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Recyclability, durability or remanufacture –

An unsolvable conflict?

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Introduction

Fig. 1 Tropical Deforestation, Southern America.

The dilemma is obvious: The greenhouse effect, dying forests and polluted oceans have become part of our daily lives. We have long recognised these problems and know they have been aggravated by our way of life. Everything we do, everything we create, messes up the world in some environmental way. Everything. Every house we inhabit, every journey we take, every process of design we have ever been able to invent, everything we hold in our hand or put in our mouths, takes some resource and inefficiently transfers it to waste. Yet we have become virtually dependent on the quality of life and great conveniences our modern world can offer, and can scarcely imagine an alternative. An unsolvable conflict?

There is certainly no simple solution to this dilemma. This enormously complex problem must be tackled from all sides: individuals, nations, producers, consumers, politicians, and industries. However, according to Victor Papanek, who some thirty years ago claimed that designers held the most powerful position in creating a world that was compatible with the environment:

> In this age of mass production when everything must be planned and designed, design has become the most powerful tool with which man shapes his environments (and by extension, society and himself). This demands high social and moral responsibility from the designer. (Papanek, 1970, p. ix).

The reason the designer holds so much responsibility is because many environmental problems are caused by the pollution which results from the production and use of products and services, particularly mass-produced products. Most products and services use up natural resources, many of which are irreplaceable. Many products have a significant effect on the environment when in use: cars, for example, or detergents. And finally the product has to be disposed of, causing another set of problems.

The designer, therefore, as the principal creator of the product itself, has a direct influence on the amount of damage which will occur at each stage in the process. What materials will be used, and from where will these be obtained? How will the product be manufactured? Will the design conserve energy? How will the product be used and disposed of? Can parts of it be re-used or recycled? Or will the design be created to last, both physically and aesthetically? Designers are in a position to determine many of these issues.

The main focus of this thesis, concerns three of the above issues, i.e. should the designer try to create products that are recyclable, durable or re-manufacturable? It questions which of these three systems offers the best environmental solution to the increasing volume of discarded consumer

durables. Chapter 1 takes a critical look at recycling and queries whether it is a viable solution or is it just diverting the attention away from a more radical response. Chapter 2 deals with durability and questions if this is the way to reduce the flow of energy and materials through the economy. Chapter 3 examines the re-manufacturing process and Chapter 4 involves a case study of an international electronics company, Siemens who spend over 14 million Irish punts a day on research and development, in more than 190 countries including Ireland.

Chapter 1: Recycling – making the most of what we have

For years, recycling has been generally taught to be beneficial for the environment. Most people automatically presume that recycling materials from products to prevent them ending up in a landfill site must be an environmentally sound practice. This concept is also supported and encouraged by manufacturers, politicians and local authorities.

Fig. 2. Landfill site

People believe that recycling is essentially 'green' because using raw materials over and over might indicate that no environmental damage need be

caused by the ever – increasing waste. Contrary to this opinion, the recycling process, like any other physical activity, undeniably affects the environment in numerous ways. Firstly, energy is consumed as the waste products are collected, sorted, cleaned and separated into their constituent materials. Pollution is also generated by the materials reclamation process and, indirectly, as a by-product of the energy waste. The succeeding manufacture and distribution of products made from recycled materials also has an impact on the environment.

For many years, recycling was only linked to packaging but recently a new recycling trend has emerged. This current craze has now been expanded mainly by manufacturers towards the promotion of products, such as cars (B.M.W. Smart car), washing machines and electronic goods, as recyclable. There is now a presumption that products such as these which malfunction will increasingly be recycled rather than repaired.

Design for Recyclability

In developed countries, recycling is only economically viable for large items such as cars and washing machines, because these items can be easily collected and the quantity of material involved is quite large. When designing products with recyclability in mind, ease of mechanical disassembly is very important. For many years now, products were usually constructed to facilitate their cheap and easy manufacture, but recently it has become common practice to apply equal importance to easy disassembly. It should now be just as easy to take them apart and separate the components according to their composition. A minimum combination of different materials requiring separation is therefore of paramount importance.

> Some companies, in particular car manufacturers such as BMW and computer manufacturers, are experimenting with production in reverse along what might be called the disassembly line, something Henry Ford, the inventor of mass production could never have envisaged (Arango, 1996, p.17).

Fig. 3 Zanussi washing machine.

"Zanussi's Nexus also have a range of washing machines and dishwashers which have a structure based on five modular sub – assemblies. A high proportion of the structure is moulded out of carboran, a recyclable advanced polymer which is also used to construct many of the functional components. The machines consist of fewer individual parts

than usual and snap - on fixtures make it easy to dismantle for repair or recycling" (Mackenzie, 1997, p.72).

The reduction in the number of different materials used in products helps prevent the problem of material contamination. Recycled materials which are made from a mixture of different elements, especially mixtures of different polymers, have unpredictable behavioural characteristics and can therefore be used only in limited applications. For example,

> copper is extremely difficult to remove in the steel recycling process and a mere 0.2 per cent of copper can cause severe cracking in the finished steel. So, while scrap steel is worth around £100 a tonne and copper about £1,000 a tonne when separate, the two together are worth only about 350 a tonne (Burrall, 1991, p.57).

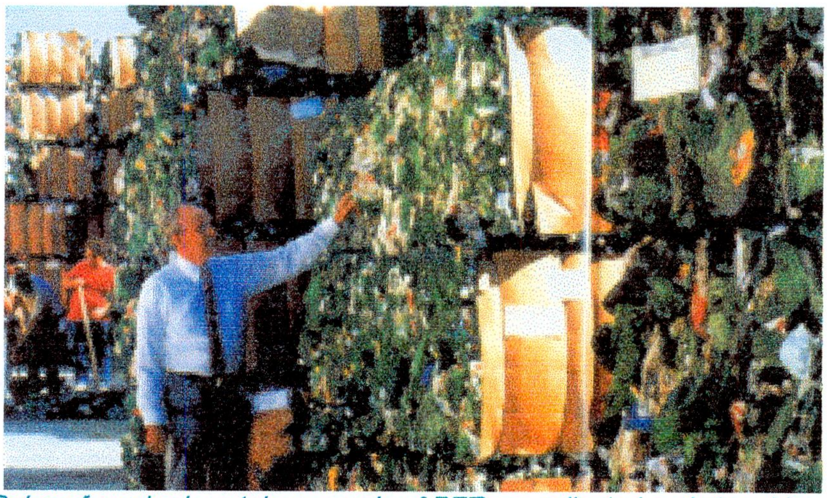

Fig. 4 Bales of crushed containers made of PET are collected and stored for recycling.

PET (Polyester) is another excellent recycling material, but certain contaminants can destroy any scrap value it holds. The main problem is other types of plastic, which tend to have the same density as PET, are difficult to divide. Some PET bottles have a tiny non-PET plastic sealing ring beneath

the cap, to make the bottle airtight. This causes a similar problem for the recycler as copper in steel scrap. The advantages of composites, such as strength and resistance to wear, should therefore outweigh the disadvantage of difficult recyclability, before deciding to apply them to a product. Recycling machines, which can identify different chemical tracers in plastics are gradually being developed, which may mean that guidelines for recyclability can be less restrictive.

One of the first guides for the designer should therefore be to reduce and account for the choice of materials. In many cases, the use of alternative materials can assist the recycling process. For example, aluminium is readily removed from steel scrap in the re-melting process and can sometimes therefore provide an alternative to copper. Another approach is to design the product, so that the ill–assorted materials can be easily separated at the recycling stage. This problem could be overcome if, for example, a designer was designing a product, which contained copper. He/she could aim to group all the copper–containing components together and attach them to a valuable component, which is usually removed for its material content. This method would also facilitate the recovering of materials that may be small in quantity but are either rare (and therefore valuable), or potentially hazardous.

Ideally, toxic or hazardous substances such as arsenic, chromium, lead, mercury, silver or sodium azide should be replaced with non–hazardous alternatives. Adversely, however, it is usual that hazardous wastes are only

treated after the applied substances have been seen to be a hazard. Although this procedure is a necessary response, it is only a short-term solution and an extremely expensive one. Principally, the solution would be to focus on the question of the continued use of such hazardous materials in the first place.

> The potential dangers of introducing these elements to products are such that none of them should henceforth be used in any application whatsoever without first considering
> (a) hazards of its use in service
> (b) problems in recovering the hazardous materials at the end of the useful life of the product
> (c) potential for hazardous residue generation (Henstock, 1988, p105).

If it is not possible to eliminate toxic materials, products should be designed for easy identification and removal of the elements, before the rest of the product is recycled. Batteries containing mercury or cadmium, for example, must be clearly identified so that they can be removed from the product and safely disposed of before the recycling process begins.

The Benefits of Recycling

Fig. 5 Siemens salvage tonnes of copper each year.

There are many profitable results of recycling when compared with the disposal of products in landfill sites. For the past decade, companies have experienced the benefits of reducing production waste by collecting surplus materials at the end of the line, shredding and melting them and using them all over again. For example, Siemens, the German Electronic Company. Siemens recycles salts, cleaning agents, metals and other reusable substances in production and salvages tonnes of copper from used components each year.

The same idea holds true on a broader scale. If products are recycled when their service life comes to an end, retrieving the materials they consist of must be a more productive means of manufacturing than just throwing them in the garbage, thereby destroying all added value. Recycling is inevitably a way to make money. This holds true for both developing and developed countries. For instance, in the West there are growing numbers of recycling companies while in Third World countries, recycling is also a way of making a modest income by collecting used plastic bags, or other objects that Westerners would consider trash, and selling them.

Emptying landfills and saving junk from an incinerator also appears to help generate ideas for new materials and technologies. It also seems to act as an inspiration for craftspeople and is a particularly relevant material for the 1990's. "Scientists are also exploring ways of breaking down waste material in order to reassemble them again into pure materials. On the design front, attempts are being made to combine waste particles and fragments into new materials. In these cases, the rationale behind recycling consists not just of sparing the environment, but also of discovering new aesthetic properties and new ways to add value, thus contributing to the quality of our surroundings" (Arango, 1996, p.18). For example, in figure 6 the electric guitar body is made from laminated layers of confetti and compression-moulded recycled plastic from detergent bottles.

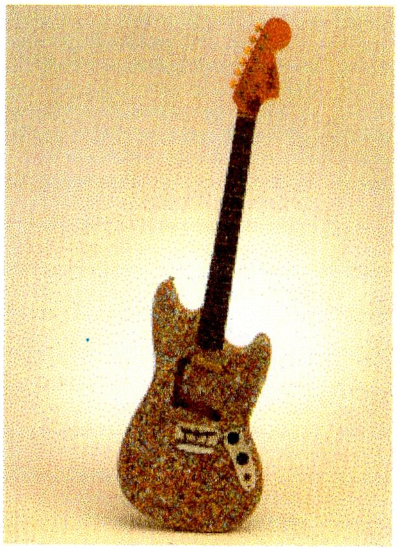

Fig. 6 Electric guitar made from recycled plastic and confetti.

The limits to Recycling

There are many benefits to recycling, as mentioned above, compared with disposal of products in landfill sites. However, worries relating to the impact of recycling on the environment, its commercial obstacles and technical limits have to be discussed to assess the future of recycling.

Environmental Impact

> Steve Ogilvie's appraisal of the environmental effects of recycling for the Warren Spring Laboratory, though in general sympathetic towards recycling, concluded that it is quite possible that the burdens created as a result of the collection of materials for recycling could outweigh any environmental benefits accruing from the recycling process itself (Cooper, 1994,p.8).

The principal concern is that the break–up of products into their constituent materials, which is the basic process involved in recycling, means that hazardous materials are no longer 'locked–up'. Other forms of pollution are also likely during recycling. For example, the dust and noise from shredders and emissions from processes used in recovering metals causes a toxic residue. For instance,

> old appliances may still have capacitors and transformers with toxic PCBs and may contain heavy metals such as cadmium, which is used as a colouring medium and as a stabiliser in plastics. One of Ogilvie's main concerns is related to the use of salt fluxes in aluminium recycling to prevent oxidation as some 450 – 600kg of slag is produced for every 100kg of aluminium and its disposal is becoming unacceptable as landfill due to high levels of soluble fluoride (Cooper, 1994, p.8).

Above all, however, it is the consumption of energy in recycling which raises most concern regarding its overall environmental impact. At each stage in the recycling process, processing scrap materials, manufacturing, transporting discarded products, secondary materials and replacement products – energy is used. Consequently, this results in pollution and waste. In other words, recycling waste reduces one environmental problem only at the cost of increasing others. In addition, if the amount of recycling is increasing, the energy required will rise as more dispersed and unworkable wastes are handled.

Commercial Obstacles

It is important to examine the economic implications of recycling products due to the fact that many consumers and taxpayers will increasingly be required to pay for recycling. This price may well be at the expense of other more radical environmental actions.

As mentioned previously, large items such as vehicles, washing machines and cookers can be recycled, so proving that recycling can offer a commercial return. The repossession of most smaller discarded products is evidently uneconomic, however, and manufacturers have been charging a levy.

> In Germany for instance, where manufacturers are preparing for 'take back' legislation, Grundig have charged DM 37 (£ 15) to dispose of a television and £6 for a video (Cooper, 1994, p.9).

The primary influences on the profitability of recycling are the volume and quality of recyclable materials, the extent to which discarded products are geographically dispersed, and the available market for recyclate (i.e. secondary material recovered from scrap). The cost of producing this recyclate is, in turn, determined by factors such as disassembly times and the degree of contamination.

Cars, for instance, that contain a high proportion of recyclable scrap metal, are worth recycling because there is usually a ready market. Scrap steel from derelict buildings or warehouses is even more profitable than that from cars and large appliances because it contains a large volume of similar materials. Plastic housewares denote the other side of the coin. Such items are widely dispersed, each contains little material and the market for polymer material is virtually non–existent. Given the absence of a healthy market for polymer recyclate, this is a major obstacle to sustaining, let alone increasing, present levels of recycling. For example,

> even recycling telephones of which over 2.5 million are recovered annually, is not apparently cost effective. And at present less than 1% of post - consumer plastic waste is recycled (Cooper, 1994, p.9).

A key problem is that secondary material generally costs more than virgin material of the same quality.

Although products are increasingly being designed to assist the recycling process by, for example, making disassembly easier, other inclinations in

design are not so positive. These trends are apparent in the miniaturisation of electronic products (the primary objective of the past fifty years of technological research), where tiny quanties of valuable materials are incorporated within a case composed of several different, low–value materials. Miniaturisation has the advantage of reducing the quantities of materials needed in the first place, but it can make recycling impossible. Material substitution is another factor, which makes recycling less desirable.

> The replacement of gold in electronic equipment with nickel–on–silver reduces the value of discarded products, from washing machines to personal stereos. For example, vacuum cleaners were once mostly metal, but are now typically over 70% plastic (Cooper, 1994, p.9).

Technical Limits

The possibility that there might be absolute technical limits to recycling is a very real concern. The main concern would be the contamination of materials due to the general lack of knowledge regarding the gradual and constant increase in impurity levels in some material scrap. In his book, Design for Recyclability', Michael Henstock has at least addressed the threat:

> Scrap is a recirculating load: each time that it is recycled it can introduce fresh contamination culmulatively raising the impurity level of the basic steel scrap. Such stock, when eventually it forms scrap, is of ever diminishing acceptability (Henstock, 1988, p.27).

He points out that the purity of steel fell after the First World War because of copper and tin impurities, resulting from recycling scrap during the war, and he notes that it has never returned to pre–war levels.

With regard to recycling plastics, there also remains limits to the number of times plastic caps can be recycled because its properties degrade after a few cycles. Fillers and additives, which are used to colour plastic or make it electrically conductive, may also inhibit recycling.

More generally, the current state of technology is such that a considerable number of materials cannot be recycled, including thermosetting plastics (polyesters used in furniture or toasters), ceramics, composites and coated materials. Most non–electrical products such as sofas and carpets and many other products made predominantly of plastics, wood or natural fibres, are unlikely to be commercially recyclable in the near future. The ultimate fate of a discarded carpet, for example, will probably still be use in cellars, garages or keeping rain off compost heaps.

It is probable, therefore, that large consumer durables manufactured primarily of metal will remain recyclable, but it is unlikely that recycling will be profitable for many small electrical or electronic pieces of equipment without a significant change in raw material market prices.

Chapter 2 – Durability – The longer life option

As discussed in the previous chapter, recycling does not represent the 'ultimate green' solution to the present throwaway culture. An important distinction also realised is that recycling reduces waste, but does not minimise it. It is essentially an 'end–of–pipe' solution. By contrast, increasing durability represents a 'front–end' solution because it requires a more radical change at the point of development and production.

Influences on the discarding of products.

There are three main reasons why consumers discard products: these can be summarised as a loss of fitness, function and fashion.

The failure of a product to work effectively, i.e. a loss of fitness, is the most common explanation for the discarding of products. Whereas a century ago products were manufactured to last a lifetime, most now have a pre-planned 'design life'. A product's life span is also affected by the increasing complexity of products which makes them difficult to repair. The quality of care given to the product by its owner is also a decisive factor in determining the life span of a product.

Another important influence is technological change, which leads people to replace ageing products with new models. These new models usually appear to sustain a higher quality or offer more functions than older models. For example, washing machines now have faster spins, telephones contain new features such as last number redial etc.etc., televisions have remote control and stereo sound and computers have become more powerful with each generation of microprocessor.

> Some products are up-gradable and consequently there is less pressure to replace them. Personal computers can be upgraded with faster microprocessors. For example, in Germany well over a million cars have been retrofitted with catalytic converters. Currently, however, few consumer products are designed to be readily upgraded (Cooper, 1994, p11).

Thirdly, replacement sales are stimulated through the influence of fashion. Changes are made to the external appearance of most goods to render older models unfashionable and encourage people to replace them even if they still function effectively. Fashion has always been a means by which many people can display wealth and therefore, possession of the 'latest' model would be an important influence on the purchasing behaviour. Adrian Forty who has written extensively on consumer patterns of behavioural claims that

> consumer oriented design is highly selective in what it chooses to express of consumers ideas and beliefs, with a strong tendency to relate only to those problems of consumers lives that the product concerned stood a good chance of being able to banish. Naturally, it was very much easier to banish false or mythical problems rather than real ones (Forty, 1992, p.221).

The overall impact of these influences upon consumer purchasing has led to an economy in which many products have a shorter life span that was intended. The following section will review the advantages that are offered by seeking to change this.

Environmental Implications

A general increase in the life span of consumer durables would reduce the throughput of energy and materials, resulting in less use of finite resources, lower emissions of pollutants and a smaller amount of residual waste to dispose of as landfill.

According to Tim Cooper, a Researcher for the New Economics Foundation in London,

> Comprehensive data is not available, but a rough, common sense estimate would suggest that doubling the life span of products should halve their net environmental impact. In the late 1970's the study by Porsche of long–life cars concluded that if cars were built to last for 18 – 25 years there would be a 55% saving in materials (Cooper, 1994, p.13).

When compared to recycling, increasing the life span of products by improved design would have greater environmental gains because most of the components remain physically intact. In addition, the methods of extending the life of products are usually done within the surrounds of the manufacturer's building, whereas the process involved in recycling involves considerably more transportation.

The main concern about increasing a product's durability is the possibility of increased consumption of materials for thicker surfaces or add-on parts and the use of non-recyclable materials, coatings and fillers. However a more valid

requirement for increased durability is better quality materials, fixtures and fittings, which would not necessarily have a greater environmental impact.

Another argument against product life concerns the possible sacrifice of improved energy efficiency in new electrical products, such as washing machines and PCs. It should be noted that the environmental improvements in these new products are sometimes offset by other innovations. For instance, a car with new extra features such as electric motors for windows and sunroofs is actually cancelling out any basic fuel efficiency gains that the car might have. Frost–free refrigerators also have higher energy consumption than conventional models and the average contemporary vacuum cleaner uses more energy than older models. In any case, most new ranges of domestic products are not designed specifically to reduce environmental impact anyway.

In summary, therefore, the effects on the environment of longer lasting products will almost always be positive.

Consumer Benefits

An understandable concern for consumers is that longer lasting products might be too costly. For many durable products, this is true, but any increase in price may well be offset by the longer service life offered. For example, a kettle costing £25 which lasts for six years obviously provides better value than one costing £15 which only lasts for three. The main difficulty consumers have, however, is identifying which models are likely to be the most durable and whether a high price represents good value. Information should accompany any expensive product, in order to reassure customers.

In the immediate post-war years, the British imposed a Utility Scheme for a wide range of goods produced to particular design specifications. This was felt to guarantee certain standards of quality, durability, and value-for-money. However, in reality this was increasingly open to question since manufacturers were given more flexibility through a gradual relaxation of Utility manufacturing requirements. As a result, they often exploited the superior tax treatment granted to Utility goods by keeping within the determined price range at the expense of quality materials and fabrication. The Government appointed the Douglas Committee to examine the implications of such practices. In its report of 1952 it concluded that consumers had a real need for advice that would assist them in distinguishing between genuine value-for-money and cheapness which simply represented false economy.The British Standard Institute of 1950 argued for the taking on

of a product certification scheme, which would protect consumers from substandard goods. Similar developments were taking place elsewhere. In Sweden, the D-Mark was established in 1951, which was essentially a labelling scheme which gave consumers a much fuller and more intelligible insight into product characteristics, with information on function, materials and durability. However it was not until the 1960's that significant shifts in consumer legislation began to acknowledge more fully the importance of individual consumer rights and of clarification of the responsibilities of the large-scale producers.

Tim Cooper believes that

> over the last fifty years people's expectations of durability have, for many products, fallen. However, just as they now expect products to be safe, there is no reason why they should not expect them to be durable. Product liability legislation was developed to protect consumers as individuals against unsafe products. The risks from a lack of durability are more diffuse, affecting the collective wellbeing of people on the planet but this is no excuse for ignoring them (Cooper, 1994, p.14).

Opportunities for Industry

The potential advantages of durable items to consumers and to the environment are reasonably self-evident. Manufacturers, on the other hand, may be concerned that their profits would suffer from reduced sales. These worries would be concerned with the high price of longer lasting products, which would reduce consumer demands. Manufacturers and retailers are also very much dependent on replacement sales, and fear that longer lasting products would reduce their future income. Another concern is that high – volume manufacturers, whose market is sensitive to changes in price, would be taking a risk if they suddenly increased their product's durability and therefore its price.

All these apprehensions are quite understandable. However, if we take a practical example of the success that can be achieved by developing longer lasting products, its easy to see that it can be a worthwhile investment. Volvo and Saab, the Swedish car manufacturing companies who enjoy strong reputations for the durability of their vehicles (average life expectancy is over 17 years), have nearly 40% of the domestic market. These companies have survived quite well despite a period of rapid growth in the

Fig.7 Saab Car (1992)

average life span of cars from 9 years to 16 years between 1965 and 1982 (Nieuwenhuis and Wells, 1994, p.64). It is likely that companies who increase the design life of their products, and offer inclusive after sales services such as repairs and upgrading, will benefit also from an increased customer loyalty.

> The planning involved in a strategy to increase product life spans could lead business to extend their 'environmental foresight', preparing them for future trends, legislation and breakthroughs in environment – friendly technologies. One trend already underway is towards a 'product stewardship' business culture, in which manufacturers accept responsibility for products throughout their complete life cycle, including the point at which they are discarded: the principle of 'extended producer responsibility'. The initial response of many manufacturers to this trend, reinforced by the threat of 'take back' regulations, has been to investigate the recycling potential of their products. It might be more advantageous to increase their life spans, thereby reducing the return flow of discarded products (Cooper, 1994, p.15).

One of the greatest irritations for the 'green' industrial designer is the extent to which recyclability and durability are interrelated. In many respects, recyclability and durability might involve similar requirements. For example, ease of disassembly makes separating materials easier. It also makes repair and upgrading work more practical and cheaper. In addition, the use of high quality materials can make a product both more recyclable (as its scrap value will be greater) and more durable (more hard wearing). The problem begins, however, when the type of material or method of construction used to improve durability may inhibit recycling. Ceramics, composites and plastics may be more durable than the materials with which they replace but, as noted earlier, they tend not to be recyclable. For example, the use of galvanised steel

prevents rust in cars, therefore lengthening the life span, but the zinc makes recycling virtually impossible. When screws are used in plastic casings to make access for repair work easy, this facilitates a longer service life, but screws hinder recycling if a piece is not disassembled manually but put through a shredder, because the output will be a mix of plastic and metal. However, if plastic snap lock fittings were used to rectify this problem, they usually have a tendency to break, thus shortening the product's life span.

Thus, there may be occasions when industrial designers may have to make decisions. According to Paul Burall, author of 'Green Design',

> If conflict does arise durability should normal take priority. Although incentives for recycling and against dumping are likely to increase significantly during the 1990's, it is wrong to see recycling or easy disposal as the only, or even the most important, concerns for the green designer. The first consideration should be the life of the product itself (Burall, 1991, p.53).

In theory, it is the marketing department of companies rather than the design team which decides these key issues. If the marketing team want to generate a 'green image' for the company, they almost always promote recycled or recyclable products. On the other hand, durability could possibly be easier to market, as it is undeniably in the consumer's own personal interest, whereas recycling depends to a large degree on environmental trends.

An important influence on the life span of a product is technological change. Industry could prepare for this by designing products to be upgradable. Such

products could be designed with distinct functional parts, standard interfacing and little interdependence of components. Manufacturers are often aware of potential future improvements, such as increased energy efficiency, through advanced research or by surveying higher quality products not yet widely available in the domestic market:

> A Government commissioned report, 'Energy Efficiency in domestic Electric Appliances', for example, has described likely improvements in the energy efficiency of refrigerators, freezers and televisions, while suggesting that little technological improvements can be expected in the washing machines, cookers, dishwashers, kettles and irons (March Consulting Group, 1990).

Companies who manufacture products intended for above average life spans have invariably tended to be at the expensive end of the market. For example, the cars of the top range manufacturers, such as Rolls Royce, Mercedes-Benz and Porsche have always had to be durable because of their market position, as have Land Rover which last, on average, for 30 years.

Significantly though, volume manufacturers such as Philips, Braun and Miele have stated publicly, in recent years that

> they intend increasing their product's life spans. They have evidently concluded that there will be net benefits from such a strategy, and that gaining a competitive advantage through increasing quality will outweigh any loss of replacement sales (Philips, 1998, p.2).

Even so, if there is to be a widespread move towards increased durable products much will depend on the extent to which the government changes the commercial trend in order to encourage environmentally sound practices.

Although longer life is a more desirable option than recycling, it does not offer a definite solution. There is another alternative that could be chosen which will be examined in the next chapter.

Chapter 3 - Design for Remanufacture

As previously discussed, when the so-called durable product such as a vehicle or an appliance reaches the end of its serviceable life, it is usually disposed of in landfill or is reclaimed for the sake of its raw materials. With either direction, the costs associated with collection and operation of the landfill or the costs of shredding, sorting and melting recoverable materials may exceed the direct financial benefits of these procedures. Nevertheless, these operations may not be executed and the durable product may simply be discarded in any case. Frequently, there are still–serviceable spare parts in any single product which can be removed and re-used. This action italicizes the process of remanufacturing. This may be defined as

> the restoration of used products to a condition which if not precisely as new, has performance characteristics which approximate to new (Button, 1988, p.389).

Remanufacturing employs a series of industrial processes to worn out or discarded products. The processes usually involve disassembly, cleaning, refurbishment of usable components, providing new parts where necessary, re-assembly and testing.

> "For many years, such rebuilding of unserviceable automative electrical equipment has provided the consumer with a practical and economical alternative to the purchase of items manufactured from new components. Typically, a factory rebuilt starter motor for a popular type of family saloon might offer the purchaser a saving of 30% on the price of a brand–new unit. A study on the remanufacture of chainsaws in the U.S.A. concluded that the operation could be profitable if the volume could reach 2000 – 5000 unit per year. A volume of 25,000 per year would be highly

profitable: such a volume would still be less than 2% of the average annual sales of chainsaws in the U.S.A." (Henstock, 1988, p.29).

In general, the service life of most products can, in theory, be prolonged indefinitely. For example, most of the electrical units used in vehicles may be replaced when worn out or out of order. In some cases, the restoration of such units to extend the product life may be necessary because the equipment is no longer in production or because currency restrictions prevent the import of replacement units or spare parts. In the majority of cases, however, the incentive for rebuilding is the immediate saving in cost. The practicality of this exercise depends on the relative costs of new components and of the total labour involved to rebuild a product. Conventionally though, labour costs have been kept relatively low through the use of power tools in disassembly. Since 1973, however, differences in the costs of energy have caused an energy audit of the rebuilding process, to establish whether the remanufacture of units is energy efficient as well as cost effective.

The restoration of used items in Third World countries is standard practice due to the shortage of suitable manufacturing facilities and the relatively low labour costs when set against the cost of the materials involved. Products designed in the first place for eventual disassembly and remanufacture need not involve high labour costs nevertheless, although frequent design changes may inhibit re-manufacturing due to the difficulty associated with non–interchangeable parts.

Eligibility of Products for Remanufacture

A wide range of products are re-manufactured including

(a) Vehicles – This sector contains the largest number of re-manufacturers. The parts vary in scope and complexity, from a simple starter solenoid to complete engines.
(b) Industrial equipment – This category includes valves and other hydraulic equipment, metal-working machinery, industrial electromagnets and motors and a wide variety of others. Since many of the products were initially custom – built they tend to be remanufactured individually.
(c) Commercial products include office machinery, vending machines and communications equipment, also remanufactured individually.
(d) Domestic Sector: Re-manufacturing in this sector tends to be concentrated in the area of power tools, garden and leisure equipment and small appliances. (Henstock, 1988, p.133)

Certain common characteristics such as product value, market stability and product design are very important factors influencing the eligibility of product remanufacture.

Product Value

To justify remanufacture, the potential worth of the product must exceed its market value as scrap. That potential worth exceeds its market value as scrap. That potential worth is determined by the cost of refurbishing and by the final price that it could, after remanufacture, command in the market place. Another factor, of course, includes the cost of disposal. An unserviceable product that gains high disposal costs obviously has a negative market value, which helps to justify the re-manufacturing argument.

Market Stability

It is essential of course that a market should exist for the remanufactured product at an appropriate price level. The fact that a remanufactured product might be more than ten years old, and the styling therefore dated, might possibly deter anyone other than those in the lowest socio-economic levels of society in developing countries. The question of the exterior appearance is, however, sometimes a secondary issue when compared to technological change.

Re-manufacturing in the domestic sector tends to be centred in the area of power tools, garden and leisure equipment and small appliances. Usually, in these products, the effects of styling are likely to be minimal. Loudspeaker drive units are examples of products which are not seen, so their appearance is irrelevant. Their performance, however, may be improved significantly and inexpensively by change of materials.

> The largest re-manufacturer in the U.S.A. is evidently the Department of Defence, which has a continuous programme of re-manufacturing, designed to maintain items ranging from small arms to battleships – several examples of the latter, dating from World War II, have so far been recommissoned with modern weapons systems – with a view to incorporating technological advances at much lower cost than building from new (Henstock, 1988, p.113).

Designing For Remanufacturing

The actual design of the product plays a key part in the criteria for selection of products as suitable for remanufacture. Today, in some industries especially car manufacturing, it is likely that designers will have to take into account the demands of the re-manufacturers from the onset of creating a new product.

Typically, re-manufacturers avoid products whose design is undergoing rapid change in either design or materials. Therefore, the products favoured for remanufacture are those with a slow rate of design change from year to year. As in most manufacturing processes, a constant supply of raw materials of dependable quality is preferable. Consequently, there must be a high ratio of technological life to product life to ensure that the product does not become obsolete before it wears out.

The ability to identify the faulty part could save the re-manufacturer time and money and should therefore be considered at the design stage. The product should also be standardised and made with interchangeable parts, which have been factory assembled, to aid the disassembly procedure. Certain construction methods are detrimental, not just to those wishing to repair products but to the re-manufacturers also. In metal components, welded or soldered joints are very difficult to take apart. Plastic bodies joined by rivets are also a pet hate of re-manufacturers and recyclers, while the bundling of a component that may need replacing with others that have little likelihood of

failure, is also a serious obstruction. The component parts must be easily repaired, refurbished and be capable of economic replacement. Above all, however, the final product must be efficient enough to reproduce its original performance level.

Process Stages

Re-manufacturers may be divided into 3 types

(a) The Original Equipment Manufacturer (OEM). The OEM often makes and sells both new and remanufactured versions of its products.
(b) The Independent Re-manufacturer : This type purchases unserviceable products and re-manufactures them for sale.
(c) The Contract Re-manufacturer : This type refurbishes products under contract to a customer who retains ownership of the products (Henstock, 1988, p.111).

Re-manufacturing begins when a user, through abandonment, sale or trade – in, hands over a product to a collection system which forwards them to a re-manufacturer. This stockpile is then subjected to disassembly, cleaning, refurbishing of component parts (welding, straightening of shaft, surfaces reground and scraped etc.), re-assembly and then testing. The intention is to restore a part to its original condition by rebuilding the failure in the product so as to eliminate any weakness. Therefore it is even conceivable that the re-manufactured product may be more efficient or more durable than the original.

Measurement, testing and quality control methods used in remanufacture are similar to those used in original manufacture but with one important exception. All parts must be presumed faulty until proved to be otherwise.

Barriers to Re-manufacturing

The main obstacle with regard to a re-manufactured product is customer prejudice towards it. The purchaser is often discouraged from buying such an object because of lack of knowledge about it or, where market attitudes influence the customer, that newness is more important than utility. However, this type of obstacle is yet again less concerned with re-manufacturing than it is with marketing.

Frequent design changes in manufactured products may also inhibit any interest into re-manufacturing them. A major difficulty associated with such changes is that parts for newer models tend to be incompatible with older units.

Overall however, the process of re-manufacture is seen by many people as a most desirable alternative to recycling or even durable products. Re-manufacturing should be widely encouraged where the worn-out product will, after restoration, still deliver an acceptable standard of safety.

Chapter 4 – Case Study: Siemens

> A survey on ' European Mangement Attitudes to Environmental Issues' carried out in 1990 by the management consultants Touche Ross revealed that German and Dutch companies placed an increasing premium on the management of environmental concerns, with a significant percentage of companies committed to the alteration of product ranges in response to environmental considerations (Woodham, 1997, p.237).

German design has always placed an increased emphasis on a more systematic and scientific analysis of design problems. This scientific, rational and efficient outlook associated with German design is typified in the simple aesthetic of Siemens products.

Siemens is at present one of the leading companies in the world. More specifically, it is the sixth largest in the growth sector of electrical engineering and electronics. Siemens has a market presence in 190 countries, sales in excess of DM 100 billion more than 100 production facilities in Germany, almost 400 international ones and daily spending of DM 35 million (14 million Irish punts) on research and development.

Siemens – Initiatives for the Environment

Reuse before Recycle

Recycle before Disposal (Siemens,1998, p.14).

Siemens are an example of high volume manufacturers who are determined to follow the above hierarchy. They have adopted an all-encompassing approach to the environment problem, which includes the stocking and processing of raw materials, the production process, use of the finished product and of course regeneration at the end of its life cycle.

Siemens recognised their ecological responsibilities in 1971 when they set up a Corporate Office for Environmental Protection in Germany. Several other corporate offices were set up in the 1980's and mandatory environmental protection principles were issued in 1990. In this year also all professional environmental protection principles were updated in line with current standards and regulations. They also made environmental protection a theme at the Hanover Trade Fair in 1995, with the main Siemens press conference being devoted entirely to this issue.

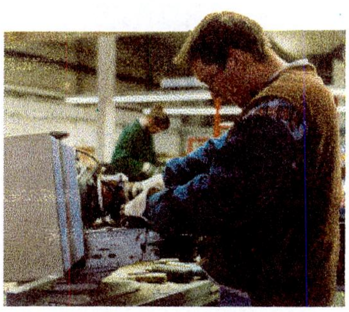
Fig.8. Sorting and dismantling

For Siemens, recycling is not prioritised through legislation. Their policy is to reuse before recycling and recycle before disposal. For example, retrieved worn out devices are reworked and valuable

components are sold in second hand shops. This is a considerably lucrative business for Siemens, as their second hand shop makes ca. DM 20 million annually in sales. When repairs or reworking are not possible they check whether certain groups of components can be reused. They then dismantle parts into 60 different material fractions. It is possible for Siemens to directly reuse 10% and recycle 76% out of 5,000 tons of computer scrap. By the year 2,000 they hope to reduce the sole 14% which goes to the landfill down to 10%. All metal materials are also recovered during scrapping of used-up resin transformer. Siemen's newest telephones (Fig.9) are constructed in such a way that they are more than 95% recyclable.

Fig. 9 Siemens Euroset phone is almost 100% recyclable.

Siemens have also introduced 'return recovery' systems for different products segments and set up collection sites throughout Germany. Siemens customers can have their electronics scrap recycled cost-free, according to government regulations. Examples include: household devices, telephones, industrial fuses and personal computers.

The first decisive step

Siemens strategy of intergrated environmental protection begins with product development. To guide their planners and designers, they have formulated their own environmental standards, which apply to the design, production and

use of their products, as well as to their ultimate recycling. Siemens was the first major European company to elevate the design of environmentally compatible products to an obligatory corporate standard. Their approach of reducing the quantities of material used, extending the longevity of product components and planning their reuse and recycling is their way of tackling the problem of waste at the very out-set in product development. Their designers try to keep the number of components to a minimum, label the material contents of individual parts and provide instructions for disassembling products to optimise the recycling process. They also apply the same principle to their packaging, by reducing it to a functional minimum, and using environmentally compatible materials. In designing their electrical and electronic products, the designers try to reduce product consumption to a minimum. They also avoid using materials that release toxic substances in the event of a fire. Energy–saving lamps, halogen-free plastics for printed circuit boards, PCs, telephones, and refrigerators are all typical examples of Siemens environmentally compatible product designs.

PC and the Environment

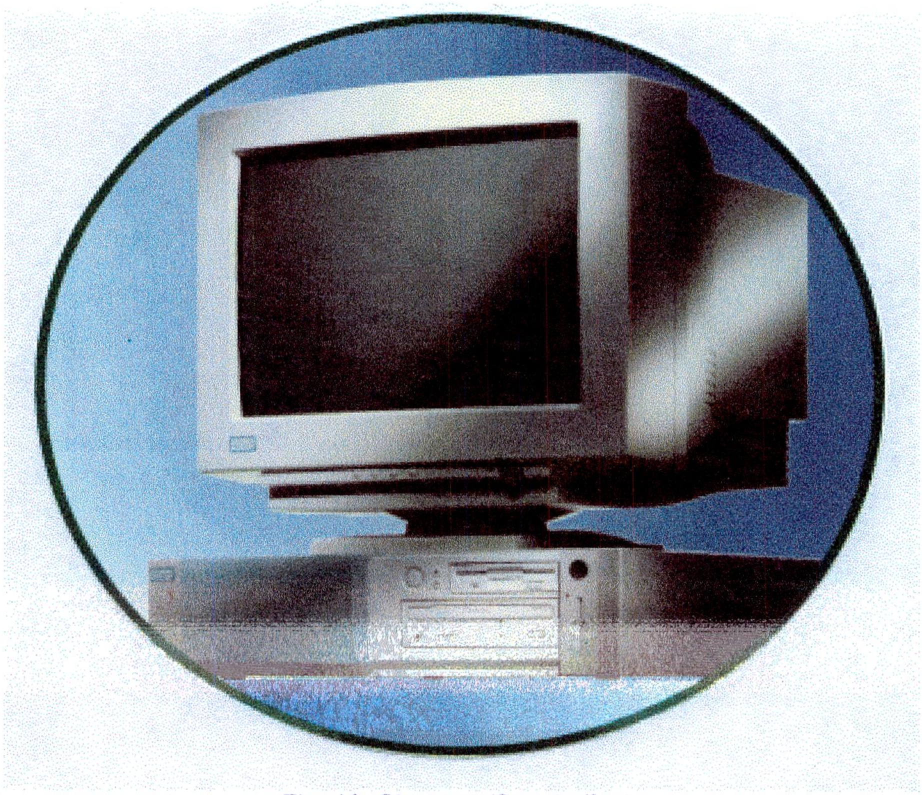

Fig. 10 Siemens 'Scenic Pro'

The 'Scenic Pro' from Siemens Nixdorf is 10kg lighter than early models, which means enormous savings in raw materials. If other PC manufacturers followed this lead, annual raw material consumption for PC manufacture world-wide would drop by 500,000 tonnes. Early models also contained several different types of plastic, which complicated recycling, so Siemens reduced the types used from seven to three. Altogether they've cut the number of different materials from 40 to 23, resulting in a 90% recyclable PC. They also identify the plastics used in their PCs with the mandatory code, manufacturer's categorisation, the tradename, the production date and the company name, plus the manufacturer's ID and parts list number. This makes

for optimised sorting and efficient recycling. As already established in Chapter 1, fast, simple disassembly is an important factor in successful recycling. Normally, a PC has over a hundred different components which means a hundred bits and pieces to sort when the PC is recycled. Siemens have achieved reductions in this area by a high degree of parts integration. For example, the new 'SCENIC Pro' has only 11 components, and most of the screws have been replaced with clips. The PC is also claimed to have a long service life because it can be upgraded within generous limits for years to come. The PC is designed to take faster processors, more memory, plug-in boards and additional drives.

The 'Scenic Pro' does not contain any hazardous substances, so it therefore does not create any problems with hazardous waste. The plastic housing of the PC does not contain any flame retardant which could form dioxins or furcans and none of the internal components contain PCB orasbestos.

Building recycling loops into their production has made the most of resources such as raw materials, energy and water. Take for example, the production of printed circuit boards where, by distilling the water used to wash soldering masks and printing screens, this means they can utilise it again and again. They distil and reuse over 99% of the water used to wash soldering masks and printing screens. So, instead of 100% waste water, they have only 1% residual sludge. Wherever possible they have introduced closed production

loops. This minimises emissions, reduces waste and cuts consumption and transport costs.

Fig. 11 The HRP 4905 printer's corrugated packaging is also easily recyclable.

The packaging used to package the PC is almost all recyclable. The boxes are made of chlorine-free bleached cardboard with high recycling content. Return and re-use programs in their production plant save 2,500m packaging waste every year. They also reuse 95% of the packaging from their suppliers. Their own packaging return system, together with the recycling programs of the nationwide German recycling system (Duales system), ensures that in Germany all packaging can be re-used or recycled.

Re-use: Don't throw away- a three stage process

Siemens Nixdorf's general policy for all their products is ' Reuse before recycling, before disposal'. "So they've developed a 3-stage concept with specific aim: less waste disposal. Their results in the PC sector for the 95/96 business year took back 5383 tonnes of used Siemens computers. They reused or recycled 86% of this amount, so only 14% was left for disposal"(Siemens, 1998, p.7). This was quite considerable load off the environment.

Stage 1 – Tested and Back on the market

First of all, returned equipment is checked for possible upgrading or reconditioning. If the product is found to be healthy, it is re-marketed as secondhand equipment. However, the pace of technological innovation means that this option is often not feasible for complete PC's.

Stage 2 – Re-use individual components

If it isn't viable to reuse the computer as a complete secondhand machine, their technicians consult a database to check which individual PC components are re-usable. Processors and memory chips are often in demand in secondary application markets.

Stage 3 – Resource Recovery

Used PCs and PC components which can't be re-used are sent to Siemens Recycling Centre in Paderborn, Germany. Here they are manually dismantled and the materials sorted. Currently, they sort into 60 different material categories e.g. ferrous and non- ferrous metals, cathode ray tube, electronic scrap, sorted plastics, mixed plastics, cables, circuits and residual waste. These substances are then sent to authorised recycling firms for further processing and return to production processes.

Admittedly, it's very difficult for most users to check whether their computer is truly environmentally friendly. So its helpful for both the consumer and

Siemens if the environmental performance of their products is assessed by an independent institution, such as 'The German Standards Institute'. They award the 'Blue Angel' mark for products which are designed to have a long service live and high recyclability. The 'Scenic Pro' was the first to gain the right to display this mark. Today, virtually all Siemens system units, monitors and keyboards meet Blue Angel criteria. This is helpful both for the manufacturer and for the consumer to check whether the computer is environmentally friendly or not.

Fig. 12 'Blue Angel' mark.

Siemens do an enormous range of other environmentally friendly products, which include telephones, refrigerators, energy saving lamps, halogen – free circuit boards, flat-bed printers made from recycling material etc. etc. Siemens' new dishwashers have a sensor to gauge the cloudiness of the water in the pre-rinse cycle and, based on this, they decide whether or not the water needs to be changed. This can save as much as 4.5 litres of water on each rinse cycle. If the machine is only half full, the water and electricity consumption can be reduced even further by using the upper basket rinsing option, for which the lower spray arm is switched off.

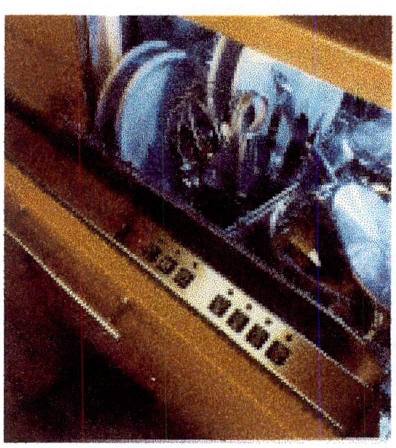
Fig. 13 Siemens' Energy efficient dishwasher.

For many years, Siemens has kept records of operating expenses and capital spending for environmental protection. As one can see from the graph on the next page, most of the spending went on waste management and protection of water resources.

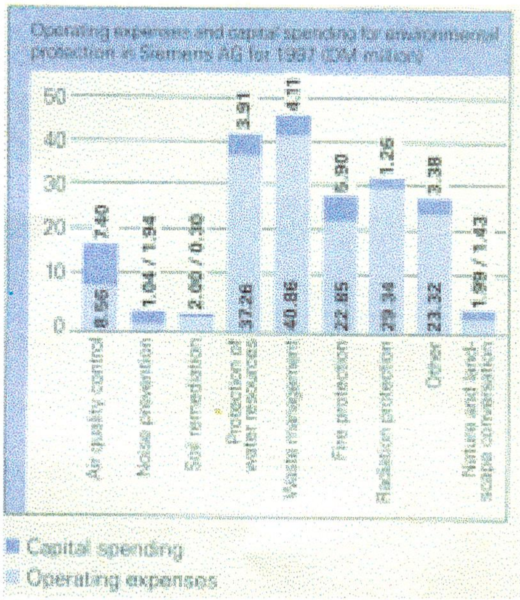

Fig. 14 Operating Expenses and capital spending for '97.

Siemens don't 'sell green', but sustain a modest profile which is better suited to the environmental strategy of obtaining long-term, lasting results.

> "And one hears it said that today Siemens represents in the design of investment goods what Braun signified in the 60's for the design of consumer goods" (Domus, 1985, p.58).

Conclusion

Once products no longer function and cannot be repaired, any component part than can be reused or reconditioned should be separated and those that cannot (where appropriate) be recycled.

Essentially, however, according to Karrie Jacobs,

> recycling is just a way of mopping up, a way of coping with the residue of the industrial system set up to generate waste. It is only one phase of a total overhaul in the way we make and do things (Jacobs, 1995, p.55).

The idea of durability implies the promotion of materials which, besides being long-lived from the physical point of view, are capable of producing objects that will last culturally.

The government will have to ask the question: can recycling satisfactorily absorb the volume and variety of waste generated in the modern industrial economy? The key question is not whether recycling is required, but whether it will suffice. Sustainable development may not be possible with an economy in which products are recycled, but no attempt is made to reduce the final consumption. A more appropriate image is the roundabout with at least six different directions to choose from, all applicable and offering part of the solution. Second–hand use, life-cycle increase, component re-use, energy recovery and even landfill can have advantages above material recycling by

disassembly as we know it today. Stimulating creativity to find new and better alternatives is the only way to create opportunities for products, materials and the environment. The ideal is still surely

> "a product which never fails you. Loyal like a friend, with everlasting beauty. Purchased for almost nothing and after years of service it turns out to be a collector's item - we would all like to own a product like that. But the truth of the matter is that most of us part with a product when a better alternative becomes available. Loyalty is temporary. The length of a product's life depends very much on subjective judgements rather than technical factors. There is, however, one thing that can prevent us from dumping products in this way. Our general satisfaction with a product, measured in terms of its reliability, user comfort, service, lack of repairs and low operational cost, determines the length of a products economic and useful life. Above all, it is the product's perceived and experienced quality that determines its environmental impact, sooner or later" (Philips, 1997, p.8).

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