, France

Abstract

Background: dematerialization vs. economic growth

Environmental problems and unpaid social costs are associated with all materials/energy intensive activities. These have already created strong pressures to reduce harmful wastes emissions, whether by end-of-pipe treatment or by adopting cleaner (i.e. more efficient) methods of production. To be sure, sometimes this can be done at low or even negative cost, as a result of uncovering previously unlooked-for opportunities to reduce costs by reducing inputs. These opportunities may be much greater than skeptics realize at first. However, when the "low hanging fruit" is picked, further reductions in materials consumption and emissions can only be achieved by other means, such as recycling, or investing in higher cost equipment or more labor inputs.

The end result will be to make materials and energy producers pay more to reduce pollution and thus more costly to users. This will *ipso facto* encourage materials/energy users to be more efficient and to seek alternatives where possible. Many of these gains in materials/energy productivity must be achieved -- in effect -- by substituting labor or capital for energy or materials. (Insulating houses to reduce the need for hydrocarbon fuels would be an example). Other gains will be achieved by extending the useful life of material products by increasing the level of re-use, repair, renovation, remanufacturing and recycling. All of these are inherently more labor-intensive than original mass production. These changes appear to be very desirable from the standpoint of reducing unemployment, but they also *ceteris paribus* reduce labor productivity. Increasing resource productivity has a downside in the form of reduced economies of scale for the raw materials processing industries and the mass producers.

On the other hand, continued economic growth itself continues to be an important political and social objective. Indeed, the needs of aging populations and increasing health-related entitlements, not to mention more investment in education and research, demand that economic growth should accelerate, if anything. A stark question arises: how is future economic growth to be reconciled with a static or declining rate of increase of labor productivity? Is it possible?

This paper starts from the observation that the economy adds value to materials extracted from the environment, in the form of embodied information. In effect, the materials -- and material products -- act as carriers of information. We can think of them as service carriers. A very large fraction of these materials consists of intermediates that are dissipated in use.

Examples include food, beverages, fuels, lubricants, soaps and detergents, fertilizers, solvents, water softeners, industrial acids and alkalis, and so on. Other materials are embodied in products with very short useful lives, such as newspapers and packaging materials. Even in the case of longer-lived products. Some of this added value is lost each year, due to various natural processes. It is worthwhile examining some of these processes and searching for ways to reduce the loss.

Whereas materials embodied in long-lived tangible assets obviously contribute to wealth, there is no such direct link between intermediate material flows and wealth creation. As mentioned, there is a large class of intermediates that is dissipated. In fact, intermediate flows of dissipative materials contribute mainly to pollution. Suppose, for purposes of argument, that all intermediate flows of materials that are not embodied in final products (i.e. materials that are `used up' and dissipated within the production process) could be magically eliminated by process changes, *without affecting the quantity or quality of durable goods and tangible assets*.

Admittedly, such a scenario would involve extensive industrial restructuring (or eco-restructuring), and it is impossible to calculate all of its economic impacts in advance. However the elimination of dissipative intermediates would leave the utility of real final services consumed by households unaffected, by assumption. Meanwhile, the real services provided by the environment would be protected, if not enhanced, inasmuch as environmental pollution would be abated considerably.

Regarding tangible man-made durables, it is worth noting that the difference between a capital asset and an intermediate good in the economy is very fuzzy, if not essentially arbitrary. Conceptually, a capital asset contributes to production (of goods or services) without being changed -- except for wear and tear -- whereas an intermediate good is immediately converted into something else, either another good or a waste. However, the distinction between durables and consumables is also somewhat fuzzy, insofar as all material goods are ultimately `transformed' into non-material services.

It might be suggested that an intermediate good is transformed into another good, whereas a final good is transformed (by use) into a service. In both cases, the material good itself becomes a waste, sooner or later. But not all intermediates are converted into other goods. For tax purposes the difference between an intermediate good and a durable item is essentially a matter of re-usability and useful lifetime. Material goods that are consumed or dissipated do not contribute directly to tangible real wealth, however much they facilitate the current production process.

What all this means is that the monetary value of tangible produced wealth is strongly dependent on the assumed rate of depreciation of durable goods (as determined by the tax authorities). The *real* value of tangible produced wealth, which may be higher than the value for tax purposes, is nevertheless dependent on the *real* rate of depreciation. It follows that cutting the rate of depreciation of durables will increase the rate of accumulation of tangible wealth. In other words, it will contribute to economic growth.

The way to combine economic growth with dematerialization must be to conserve value-added by elimination of dissipative intermediates, on the one hand, and life-extension -- by re-use, repair, renovation and remanufacturing -- of durable goods, on the other hand. The latter are the only material products that truly constitute wealth (by generating non-material services to final consumers).

Efficiency vs. sufficiency

As already suggested, there are already incentives for firms to reduce materials/energy consumption insofar as they can simultaneously reduce costs. This sort of opportunity is commonly known to economists as a `double dividend', because it has both a financial payoff and an environmental payoff.

However, dematerialization for the purpose of cutting costs -- sometimes called `eco-efficiency --has limits. When every product is made as efficiently as is theoretically possible, the problem of consumption wastes remains. Not only that, but to the extent that eco-efficiency is cost-effective, it will either increase unit profits or consumer prices. To the extent that prices drop, demand will rise. And, depending on the price elasticity of demand, total materials/energy consumption by the economy may actually rise too. This phenomenon has been termed the `rebound effect'. For instance, more fuel-efficient cars consume less fuel per kilometer travelled, but people may then travel more kilometers, thus increasing overall energy consumption.

Computers and PCs constitute a more dramatic case in point. The electric power required to operate a single computer chip nowadays is negligible -- almost microscopic. But, there are now 50 million PCs in private households, each consuming a kilowatt of power, for an average of 12 hours per week. There are 150 million more PCs in businesses, probably being used even more intensively. Annual sales are now 36 million units. Chip manufacturing is also very power intensive: approximately 1000 kwh is needed to fabricate each PC. Amazingly, the silicon fabricators and their suppliers already consume 1 percent of the electric power consumed in the US. Electric power required to operate the Internet PCs and their more powerful cousins (work stations, routers, etc.) and associated networks adds another 8 percent while non-networked computers brings the total to 13 percent.[1] Evidently the rebound effect in this case is surprisingly powerful.

An obvious question for future research is the extent to which the Internet revolution, which so obsesses the business community today, will decrease -- or increase -- the overall materials intensity of our economic system. On one side of the argument, it is suggested that the Internet will be so much more convenient and cheaper for shopping that people will no longer want to go to large suburban shopping malls. The "death of the mall" has been suggested. On the other hand, if goods are sold cheaper on the net, more goods will presumably be sold. Moreover, they will still need to be delivered. It is very unclear even whether the increased traffic of delivery vehicles would compensate for decreased traffic by shoppers.

The essential issue remains: how can the economy be restructured to consume significantly *less* energy (fuels) and less material goods? Is it realistic to talk about `zero emissions'? If so, how can dematerialization be accomplished without adversely affecting economic growth? Here economic growth must be interpreted in terms of increased output of services, not goods.

Toward dematerializing the economy: Internalizing materials use

There is only one way to achieve the two objectives mentioned above at the same time. It is easy to label, but difficult to achieve. Since products are essentially carriers of service, the trick is to find ways of delivering the service without wasting the material carrier. In other words, we need to find new ways of delivering the message without killing (i.e. discarding) the messenger. The messengers need to be used many times, not merely once.

Of course there is already a well-established business of leasing capital equipment. Many airlines lease their aircraft from specialized leasing firms. Most industrial buildings are also owned by specialist real estate companies and leased to occupants. But leasing, in these cases, does not extend the useful lifetime of the structures or equipment. Shorter term leasing is also widely practiced. Car rental firms operate in every airport, for instance. Videotapes and books are regularly leased for short periods. There are specialized firms what lease chairs, tables, glassware, even tents, for parties. There are firms that lease tuxedos, dress shirts, top hats, swallowtail coats, costume jewelry, uniforms, and even academic regalia. But, except for a few of these items, there is no clear environmental benefit. Because of the availability of leasing, formal clothes are worn more than they otherwise would be. If rentals of such garments were prohibited, most formal dinner parties would have few guests, or none.

It is much more interesting to consider what can be done to extend the lifetime of products that are normally used only once. Glass bottles are a good example. Bottles can be washed and re-used with perfect safety. This used to be standard practice with milk, soft drink and beer bottles, for instance. Yet nowadays, even where glass is recycled, bottles are deliberately smashed (why?) and different colors are typically mixed together. This sharply reduces the utility of the resulting cullet. Some other packages, such as plastic beer cases, steel drums and industrial wooden pallets are normally re-used. But most packaging materials are discarded nowadays after a single use, even though re-use, in many cases, is mainly a matter of organization.

The so-called disposable camera is a case where an item that was formerly very long-lived (the camera) has suddenly reverted to single-use status. Even though the lenses are reputedly recovered and re-used, it seems likely that photography -- taken as a whole -- has become significantly more materials intensive as a result of this particular marketing innovation.

Another case where recent trends are in the wrong direction is motor vehicle tires. the ideal system would be similar to that currently practiced by commercial airlines and some large trucking companies. There are specialized tire leasing firms that take full responsibility for providing tire service. The firm monitors the usage of the tires, changes tires on a regular basis, and recaps the worn ones. Done this way, each tire can be safely recapped half a dozen times, or more, and the overall life expectancy can be increased three to five fold over single use tires. Yet recapping is actually declining in the case of smaller trucks and personal vehicles. There are two reasons. In the first place, many tires are not changed until they are too worn for satisfactory recapping. This means that, at least, a consignment of worn tires must be pre-sorted into recappable and non-recappable categories. The latter must then be disposed of. And, in the second place, recapped tires cannot be used safely at extremely high speeds. There is a quality difference. Yet there is absolutely no reason why recapped tires could not be used safely by urban buses, urban taxis, local delivery trucks, postal vans, and other vehicles that do not put too much stress on tires.

A car-sharing or rental system with centralized maintenance could justify receiving significantly reduced insurance rates for vehicles with low engine power and limited maximum speed. This would also encourage the systematic use of recapping.

One recent idea of some interest can be characterized as `rent-a-chemical' or --better yet -- `rent a molecule'. Lubricating oils need to be filtered and cleaned of contaminants after a while, but in most cases they need not be thrown out and replaced. Used oils can be reprocessed quite inexpensively with little if any reduction in quality. To see the magnitudes involved, the total market for lubricating oils in Western Europe for 1993 was 5.319 million metric tons (MMT). Of this, at least 2.624 MMT was assessed as recoverable, but only 1.5 MMT were actually recovered, with 1.1 MMT unaccounted for and probably burned or dumped illicitly.[2] The contaminants in used oils include sulfur (0.2% - 1%), polyaromatic hydrocarbons (PAHs), lead (from leaded gasoline, still widely used in Europe) and a variety of other metals, mainly from additives or bearing wear. Chlorine (up to 0.15 %) is also found in mixed oils, due to contamination by illicit disposal of chlorinated solvents. Obviously burning or dumping into soil or waterways is highly undesirable. The main difficulty is collection and segregation. Also, it must be noted that petroleum refiners with well-established brands of high-priced motor oil (e.g. Mobil and Quaker State) do not welcome competition from cheaper recycled oils.

Solvents and antifreezes can also be recycled and re-used, at least in principle. Dow Chemical Co., and its partner Safe-Chem (which has developed specialized containers for collection and shipping) has demonstrated the technical and economic feasibility of recycling chlorinated solvents used in the electronics sector and automotive coolants (ethylene glycol) in Germany. The former is simply collected and redistilled for re-use `as new'. The latter must be decontaminated first, and then shipped to a loction where it is distilled to separate the antifreeze from the water. Dow now reclaims spent coolant from Peugeot and BMW. Nevertheless, at least 90 percent of the coolant is dumped down drains into waterways, even in Germany where the practice is illegal (because of mild toxicity of the coolant, not to mention contaminants). The quantity lost has been estimated at 100,000 tonnes. In the US dumping is not illegal and there is no recovery (as far as I know), so the loss rate is close to 100 percent. Ethylene glycol may have had other uses, possibly as an intermediate, but assuming sales of ethylene glycol were mostly to compensate for lost antifreeze, this implies that as much as 2.25 MMT of ethylene glycol may have been dumped into US waterways in 1993. (If that figure is anywhere near correct, the German estimate is far too low.)

Similarly, most solvents used in industry simply evaporate into the air. The annual output of manufactured organic industrial solvents in the US in 1993 was 2.4 MMT, which probably did not include all of the petrochemical feedstocks (benzene, toluene, xylene) that were used as solvents. Most of these solvents evaporated into the air. Chlorinated solvents (CHCs), alone, consumed in 1993 amounted to about 1.2 MMT. European consumption alone was over 1 MMT in the early 1970s, and 770 kMT in 1985, but had fallen below 400 kMT by 1993 and was still falling. This was due to increased recycling by users. One solvent, perchlorethylene (perc) is mainly used for dry-cleaning. Whereas most dry cleaning systems in the 1970s were open-circuit, increasingly strict regulation has reversed this; nearly all machines nowadays reclaim and recycle their cleaning fluids internally. Specialized solvent recyclers accounted for around 15 percent of European supply in the mid 1990s. There is no reason, in principle, why this could not be increased to 50 percent or more within a decade.

Other intermediates are less easy to recover, of course. Fuels cannot be recycled at all. To reduce combustion emissions it will be necessary to replace fossil fuels by another energy carrier. The long term solution favored by many today is a mix of renewable energy sources (wind, biomass, photovoltaic cells) with hydrogen as the primary carrier. Nuclear power advocates favor a different mix, of course.

Value-added recovery: the 4R strategy

To summarize, the 4R strategy for conserving value-added (VA) by manufacturing consists of re-use, repair/renovation, remanufacturing and recycling, in that order of priority. The priority ordering reflects the potential for conserving VA. Re-use comes first because no investment is needed, in principle, although discovering new uses for old or obsolescent products may involve some effort. The re-use of glass bottles, steel drums and wooden pallets are familiar examples, already mentioned. Old clothes and books are often re-used. A good current example might be the use of older but still functional PCs in schools for education and training purposes. Note that, under current conditions, manufacturers of new PCs have relatively little incentive to promote this activity, since it may compete with sales of newer units.

Repair/renovation is next in priority. Re-refining of lubricants or redistillation of solvents or antifreeze are straightforward examples. However the major challenge is how to increase the frequency of repair/renovation for more complex products, such as appliances and motor vehicles. In the past, renovation and repair were the norm, not the exception. Nowadays, the reverse is true. Many small appliances and electronic products, as well as major components of larger appliances and systems are now designed to discourage repair. The usual advice is for users to send the faulty unit back to the factory, or simply discard it and buy another. This practice is generally defended on grounds of efficiency. Indeed, it is often true that, for mass-produced items, repair is not cost-effective compared to replacement.

However it is also true that most of these items are easily repairable, in principle, but repair/renovation is actively discouraged by design. Working parts are often hidden and inaccessible, or accessible only by means of specialized and costly tools. The days of replacing a burned out tube or fuse are long gone. Yet, it might very well be possible to facilitate certain categories of repairs and upgrades, given manufacturers motivation to do so. The problem, once again, is that original equipment manufacturers (OEMs) apparently have had too little incentive to innovate in the direction or increased repairability. Whether this is due to rational economic calculation, oligopolistic tendencies, or simple neglect of a possible competitive advantage is unclear. The answer certainly depends considerably on the complexity and life expectancy of the system in question. For example, commercial aircraft are subject to scheduled maintenance checks for safety reasons, and designed with this in mind. An elaborate maintenance infrastructure is thereby mandated by the regulatory authorities. One consequence is that some aircraft built as far back as the 1930s (DC 3s) are still in service, although virtually every moving part (and some non-moving parts) may have been replaced several times. On the other hand, cars and trucks, which are much less complex, are routinely junked after ten to fifteen years, and computers are discarded even sooner (four years, typically).

Remanufacturing is the third priority insofar as value recovery is concerned. Possibly this can be attributed to the fact that the repair/renovation option is less becoming feasible with the passage of time. At any rate, remanufacturing has great potential, insofar as it can be regarded as a variant on repair/renovation that is carried out on a production line in a factory making some use of specialized tools, and division of labor. Some standard products like truck or aircraft tires and diesel engines have been remanufactured routinely for many years. According to a recent survey in the US the two biggest areas for remanufacturing surrently are automotive components for the aftermarket (37.6 %) and electrical/electronic equipment (29.1 %) with toner cartridges in third place (13.6%).

More recently, the remanufacturing concept has been adopted -- and applied to very complex equipment -- by Rank-Xerox (Europe) -- which now offers to trade in or buy back all of its used copiers. The reason for this decision, made in 1987, was that local remanufacturers were not only competing with R-X but also harming the firm's quality image. The Rank-Xerox asset recovery operation is now very profitable. After eight years of operation (1996) it processed two thirds of the Xerox copiers retired in Europe, and demand for remanufactured machines exceeded supply by 50 percent. Components and subsystems that meet standard specification are sold to the parent company for use in `remanufactured' machines that are sold in the market with a 30 percent price discount but full warranty. Some substandard components are sold to others for re-use in less demanding applications. (For example, substandard bearings are sold to yacht manufacturers for uses where some play is actually desirable). Some materials, such as aluminum alloys of known composition, can go directly back to component manufacturers. Plastics are mostly recycled within the company. Only non-recyclable materials go to landfills, and the goal is to eliminate all such waste flows within a few years. While some sales of all-new machines were lost to the cheaper remanufactured units, some sales were also apparently recaptured from lower priced competitors of new copiers.

Repurchased R-X copiers are shipped back from local distributors to a specialized subsidiary adjacent to one of the firm's assembly plants at Venray in the Netherlands. There they are sorted, tested and classified into four quality categories. One category consists of nearly new machines -- mainly demonstrators -- that need a minimum of attention, mainly cleaning. The second category consists of machines that have been used for a short time under moderate load. These machines can be renovated by refinishing (in some cases) and replacement of a few critical parts. The third category consists of functioning or easily repairable older machines that have worked for up to two years at full load. They are disassembled to the subsystem level, each subsystem is then tested and either cleaned and repaired or replaced. Replaced subsystems are then sent back to original manufacturers for further reconditioning. The last category consists of obsolete machines that have operated for more than the equivalent of two years at full load. They are dissassembled for testing and recovery of long-lived components (such as motors) and materials recycling.

The fourth `R' is recycling of materials, either to recover the material itself, or some energy service. As an example of a new recycling technology, zinc from galvanized iron sheets can now be recovered economically and used again. Tin from tin plate can also be recovered in a similar way. For an example of the second kind, old tires that cannot be recapped can be used as fuel in cement plants. Coke oven gas was once wasted. It is no recovered for use as fuel, the tars are recovered separately, and the ammonia content is also captured and used for fertilizer. Blast furnace gas that was formerly released to the atmosphere is now blended with other fuels in power plants. In fact, incinerators burning waste are a component of many modern energy systems. Some organic materials can also be recycled in the form of compost, which is both a useful fertilizer and soil conditioner.

More imaginative uses of waste materials can be cited. For instance, waste organic materials from brewers can be used to feed cattle or grow mushrooms. Bones from meat processing plants are also converted to fertilizer (bone meal), while hooves, glands and other animal parts are also increasingly recovered for special purposes. Waste materials from flue gas desulfurization units on coal burning power plants can be converted (as a substitute for natural gypsum) into wallboard. Wastes from phosphate rock processing operations can be a source of fluorine chemicals.

What can be done

The main technical problems of the durables remanufacturing industry, at present, are evidently related to small scale and lack of vertical integration with OEMs. According to a recent survey shows that most remanufacturers cannot afford to utilize modern materials handling, cleaning and materials processing technologies. Yet the fact that there are so many successful and profitable firms engaged in remanufacturing[3], despite these drawbacks, suggests that the range of unexploited opportunities is very large indeed.

The opportunities for remanufacturing would be even greater with more direct feedback between remanufacturers and OEMs with regard to design problems and opportunities. While "design for environment" (DFE) has received considerable attention in academic engineering circles in recent years, it is rarely applied to remanufacturing except where OEMs (like Xerox) are involved.

Even without extensive direct experience in manufacturing it is possible to identify some general design principles that would facilitate remanufacturing. Some of these principles are applicable to both OEM and remanufacturing; others are not. The first of them -- applicable to both cases -- is to minimize part numbers and the number of different (and incompatible) alloys and plastics that are used. However this principle should not take precedence over the next two.

The second principle relates only to disassembly. Whereas the recent trend has been to reduce the use of metal nuts and bolts -- often replaced by rivets, adhesives or plastic clips -- to simplify the assembly process, this often makes dissassembly for repair or remanufacturing more difficult if not impossible. For instance, air-cooled engines (such as the old VW Beetle engine) are easier to serive and therefore to dissassemble than water-cooled engines. VW formerly remanufactured air-cooled engines in Brazil, but does not remanufacture water-cooled ones [Ferrer 1997]. Similarly, most shock-absorbers are designed with a welded top that prevents access to the interior components. However one Brazilian manufacturer of shock absorbers incorporates a bolted top to facilitate dismantling and remanufacturing . While nuts and bolts may not be the ideal solution, high value assemblies should be routinely designed for dissassembly and even for upgrading.

A third principle for facilitating remanufacturing would be to design complexity as much as possible into non-wearing parts and to make wearing surfaces as simple and replaceable as possible. Washers, gaskets, bearings, piston rings and protective sleeves for cylinder linings are all examples of wearing surfaces that should be made removable and replaceable with minimal difficulty. By contrast, crankshafts, camshafts and complex castings and forgings should be protected from direct wear and vibration as much as possible, to maximize potential useful life. Needless to say, this principle is also inconsistent with minimizing the number of parts.

There are delicate subassemblies, like hard drives, that should be remanufacturable by specialists without being easily accessible to amateurs. This suggests the possibility of designing specialized tools, such as those used by jewelers to service expensive watches.

The fourth "R" is recycling of materials that cannot profitably be remanufactured. While recycling is not practiced nearly as would be desirable, there is not much to add on the subject here. However it is worthwhile to make one point: The major barrier to more recycling is precisely the lack of remanufacturing. If remanufacturing were more prevalent, recycling would be also.

The reasons are obvious on reflection. In order to remanufacture a family of durable products, the obsolete or worn out items must be collected, shipped to a central point, sorted and tested. Then comes dissassembly, cleaning, and various kinds of treatment. Some parts may be collected and shipped on to subcontractors for further treatment, etc. But obviously some `leftover' components and materials, especially packaging and wearing parts, are suitable only for recycling as materials. But, having already been through a process of collection sorting and testing, these leftover materials are bound to be much more precisely characterized -- and hence of higher value -- than mixed scrap. It follows that there wil be less waste sent to landfills and more recycling (either via remanufacturing or as materials) than would otherwise be the case.

Indeed, high value metals such as stainless steel, copper, aluminum, and even chromium gold or platinum can be recovered from a sophisticated multi-stage recovery system. But such a system can rarely if ever be justified for purposes of materials recycling alone. It can only be justified if there is a potential for recovering much higher value subassemblies and components.

This brings me to the organizational side of the problem. No doubt there are a number of technical possibilities for recovery and re-use of wastes, *if* the produceers and users could be clustered together appropriately. Unfortunately, this is rarely possible. Firms are reluctant to use feedstocks -- raw or secondary -- that do not have guaranteed quality and long-term supply. But waste generators are rarely willing to guarantee the composition of their wastes, and even less willing to provide long term guarantees of quantities to be supplied in the future. One possible resolution of this problem is vertical integration, but vertical integration of firms in different lines of business is out of favor. Electric power companies produce a lot of FGD waste but they do not want to go into the wallboard business.

Local governments might accomplish some useful clustering through the creation of specialized industrial parks. But they seldom have enough power to enforce information exchange and cooperation on the needed scale. National governments have the power, perhaps, but nowadays they do not want to micro-manage industrial eco-systems-- and they do not do it well. It is unclear what the best solution to this problem might be or, indeed, if there is any satisfactory solution.

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1. This data comes from a recent article by Peter Huber and Mark Mills in *Forbes Magazine* May 31 1999.

2. In 1993 the remainder (5319 - 2624 = 2695 MMT) was mostly burned or leaked from motor vehicle or aircraft engines (896 MMT), burned by ships mixed with fuel oil (496 MMT). leaked from industrial equipment (462 MMT), lost in steel rolling and cutting operations (235 MMT) or consumed in unspecified industrial processes (606 MMT) .

3. The average profit margin for all parts remanufacturers surveyed is 20.13%.

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Zero Emissions Forum
Environment & Sustainable Development
53-70 Jinguame 5-chome
Shibuya-ku, Tokyo 150-8925
Japan

Tel.: +81-3-3499-2811
Fax: +81-3-3499-2828
Email: unu-zef@hq.unu.edu
http://www.unu.edu/zef

Zero Emissions Forum
Focal Point for Europe
c/o Rüdiger Kühr
Seehofstr.106,14167Berlin
Germany

Tel.: +49-30-42808559
Fax: +49-721-151234313
Email: mbox@zef-germany.de