10 Waste Management and Product Design

10.1 Waste Management Strategies

10.1.1 Reasons to Reduce Waste

In the life cycle of a product waste management is as important as resource management. Product developers should concern themselves with the end-of-life phase for several reasons.

Firstly, the magnitude and diversity of waste problems are increasing in our consumer society. At some stage it becomes too difficult to collect all solid waste in landfills. It is simply too much, too expensive to manage and too polluting. Among the most important environmental threats is leakage to ground water. Germany was the first country to restrict the dumping of waste in landfills for such reasons and to introduce rules and taxes to reduce waste. Later other countries in Europe followed. Today the EU waste directive applies strict rules to reduce the stream of waste to landfills.

Secondly society becomes aware that waste consists of natural resources, and that materials and energy must be used more efficiently and sustainably. There is a long tradition to fall back on. In pre-industrial society discarded material was not thrown away but used for some purpose. Products were repaired, or parts of it were used in new products or for new purposes; organic material was sent back to cultivated land, and burnable material was used for heating. One could simply not afford to be wasteful. Today reuse and recycling are again important.

But the most basic reason for a proper waste management – as with proper resource management in general – is that we need to reduce the material flows in our societies. Today a very large share of the material flows is linear, from the origin to the waste dump. This is not sustainable. In the longer term we need to improve waste management to make the material flow more cyclic, and reduce the absolute amount of material used in our societies drastically.

10.1.2 The Amount and Kinds of Waste

Waste may be solid, water-born or gaseous. Wastewater management will not be discussed here. Still, it should be pointed out that treatment of wastewater leads to the production of sludge, which is a resource for both energy production and nutrients. Wastewater may thus be treated as a resource, just like solid waste. Similarly, gaseous waste, sometimes called molecular waste, may be treated as a resource, e.g. when sulphur in flue

In this Chapter

gases is used for gypsum. More often it is not, while e.g. its heat content can be used in a heat exchanger.

Solid waste is an important part of the material flows, amounting to about one tonne per year per person. In general one third of the waste is generated by households and two thirds by industry, although it varies by country [Berg, 1997]. Thus in Sweden the relationships is close to 50:50, while in Poland industry generates close to 90% of the waste [Andersson, 2003].

The largest waste stream is created in connection with extraction of material from mines and quarries. This *mining waste*, typically sand, gravel, rock and other overburden, stays on the mining sites. Sometimes it is used for construction work, such as road building. Increased recycling will reduce this kind of waste as virgin metals then are less needed. Designers may reduce this waste stream by dematerialisation of products.

The *construction industry* releases an increased amount of waste, consisting of wood, metal, plastics etc. The proper use of this waste is an important issue in our societies, especially as construction is increasing greatly. This waste stream is very much affected by the way houses are constructed. Since houses and infrastructure account for an important part of the material flows in our societies even a small slimming of the material used for single buildings is significant.

Municipal waste is fairly similar in all countries in the region. Differences are due to the relation between commercial vs household as sources of waste. Packaging material is an important part of household waste, as is organic waste from kitchens. Packing materials can easily be reduced by design decisions.

The *size* of the waste streams in our societies is not decreasing, but the management of the wastes is changing. Less and less ends on the landfill as will be described below.

10.1.3 Practices in Waste Management

Before the industrial age the farming society's waste management practices were, as mentioned, well established. Waste was taken care of as a resource. In the cities, however, waste was more often just thrown out on the street. With increasing urbanisation this became impossible. Landfills developed, although with bad environmental consequences, such as leakage to ground water, bad smell and emission of gases. In addition many did not use the organised places for waste, but threw their waste out anywhere. The bad smell of so-called pits in many industrial towns was terrible [Sörlin and Öckerman, 2002].

During the last few decades waste management has been more organised. Improper deposition of waste leads to fines (when detected and registered). But bad habits still remain, especially when it is costly to get rid of waste. It is especially serious to leave old cars in the forests. Here cars and other metallic and plastic waste not only destroy nature and threaten wildlife, but also pollute. In a 2004 survey the national NGO *Keep Sweden Tidy* found one hundred thousand waste cars in the country. The Baltic Sea region-wide NGO *Keep Baltic Tidy* for several years has made efforts to keep waste away from beaches and the Baltic Sea itself. Marine waste is very destructive for marine life and fish reproduction (see Internet Resources).

Proper waste management requires that waste be sorted according to fractions which are collected and treated separately. Experiences from sorting already collected waste are in general very negative. Instead, solid waste must be sorted by the producer, household or other business or organisations. Sorting of waste by households is now legally required in some countries and encouraged in others. However the infrastructure required for taking care of the sorted waste is lagging behind in many cases. All these factors are needed for proper waste management.

The reuse of products and recycling of materials is the preferred option for reducing waste streams. Again this can hardly be efficient unless the original user of the products helps to achieve this. Recycling is improving in many places, stimulated by increased market prices for such material as scrap metal, plastics, and paper.

In industry the use of waste is most efficient in so-called industrial symbiosis. Here the outflow from one factory is used in a second one. In some cases it is simple, e.g. steam produced at one site can be used as an energy source in another. In other cases it is more sophisticated, as when sulphur in flue gases in a power plant is used to produce gypsum boards for the construction industry. Also here there are good economic and environmental reasons to take care of waste as a resource properly.

10.1.4 Business and Waste

One of the most salient new elements in ecodesign is that it forces businesses to start thinking about what happens to the product after it leaves the factory. Furthermore, businesses have to develop a scenario for what happens to the product when the user no longer wants to use it: this is the end-of-life phase. The end-of-life of a product refers to all that can happen to a product after it has been discarded by the initial user. Is the product taken back and reused? Are useful components removed from the product for reuse, or are only the materials reused? Is the entire product incinerated or is it just dumped on a rubbish tip?

Partly because of the developments in legislation on manufacturers' responsibilities and the increased level of environmental awareness, all entrepreneurs need to be able to answer the above questions. The view taken by management of the end-of-life system of the product is a strategic consideration which depends on consumer behaviour, infrastructure, and local and international legislation. It is also necessary to determine at the product level if an intended end-of-life system is technically and economically feasible. Subsequently, it is the designer's job to redesign the product so that it is suited for the chosen end-of-life system.

End-of-life systems can been seen as an important part of producer responsibility. Industry, of course, wants to achieve environmental improvement at the lowest possible cost.

10.2 Integrated Waste Management

10.2.1 The EU Waste Management Hierarchy

Integrated waste management systems address the whole municipal waste stream, the materials to be recovered and the optimal treatment methods to be employed.

Figure 10.1 visualises that a waste management system includes material recycling, biological treatment, such as composting or biogasification, and the energy-from-waste methods. All of these are potentially feasible in different situations, and none should be ruled out.

It must be noted though that integrated solid waste management systems ought to be developed at the local level because only then can they be optimised to the local conditions. These differ from region to region and from urban to rural areas. The environmental management tool of a Life Cycle Inventory (Figure 10.1) can be used to develop the optimum solution for a specific location [McDougall et al., 2001].

The EC Waste Directive has established a *waste management hierarchy*, a list of options to treat waste of which the first is the preferred and the last should be as far as possible avoided. Policy measures, such as landfill taxes, have been implemented to achieve this. The hierarchy contains the following eight items:

1. Waste reduction
2. Reuse
3. Recycling
4. Composting
5. Biogasification
6. Incineration with energy recovery
7. Incineration without energy recovery
8. Landfill

It is not always wise to see this as a rigid hierarchy, but rather as a set of guidelines or a menu of options. This allows for the flexibility required when selecting the most environmentally effective and economically efficient method of waste management for a specific geography/location. There is not always a scientific or technical basis for listing the waste treatment options in this order, for example, why materials recycling should always be preferred to energy recovery. Waste policy needs to be aligned with overall environmental policy objectives.

In practice one has to use a set of methods. The hierarchy approach as such does not allow a comparison of the environmental advantages and disadvantages of the combination of different municipal solid waste treatment options. In addition the hierarchy does not address costs and therefore does not lead to or promote economically efficient waste management systems.

Packaging waste policy is sometimes discussed separately, but in fact it should be part of an overall waste policy.

10.2.2 Strategies for Optimising Product End-of-life

In the overall end-of-life system two strategies (see Chapter 3) were especially relevant. They are:

Ecodesign strategy 6: *extending life-time*, Prevent the user from discarding the product – for instance by extending its life.

Ecodesign strategy 7: *end-of-life system*.

- Reuse the product as a whole, either for the same or a new application.
- Reuse sub-assemblies and components by remanufacturing and refurbishing.
- Recycle the materials involved by:
  - recycling in the original application (primary recycling).
  - recycling in a lower-grade application (secondary recycling).
  - recycling of plastics by decomposing their long plastic molecules into elementary raw materials which are subsequently reused in refineries or for the production of petrochemicals (tertiary recycling, also known as feedstock recycling).

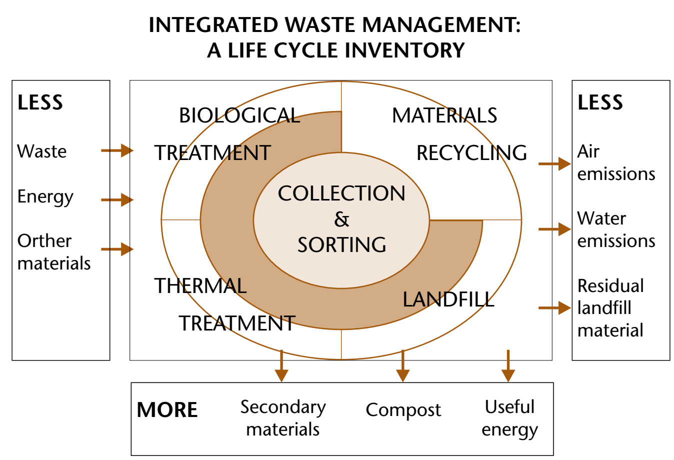

Figure 10.1 Integrated waste management. *The total waste emitted during the end-of-life of a product [McDougall et al., 2001].*

Box 10.1 Step-by-step Plan for the End-of-life Analysis of a Product

When planning for end-of-life design guidelines in product redesign, the current product – the one to be redesigned – will be used as a *reference product*. The guidelines to determine the end-of-life destinations are described in the flow chart in Figure 10.2.

Product parts can have different end-of-life destinations. It is entirely possible that some parts can be reused, that e.g. a housing can be disassembled and recycled, and that the remaining parts can be mechanically processed. This will depend on how different parts age and on how easy it is to free parts from the product.

When the reference product is run through the chart, an estimation of the end-of-life destinations of the product parts can be made. For example, it becomes clear which parts can be recycled. On the basis of these estimations, the management policy and the interactions between these two, guidelines for redesign can be drawn up. The decision points in the chart are described below.

1. Will the material cycles be closed? The entry to the chart is the strategic choice for a certain end-of-life system. This choice determines whether or not the product will be kept in the loop and therefore roughly what the end-of-life system will be. After this the consequences for the reference product will be examined.

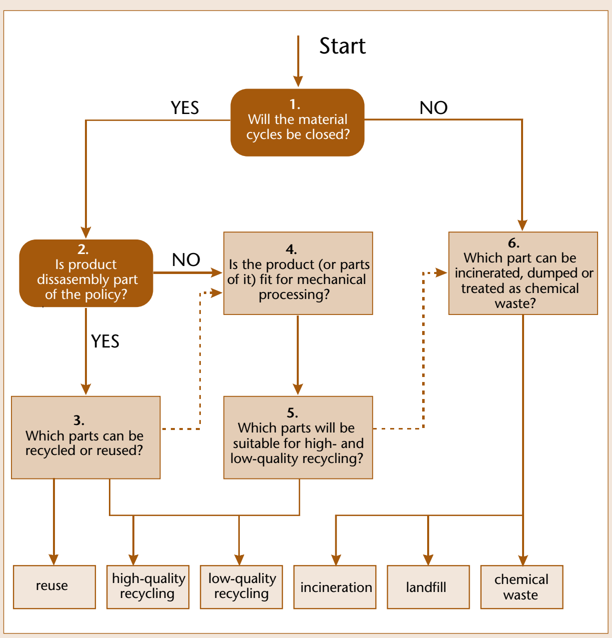

Figure 10.2 *Flow chart with general guidelines to determine the end-of-life destinations for a product. [TNO Industry, Delft, The Netherlands].*

2. Is product disassembly part of the policy? Disassembly is done for two reasons. Firstly, it is important to obtain the purest form of secondary materials possible. Secondly, hazardous substances must be isolated so they do not contaminate other material or exert too great an influence on the environmental impact of the whole product or on the financial return.

Disassembly is done by hand and is therefore costly. In Western Europe the total industrial rate is approximately Euro 0.5/minute (including wages, overheads and housing). Such rates imply considerable restrictions on the amount of material that can be retained from disassembly.

The decision whether or not to disassemble will be taken on the basis of a rough estimation of the entire product.

3. What parts can be reused? Parts can be reused when the technical life of the product is longer than the economic life. Furthermore, it is important that there is a market for these parts – a current market or a possible future market. The value of secondary parts depends strongly on their application; if this is at the same level as in the original application, reasonable prices (20-60% of the original price) can be obtained. The price falls rapidly for lower grade applications. Generally, a part cannot be reused if it fulfils only an aesthetic function.

4. Is the product (or parts of it) fit for mechanical processing? Material not detached in the disassembly process usually ends up in a combined form on mechanical processing lines. This processing consists of two steps: reduction of the materials to small sizes (by compaction or shredding, for example) and then separation.

Size reduction is essential to break down the different sorts of material and reduce volume. This can be done, for example, in hammer mills, cutting mills or by means of cryogenic milling. Separation is achieved in several stages. First, materials containing iron are separated magnetically. Materials containing aluminium are then separated by eddy current processes. Several other separation methods are then used to separate copper-content materials, mixed plastics and precious metals.

5. Which parts will be suitable for high- or low-quality recycling? Of product parts containing ferrous materials, 95% of the magnetic material can be made suitable for high-quality recycling by means of magnetic separation. High-quality recycling of other parts (and the remaining fraction) can be achieved when the material consists of more than 95% of thermoplastics of one kind. When this 95% consists of exactly two materials, the part can be low-quality recycled. Parts that contain less than 95% of thermoplastics can be considered for other separation techniques. Of these parts, 60% of the precious metals can be separated and recycled with high quality, and 80% of the aluminium and 90% of the ferrous materials can be recycled with low quality. Other parts and the remaining fraction can be considered for incineration and landfill.

6. Which parts can be incinerated, dumped or treated as chemical waste? When a choice between incineration and landfill has to be made, the calorific value must be considered. Materials with a high calorific value produce energy during incineration, so this is therefore preferable to landfill. Metals produce zero energy while plastics produce 40 MJ/kg. The best solution for plastic parts which cannot be reused or recycled is therefore incineration. Generally, when the calorific value is more than about 8 MJ/kg, incineration is preferred.

If the product is not stripped of its toxic components, the entire product has to be treated as chemical waste. This will involve certain costs. Separation of parts will be attractive when the costs of dismantling and processing of toxic parts, less the economic value of the remaining non-toxic materials, are lower than the costs of processing the entire product (see also Step 2).

Results of the flow chart e.g. on the feasibility of disassembly and mechanical processing, can influence the decision on whether or not to close material loops. Once we have looked in detail at the consequences (on the level of product parts), strategic decisions on take-back, reuse and recycling can be made. When this feedback has been made, priorities within the end-of-life system can be set and the product optimised.

- Safe incineration with energy recovery and waste disposal:
  - incinerate non-reusable materials by using energy generation technology and good flue gas purification (quaternary recycling, also called thermal recycling).
  - incinerate non-reusable materials without energy generation technology but with flue gas purification.
  - dispose of the residual material in a controlled fashion as solid waste.

Incineration without flue gas purification and uncontrolled dumping fall under the category of prohibited options.

Priorities have to be set when developing an end-of-life system. This is necessary because there are usually numerous design options, some of which may conflict. Priorities also have to be set because conflicts can occur when the two other main options for ecodesign, the reduction of materials usage and energy consumption, are simultaneously taken into consideration. Examples:

- Reduction of the energy consumption of any device through miniaturization and integration of electronics generally leads to a lower end-of-life value. This is because useful components become difficult to detach after the product's first life.
- If a product is usually discarded due to a weakness resulting from poor construction, the design should be improved rather than searching for ways of reusing the product or replacing the faulty component.

10.2.3 Solid Waste Incineration

The strategies above are listed in preferential order. However, recycling or safe incineration with energy recovery is sometimes preferable to reuse or remanufacture. Examples:

- The energy consumption of an electric appliance (such as a television set) has been reduced to such an extent over the past ten years that it no longer makes sense to promote the reuse of the appliance for more than ten years.
- For materials containing toxic organic compounds, safe incineration (destruction) is better than recycling.

Which of the above environmental priorities apply to specific end-of-life systems is determined by the cascade concept: the aim is to keep a material in the highest grade application for as long as possible. An example in the chemical industry is that the high-grade raw material natural gas is not used initially for heating but is first used for other purposes:

1. The gas is initially used to produce plastics.
2. These plastics are then used in high-grade products.
3. When these products have been disposed of, the plastic is recycled and used in a low-grade product.
4. After this product has been discarded the plastic is used as packaging material.
5. This packaging material is then converted, for example by feedstock recycling, into low-grade fuel.
6. Finally, this fuel is used to generate energy.

10.3 Preparing the Product for End-of-life

10.3.1 Product End-of-life Analysis

Design for the end-of-life of a product can be analysed systematically. A method for this is described in Box 10.1. It is summarised in Figure 10.2. The parts of a product are analysed separately in a six-step system. The analysis should define the best answers for questions such as should a product be designed to make disassembly possible; should parts be made to be exchangeable and thus the product itself possible to repair; should parts be possible to reuse; should the product be designed so that the material is possible to recycle; should some (all) material be possible to incinerate for energy recovery.

The results from the flow chart (Figure 10.2) will feed into the design strategies and make optimal decisions on the design.

10.3.2 Optimising the Product According to End-of-life System

A number of design rules can be formulated to optimise the product according to the end-of-life system. Chapter 3 *Strategies for Ecodesign*, provides design rules for extending the life of a product, product reuse, remanufacturing and refurbishing, and recycling.

By following the priorities set above and elaborating them with the steps in Chapter 3, a realistic end-of-life strategy can usually be obtained. This can be quantitatively underpinned by using additional methods such as life cycle assessment, an analysis of life cycle costs and/or an analysis of the end-of-life costs.

Life cycle assessment (LCA) methodology has as yet been unable to generate complete environmental profiles for end-of-life problems due to methodological problems e.g., such as difficulty in estimating the system boundaries for recycling. Secondly, it is not yet clear how we should deal with "enclosed" toxicity. How should toxicity which is released into the environment, for example through leaching from buried waste, be included and on what time scale (1, 10, 100, 1000 or 1 million years)? Thirdly, it is not clear how "emissions" formed by the physical presence of a rubbish mountain (which does not fit in any landscape) should be included. A fourth problem is that reliable data on the environmental impact of collection, separation and recycling processes of waste are still inadequate (see further Section 10.4).

In Table 10.1 very approximate figures are given for the reduced impact of recycled materials. The figures are based upon eco-indicator values for the environmental impact of materials [Goedkoop, 1995]; transport energy for collection is included. It is evident that the use of recycled material has a beneficial effect on the environment.

Box 10.2 A New Waste Strategy

Making Europe a Recycling Society

The European Commission proposed in 2005 new strategies on resources, and the prevention and recycling of waste. The proposal is revising the 1975 Waste Framework Directive to set recycling standards and to include an obligation for Member States to develop national waste prevention programmes.

Environment Commissioner Stavros Dimas said: "Waste volume has been disproportionately increasing, outpacing even economic growth. Waste generation, disposal and recycling are of concern to all of us: individuals, companies and public authorities. Now is the time to modernise our approach and to promote more and better recycling. Our strategy does precisely that. EU environment legislation has helped improve the way we dispose waste and recycle specific waste streams, such as municipal waste, packaging, cars and electric and electronic equipment. Waste management has moved a long way from being a dirty, polluting business. High standards exist for landfills and incinerators. Industry now seeks to make a profit from waste instead of dumping it."

However, waste generation in the EU is estimated at more than 1.3 billion tonnes per year and is increasing at rates comparable to economic growth. For example, both GDP and municipal waste grew by 19% between 1995 and 2003. One consequence of this growth is that despite large increases in recycling, landfill – the environmentally most problematic way to get rid of waste – is only reducing slowly. What is needed now is to modernise and widen EU waste policy in the light of new knowledge. Companies and public authorities need to take a life-cycle approach that does not only look at pollution caused by waste. It must also take account of how waste policies can most efficiently reduce the negative environmental impacts associated with the use of resources through preventing, recycling and recovering wastes. To move towards this objective EU waste law must create the right regulatory environment for recycling activities to develop.

The main elements of the proposed revision of the Waste Framework Directive are:

- Focusing waste policy on improving the way we use resources.
- Mandatory national waste prevention programmes.
- Improving the recycling market by setting environmental standards that specify under which conditions certain recycled wastes are no longer considered waste.
- Simplifying waste legislation.

Further measures are programmed for the next five years to promote recycling and create a better regulatory environment for recycling activities. An Impact Assessment accompanies the strategy.

Text extracted from the press release at: http://europa.eu.int/comm/environment/waste/strategy.htm

10.3.3 End-of-life Costs

When making life cycle cost calculations it will appear that the end-of-life costs make up only a small part (1 to 7%) of the total costs. The obvious implication, that end-of-life costs are insignificant, is incorrect. This is because one must not only look at the absolute size of the amounts but also at the degree to which they can be influenced. There is a big difference here in comparison with the other items of expenditure: whereas ways to reduce the costs of production and transport, for example, have always been sought (and indeed many options to achieve this have already been found), end-of-life expenditure has only more recently been studied.

It is important to calculate the *end-of-life costs* on the basis of price quotations from service providers in the field of logistics and recycling/processing. The company itself must also build up an insight into end-of-life costs. Experience has shown that this generates a great deal of understanding of the subject and stimulates environmental design improvements.

Data must be gathered on rates charged for waste and incineration while the value of the secondary material must also be known. For metals, scrap prices are related to the prices quoted on the London Metal Exchange, for plastics the value of high-grade secondary material is approximately 60 to 70% that of the new price.

A significant question for complex products is: which components must be separated and which parts should be eligible for mechanical processing? A rough estimate can be made with the help of Table 10.1 and on the basis of self-established standard disassembly times and current hourly rates.

Calculating end-of-life costs for packaging is relatively simple since agreements have been reached in several countries for the return and processing of packaging and the economy of this.

10.4 Life Cycle Assessment and Waste Management

10.4.1 Waste Management and the Beginning of LCA

Concern about solid waste and waste management was one of the driving forces behind the development of Life Cycle Assessment methods in the 1970s and the following years (Box 5.1). Issues such as which were the best options, recycling or incineration, returnable cans or non- returnable cans, were studied by LCA methods back in the 1970s. Packaging waste in general has been a major topic in many LCA studies in the 1980s and 1990s. The results of the studies have been the basis for deciding on recycling of products and its parts, especially containers, as well as recycling of materials, such as glass, paper and metal.

The application of LCA to packaging has been enlarged to include the study of wastewater, especially the use of sludge, which often ends up on landfill, including if the separation of urine is a good environmental option. Other LCA studies have been concerned with hazardous waste, such as solvents of different kinds.

Even if a majority of studies have been concerned with household or consumer waste, industrial waste has also been studied. Major questions have been the comparison of different recycling options. Here it is often less complicated than consumer waste since open loop recycling, where the systems becomes very large and complicated, is largely avoided.

LCA studies have been concerned with waste in general, with materials such as paper or metals, or with individual products. Waste studies are of importance for municipalities which normally have the responsibility. Individual materials can be studied to evaluate options such as energy from incineration, or even fuel production from plastics.

The options for end-of-life for products are often multiple and complicated. It is simpler to evaluate not whole material but rather defined products. One of the larger difficulties is open loop recycling, that is the waste form one product is fed into a second product, often of lower quality, such as packing material from newspaper,

10.4.2 Difficulties in LCA of Waste Management

Waste has to be dealt with in almost any LCA since it is part of the product life. A number of difficulties are then typical and appear every time. One way to avoid these difficulties, sometimes used in early LCA studies, was simply to count waste as an impact category and make no further analysis. This is not common any longer.

Table 10.1 Reduction of environmental load by recycling.
Reduction of environmental impact when recycled materials are preferred to virgin materials according to Eco-indicator 95 [Goedkoop, 1995].

100% recycled glass has an impact which is	= 0.8 x that of completely new glass
100% recycled iron	= 0.4 x that of completely new iron
100% recycled plastic/paper/cardboard	= 0.4 x that of completely new material
100% recycled copper	= 0.25 x that of completely new copper
100% recycled aluminium	= 0.1 x that of completely new aluminium

Box 10.3 Recycling Electronic Waste – Mobile Phones

Eco-phones?

The market for electronics is steadily increasing, and technical development are very intensive with dramatic increases in product quality. A significant feature is also that the life-cycle of some electronic products is growing shorter. A computer bought today is often considered old after just a few years of use. New and more powerful products are launched with double-sized hard discs, quicker CPUs and, on the bonus side, often also at reduced prizes. The result is a huge and quickly growing mountain of electronic waste and with a material content which is often considered harmful for our environment. There are an today estimated over 1 billion mobile phone subscribes worldwide. The chairman of Nokia company, Jorma Ollila predict that this figure will increase to 2 billion in just a few years time. See article: *http://www.siliconindia.com/shownewsdata.asp?newsno=23296&newscat=Technology*

Research from the UK also suggest that users replace their mobile phones after only having used them for a year and a half. In Europe about 105 million phones are replaced every year. If these were placed one on top of the other the height would equal Mount Everest multiplied by 324!

Theoretically speaking, the life-cycle of these phones could be enhanced by quality measures that would make them last many, many years after they are thrown away in favour of smaller phones with increased functionality. If we, however, have to accept that many electronic products will have a short period of productive life, other measures must be taken to safeguard that computers, cell phones and other electronic products are manufactured, used and recycled in an environmentally friendly way. As mentioned legislative measures have been taken to increase producer responsibility for products and many initiatives have also been taken, for example the WEE and RoHs directives.

Starting on the production side, most electronic products today are based on the technology of semiconductors. These are used in everything from computers and washing machines to cell phones and portable mp3-players. Semiconductors have until now contained lead and halogen compounds which now, in accordance with the WEE and RoHs directives, are scheduled to be phased out in Europe after 2006.

Figure 10.3 Lead-free semiconductor from Samsung. *4Gb NAND Flash memory to be used in products such as mobile phones, digital still cameras, handsets, MP3 players and USB Flash drives, etc. Photo: © Samsung.*

Figure 10.4 The Nokia 6650 phone. *"Designed for recyclability" is the heading on one of Nokias web pages presenting it as a case study for ecological product design. Photo: © Nokia. See case study: http://www.nokia.com/nokia/0,6771,27593,00.html*

Figure 10.5 Recycle your old phone. *One of Fonebaks recycling-collector boxes for mobile phones set up in a store. Photo: © Fonebak pic.*

Figure 10.6 Researchers compost old mobile phones and transform them into flowers. *Dr Kerry Kirwan at the University of Warwick showing the old mobile telephone cases disintegrating and growing into flowers. Photo: © University of Warwick.*

A few years ago Samsung, as the first company in the world, developed a new technology to produce lead-free semiconductors, and developments are under way also to phase out halogen compounds.
http://www.samsung.com/Products/Semiconductor/DivisionPolicy/Ecoproduct/

Another example of innovation are the batteries in mobile phones. Today most of them contain lithium. Recently the recycling company Umicore SA in Belgium developed a closed-loop-solution for sustainable recycling of Li-ion batteries with a patented process called VAL'EAS™. Umicore was presented with the European Environmental Press (EEP) Association's Gold Award 2004 (conferred in collaboration with European Federation of Associations of Environmental Professionals (EFAEP) and Pollutec) for their innovative environmental technology.
http://www.recyclingsolutions.umicore.com

Sustainable recycling of electronic waste is becoming increasingly important, and for mobile phones efforts are being made in many countries. One example is the English company Fonebak, with branches in several countries in Europe. According to the company the phones handed in to them are 100% recycled.
http://www.fonebak.com/

Efforts to increase recycling of products by using biodegradable material instead of ordinary plastic is ongoing, and one interesting example of this is the research done by Dr Kerry Kirwan at the University of Warwick.

Together with PVAXX Research Development Ltd and Motorola he has created a mobile telephone case made of biopolymers that, when discarded, can be placed in compost in such a way that just weeks later the case will begin to disintegrate and turn into a flower.
http://www2.warwick.ac.uk/fac/sci/eng/ug/elect/xs/xscase1/

Box 10.4 Waste Management Initiatives – Examples

1. Heinz adopt lightest steel can 2006
HJ Heinz, in conjunction with Impress Group BV, has carried out successful trials of a new light-weight "easy open" steel can end. The new end has a thickness of just 0.18 mm – beating the lightest food can end previously available by 0.02 mm and creating a new "best in class". Heinz now intends to convert its entire range of 200 g and 400 g cans to use the new lightweight can end, a move that will eliminate around 1,400 tonnes of steel waste annually. If this is taken up across the sector, the scheme could reduce UK household waste by as much as 28,000 tonnes per year.

2. Belgian tyre producer responsibility gets off the ground
Recyctyre, the Belgian take-back organisation for tyres effective from 2005, is funded by a levy on new tyres, EUR 2.4 for smaller tyres and EUR 10.3 for larger tyres. 65,500 tonnes of the 80,380 tonnes marketed were recovered for recycling, a collection rate of 81.5%. Car and van tyres were the major contributor. The recovered tyres were treated as follows: energy recovery 36.9%, granulation 30.7%, exported for treatment 15.2%, re-treading 4%, re-use 2.4%, other treatment 10%.
http://www.recyctyre.be

3. US C&A's carpet recycling programme
C&A Floorcoverings Company is mining buildings for resources instead of the Earth. It has recycled more than 50,000 tonnes of reclaimed vinyl and vinyl-backed carpet, since it introduced the Infinity Initiative 10 years ago. C&A's recycles any post-consumer vinyl-backed carpet, regardless of original manufacturer, into 100% recycled content backing for new ER3 (R) floor coverings. Containing a minimum of 25% post-consumer carpet, the remaining 75% of the ER3 backing system consists of post-industrial waste generated during carpet manufacturing and industrial waste from the automotive industry. C&A instituted FLOORE is a "buy-back" programme offering customers financial incentives to return and recycle their old vinyl-backed carpet.

4. Scottish business recycling directory on-line
The Scottish Waste Awareness Group (SWAG) has produced an on-line recycling directory for businesses throughout Scotland. This web based tool is accessible via their web site. Businesses can search for reuse and recycling services by location and material to find out what is available to them in their local area. A range of service providers are included such as local authorities, the private waste management sector, and community sector organisations. The web site also contains a number of useful links to other initiatives and organisations that are working with businesses to facilitate resource efficiency, such as Envirowise and the Business Environment Partnership (BEP).
http://www.wasteawarebusiness.com

5. Japanese Sekisui House achieves zero waste at new construction sites
Sekisui House, a leading Japanese home builder, achieved zero waste at its new home construction sites in July 2005. At each construction site, waste is sorted into 27 categories and carried to the company's recycling centre by delivery trucks returning from the site. These resources are further broken down into about 60 categories at the recycling centre.

Sekisui House already achieved zero waste at all of its six factories in May 2002. Utilizing their existing recycling routes, the company has since successfully established a new system for construction waste. Some items are entrusted to outside recyclers depending on the type of material; iron, aluminium and concrete are recycled for use as building materials, and resin is recycled into pellets. Sawdust and degraded resin are processed at the company's own facilities and recycled into roof battens and interior materials.

Such efforts by Sekisui House have also helped reduce waste generation at construction sites. The average amount of waste from a construction site was reduced from about 2,900 kilograms in 2000 to about 1,800 kilograms in July 2005. Cost reductions through zero waste reached 39 million yen (about U.S.$350,000) in July 2005 alone. The company expects costs to be reduced by about 250 million yen (about U.S.$2.2 million) in the second half of its fiscal year ending in January 2006.

6. British Government and magazine industry strike producer responsibility agreement
The Periodical Publishers Association (PPA) and the Minister for Local Environment signed a producer responsibility agreement for the magazine sector. The agreement will increase the recycling rates for post-consumer magazines by 30% within eight years. Latest industry figures show that around 40% of magazines are currently recycled by consumers – many of them going to make up recycled-content newsprint for the newspaper sector. The agreement targets increasing this rate to 50% by 2007, 60% by 2010 and 70% by 2013. The agreement also endorses the current practice of unsolds going directly into the recycling process and work with local authorities and the public to promote recycling. Currently more than 500 magazines are carrying the Recycle Now logo.

Source: Resource Recovery Forum News service, 2005.
http://www.resourcesnotwaste.org

Open loop recycling is one of these difficulties. An open loop is when a product waste is used for a new product or a new purpose, which in turn may be used for a third purpose or product. The common way to deal with this issue is systems expansion, that is, the model has to include the new products. However, this may be difficult and lengthy and setting system boundaries may be a problem.

Multi-input allocation refers to the recurring difficulties that waste treatment mostly is done on a mixed waste and thus it is problematic to know what happens to the product waste under study. Waste incineration gives rise to emissions which need to be allocated to different parts of the process. These emissions are very dependent on the conditions under which the incineration is done. Thus chlorinated hydrocarbons such as dioxins, or carbon monoxide are not generated if conditions are right.

The time horizon is also problematic to deal with. The processes in landfills are very long, maybe centuries, and not at all comparable to what is common in industrial processes. The time over which data exist is about one century, and this is the time horizon used in LCA. One way to deal with the problems is to use weighting.

10.4.3 Waste Management Models

Several models have been developed to serve as generic, generally applicable, tools for deciding on waste management, either for municipalities using them for consumer waste in general, or for production waste in industry, or for specific products. Many of these models also provide additional data, for example, on cost calculations and substance flows analysis. The models typically consist of models of partial processes, such as collection and separation into fractions, incineration, composting, gasification and landfilling. The results of the model are useful to support multi-criteria decision support analysis (MCDA). They are useful tools for a municipality to track how it fulfils the obligations of the EU waste directives. In Sweden – it will be similar for all of the European Union – municipalities are requested to deliver waste management plans; these are also supported by the models.

Among the models intended for municipal waste management is the Canadian ISWM (Integrated Solid Waste Management) [Mirza, 1998]. The models typically contain LCI data and cost data for various waste processing alternatives and sometimes optimisation tools. Outdata includes the environmental impacts of the waste treatment. The Swedish ORWARE model developed by Eriksson et al. [2002] includes, in addition to the above, wastewater treatment processes as well.

The CHAMP [Mellor et al., 2002] is part of a model used for specific materials. CHAMP was developed to study plastics, polymers, which is more complicated and multifaceted than paper, glass or metals. It is compares options such as extraction, polymerisation, blending and production of fuels (Figure 10.2).

10.5 Some Examples of European Waste Management

10.5.1 Waste incineration

Despite EU policy to divert biodegradable waste from landfill, landfilling remains the dominant method used in Europe – approximately 50% of the 243 million tonnes of municipal solid waste generated in EU-25 each year is still landfilled. There is still public reluctance to the *waste-to-energy (WTE) plants* as a safe treatment option. However approximately 50 million tonnes of waste is currently thermally treated each year in about 400 WTE plants in Europe. This is enough energy to supply electricity for 27 million people or heat for 13 million.

http://www.earthscan.co.uk/news/article/mps/uan/513/v/5/sp

10.5.2 Recycling Examples

The European Association of the Rubber Industry (BLIC) reports that each year approximately 3 million tons of *used tyres* need to be treated in Europe. Material recycling expanded its share from 5 % in 1992 to 28% in 2004. The use as alternative fuel has increased from 14 to 30%; the EU total recovery rate reached 79% in 2004.

The non-profit European association Petcore has announced that European *post-consumer PET* collection rates reached 665,000 tonnes in 2004, representing an 8.5% increase over the previous year. Germany, France and Italy together delivered 60% of these. Petcore expects that by 2010, more than one million tons of European PET will be collected and recycled. The European markets for recycled PET are gradually moving towards high quality applications. More than 90% of polyester strapping is nowadays made of recycled PET, using 11% of the collected bottles. Packaging material like thermoformed polyester and PET containers accounted for 23.2% of the market, and polyester fibre 65%.

In 2004, EBRA's, European Battery Recycling Association, 15 members recycled 23,900 tonnes of *used portable batteries and accumulators* and more than 4,000 tonnes of used nickel-cadmium (Ni-Cd) industrial batteries, making a total of 27,946 tonnes, which represents a 36% improvement on 2003. This increase is due notably to the arrival of five new members in the EBRA fold, accounting for the recycling of more than 8,000 tonnes of batteries and accumulators in 2004. Recycling of nickel-cadmium batteries (industrial and portable) increased most sharply between 2003 and 2004.

10.5.3 Producer Responsibility and Waste Collection

The mentioned companies Blic, Petcore and EBRA are examples of non-profit industrially owned companies for managing a waste common for an industrial sector. The creation of such companies is prompted by EU and state legislation on producer responsibility. These appears in many different branches.

The EU Directive on *Waste from Electrical and Electronic Equipment (WEEE)* requires all EU Member States to introduce specific rules for collection, waste treatment and recovery of electrical waste, and to place responsibility for these matters on producers and importers. Danish legislation will affect producers of refrigerators, alarm clocks, electric toothbrushes and other electronic equipment from April 2006. In future, new products must be labelled and producers must pay for treatment of the waste, rather than the municipalities paying for it, as is the case today.

More than a decade has passed since *Producer responsibility* was introduced in Sweden in 1994. The recycling level, then some 40%, has since increased to around 67%, based on the Packaging Directive criteria. 49% of the packaging waste goes to recycling, and another 9% to energy recovery. Only glass and corrugated cardboard, however, have reached their recycling targets. Aluminium, with a recovery rate of 27%, has a target of 70%. Only 57% of agricultural plastic has been recycled. 85% by weight of scrap vehicles were reused or recovered in 2004.

10.5.4 Dematerialisation and Waste Reduction

Over 2.2 million tonnes of *post-consumer steel packaging* were recycled in Europe last year, a recycling rate of 60% in the enlarged EU25. In Central and Eastern Europe, according to the level of collection infrastructure in place, recycling performances of Green Dot systems ranged from 11% (metals) in Lithuania to 43% (steel) in Hungary. Over the last 10 years, more than 16 million tonnes of steel packaging has been recycled, saving 40 million tonnes of CO_2 emissions, equivalent to the CO_2 emissions of 22 million cars, travelling an average of 10,000 km.

Source: Resource Recovery Forum News service, 2005. http://www.resourcesnotwaste.org

Abbreviations

ISWM Integrated Solid Waste Management.
LCC Life Cycle Costing.
MCDA Multi Criteria Decision support Analysis.

Study Questions

1. Describe the relation between waste management and product design.
2. Describe how end-of-life design is using integrated waste management strategies.
3. Explain the sequence of items in the Waste Hierarchy, and explain in particular, why landfill comes last, instead of e.g. incineration.
4. List the items in the end-of-life cost of a product, and explain how it is possible to take these into account in the product cost.
5. Explain how the European waste-to-energy policy is working and describe its advantages and disadvantages.

Internet Resources

European commission
http://europa.eu.int/comm/environment/waste/strategy.htm

International Solid Waste Association
http://www.iswa.org/

Resource Recovery Forum,
http://www.resourcesnotwaste.org

Chartered Institution of Wastes Management, IWMA, UK
http://www.iwm.co.uk/

The Air & Waste Management Association,
A&WMA, International
http://www.awma.org/

Waste Management, Inc.
Comprehensive waste and environmental services, USA
http://www.wm.com/

Environmental Protection Agency, USA
http://www.epa.gov/seahome/hwaste.html

Purdue University Household Waste Management software
http://www.purdue.edu/dp/envirosoft/housewaste/src/title.htm

Keep Baltic Tidy (in swedish)
http://www.hsr.se/sa/node.asp?node=1110

The Global Marine Litter Information Gateway
http://marine-litter.gpa.unep.org

The Global Marine Oil Pollution Information Gateway
http://oils.gpa.unep.org