Manual on Eco-Design and End-of-Life management of Electronic Products

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Introduction

The Integrated Product Policy (IPP) provides the general framework in which European and national policies should be formulated, aiming at the minimization of environmental impacts during the product’s life cycle. The implementation of IPP in the Telecommunication sector, with the participation of the key national stakeholders at the whole life-cycle of the telecom products, was the main objective of the project IPP-TEL.

This manual has been prepared in the framework of the LIFE-ENVIRONMENT project “Integrated Product Policy in the Telecommunication Sector” with the aim to promote the ecodesign of electronic products.

The manual includes abstracts and conclusions from the studies conducted throughout the IPPTEL project (techno-economic studies, market research, LCA, etc.) and guidelines on the eco-design of electronic products in combination with optimised end-of-life management options. The case study of a ISDN modem and a fixed telephone device, both produced by Intracom S.A., will be used as an example of the implementation of ecodesign strategies to electronic products.
1. CONSUMER BEHAVIOUR ON ECODESIGN

The development in electronics has resulted in products with rapidly increasing functionality, lower weight and less volume, giving users big advantages in the use phase. With its complex composition, an increasing number of new applications, shorter product life, use of hazardous substances and lack of data on the material contents, electronic and electrical equipment (EEE) constitute a threat to both man and the environment.

EEE manufacturers and their suppliers will face a number of important challenges in the near future affecting their business. These are among others the new EU directives putting forward an increasing need to design and build products in an environmentally conscious and profitable way and a need to cope with the demands and the expectations from the customers and society. But it is not enough just to deal with the expectations from the immediate vicinity. They have to put focus on the entire lifecycle of the product and the interested parties involved in the success of the product concerned.

Eco-Design of a telecom device aims at developing an electronic product with minimised environmental impacts during the whole life cycle. It is obvious that eco-design is based on life cycle thinking. The effect a product has on the environment should be considered and reduced at all stages along the product life cycle. These stages include the extraction of the raw materials, the manufacturing of the product, its marketing and distribution, the use and finally, the disposal of a product.

![Diagram of product lifecycle stages: Materials, Manufacturing, Use, Transport, Disposal]

- Resources - Energy consumption - Energy consumption - Mass - Reuse
- Waste - Hazardous materials - Maintenance - Distance - Recycling
- Hazardous materials - Waste - Mass - Distance - Recycling

*Figure 1.1: The most important environmental issues for each life cycle stage*
The environmental impacts in the different stages in a product’s life-cycle are generated e.g. from:

- inputs, like energy and raw materials
- outputs, like emissions to earth, air and water
- production of solid waste
- problems with the occupational health and safety

Figure 1.2: Life cycle assessment

A life cycle approach highlights the main areas of environmental impact which may have previously been hidden upstream in the supply chain or downstream at product use or disposal.

Eco-design involves design procedures that minimise material and energy consumption while maximising the possibility for reuse and recycling. By knowing exactly what materials are used in the products, any dispersion of potentially hazardous substances can also be avoided.

A market research has been accomplished through questionnaires, in order to investigate the consumers’ attitude towards eco-design and end-of-life management of telecommunication devices. From the statistical analysis of the questionnaires
distributed to simple consumers it was concluded that less than the half of respondents (46%) were aware of the term “eco-design telecom device” (Figure 1.3).

![Figure 1.3: Answers to the question whether consumers are aware of what an eco-design telecom device means](image)

It should be noticed that the percentage of people aware of eco-design turns out to be quite low. This remark is quite interesting, if we take into account that most of the respondents are students or graduated, and leads to the conclusion that their environmental awareness and sensitization are generally deficient.

In Figure 1.4, the above answers are attributed to three main age categories, 18-25, 25-40 and >40.

The most important conclusion that is derived from the analysis is that respondents aged over 40 are not familiar with eco-design, by a percentage of 60%. The low response rate could be attributed to the low interest of people over 40 for telecommunication matters.

Another point that could be mentioned is that people over 40 are less familiar with the environmental issues, mainly due to the lack of information they had during their education period. Lack of information can be attributed to the fact that environmental awareness has only risen the last decade because of intensification of the environmental problems. As a result, the majority of people over 40 didn’t have the chance to learn much about the environmental issues during their youth, but only through mass media.
Figure 1.4: Answers to the question whether consumers are aware of what an eco-design telecom device means, attributed to age categories

As far as for the rest of the respondents concerning, the age doesn’t seem to play a significant role in the awareness of eco-design, since the percentages are about the same for the ages 18-25 and 25-40. However, this percentage seems to be quite low, taking into account that their information comes from various sources (school, university, environmental organizations, awareness campaigns and mass media). Another important point concerns people’s behaviour towards an eco-design telecom device, if such a facility was available in the market. The conclusion that arises from the statistical analysis is that the great majority, by a percentage of 96%, would be willing to buy such a device, if it had the same price with the conventional ones (Figure 1.5).

The high percentage of positive responses represents an indication of consumers trending towards products with reduced life cycle environmental impacts, since it seems to be a common belief that we “spend” far more environment than we have. This should be a challenge for producers of electrical and electronic equipment to integrate environmental considerations systematically into the development of their products, in a way though that will not increase their price.
However, an important percentage of consumers (42%) appears to be hesitant towards any initiative concerning the recycling of telecom devices. This conclusion is reflected to Figure 1.6, where people respond about their interest to participate in a pilot project for the recycling of telecom devices.

**Figure 1.5:** Answers to the question whether consumers would prefer an eco-design telecom device with the same price

**Figure 1.6:** Interest of respondents to participate in a pilot project for the recycling of telecom devices
The quite important percentage of people unwilling to participate in a pilot project concerning the recycling of telecom devices could be attributed to the current lack of any infrastructure, suitable to handle such an action. As a result, many people seem to be unwilling to the prospect of committing themselves to a recycling process that sounds unsystematic and probably troubling. However, the interest to participate in a pilot project appears to be highly dependent on the respondents’ age. This remark is illustrated in Figure 1.7, where the responses have been attributed to certain age categories.

![Figure 1.7](image)

**Figure 1.7: Interest of respondents to participate in a pilot project for the recycling of telecom devices, attributed to age categories**

It is obvious that younger people, aged between 18 and 25, have relatively low interest to participate in a pilot project for recycling telecom devices, by a percentage of 53%, comparing to older ones. This is a quite unforeseen remark, because young people are familiar enough with the severe impact that telecom devices have on the environment and they should be expected to be more interested for such a project. However, it seems that they lack motivation in order to put themselves in recycling processes.
The greatest interest for participating in a pilot project for recycling telecom devices comes from people over 40, even though they less familiar with eco-design. This remark shows that older people, despite the information deficiency, are more sensitive towards the environment and more willing to move to actions than younger ones.

The responses, related to the interest of people to participate in a pilot project for recycling telecom devices, were also attributed to their awareness of eco-design. The results are presented in Figure 1.8.

It is quite clear that people, aware of what an eco-design telecom device means, are more willing to participate in a recycling pilot project, by a percentage of 75%, than those that are unaware of the term, by a percentage of 43%. This conclusion represents the close connection of environmental information and awareness and indicates the great need for increase of public information on environmental issues.

The same conclusion arises from attributing the responses, related to people’s willingness to collect separately and dispose devices for recycling without being reimbursed, to their awareness of eco-design. It is quite evident that the majority of
people aware of eco-design is very willing to recycle, by a percentage of 72%, while people unaware of eco-design are mainly "a little" interested to recycle, by a percentage of 42%.

Regarding the companies behavior on eco-design, they all appear to be aware of eco-design and willing to buy an eco-design device, if it had the same (or even a little higher) price with the conventional ones. Furthermore, they all appear positive towards the initiative of a pilot project for the recycling of telecommunication devices.

It is commonly accepted that the global market for telecommunications is facing a rapid expansion. The reasons of this expansion can be attributed to the high rate of technological change in this sector, to encouragement of consumers to buy the latest versions before their old appliance has stopped functioning, and overall to an increasing reliance on telecommunications and information technology in every area of human life.

This is the reason why waste of telecommunication equipment and on the whole waste of electrical and electronic equipment (WEEE) is one of the fastest growing waste streams and is increasing at a rate three times that of average municipal waste growth. Another point that should be stressed out is the content of such equipment in hazardous substances, such as heavy metals. The above factors render waste of telecommunication equipment as an issue of high environmental priority.

Even though waste of telecommunication devices represent such a small percentage of WEEE, their management is considered to be very important, because they contain in a quite higher level hazardous components, comparing to other WEEE. A characteristic example worth mentioned is that a mobile telephone that weighs less than 1% of a cooker may contain more hazardous components than the cooker.

Some of the most important hazardous components and substances of a telecommunication device are the following:

- mercury in printed circuit board
- brominated flame retardants in plastics
- liquid crystal display
- cadmium in nickel-cadmium batteries, which is toxic and carcinogenic

For example, the presence of brominated flame retardants in the plastics of telecommunication devices causes severe environmental impact, after the end-of-life
disposal. Another point is that flame retardants render difficult and economically inexpedient the management of these plastics by incineration. Thus, other management methods, such as recycling, have to be used for the management of this component, which comprises more than 20% of a telecommunication device weight.

The management of waste of telecommunication equipment is not an easy case. The collection of telecommunication devices waste can be an easy and inexpensive step of management, supposing the effectiveness in the design and operation of the take-back system. This is because telecommunication devices are generally small in size and light, unlike other electrical and electronic equipment, therefore rendering quite simple their separate collection by the consumers.

On the other hand, the most difficult part of the telecommunication devices waste management is their treatment for the removal of the hazardous components and the separation of the different material fractions. This is attributed to the fact that such devices contain many components in their small volume, making difficult and economically inexpedient their disassembly.

Regarding recycling, it is concluded that more than the half of the consumers are very willing to separately collect and dispose the telecommunication devices for recycling, without being reimbursed. Environmental awareness seems to be in a relatively high level, but it can be further increased via information campaigns, advertisements, school seminars etc.

Age seems to play a role in consumers attitude towards recycling. It appear that respondents aged over 40, even though they are not very familiar with eco-design issues, are more willing to separately dispose their old telecommunication devices, than young people aged 18-25.

Another significant factor that is directly related to consumers attitude towards recycling is familiarity with eco-design issues. This conclusion represents the close connection of environmental information and awareness and indicates the great need for increase of public information on environmental issues.

Regarding the matter of reuse, it was concluded that the consumers’ most common practice, regarding old telecommunication devices, is reuse (even if they are not working), either by repairing them, or by storing them for future use (e.g. for spare
parts, future repair). This common practice concerning reuse explains also the percentage of respondents (less than 50%) that has ever disposed a telecommunication device in the waste bin, which is quite low we take into account that there is still no structured take-back and recycling system in full operation.

It should be noticed that the percentage of people aware of eco-design turns out to be quite low. This remark is quite interesting, if we take into account that most of the respondents are students or graduated, and leads to the conclusion that their environmental awareness and sensitization needs to be further increased.

Although awareness of eco-design appears to be relatively low, people’s attitude towards an eco-design telecommunication device is very positive. The conclusion arises from the statistical analysis, where the great majority of consumers (more than 95%) would be willing to buy such a device, if such a facility was available in the market and had the same price with the conventional devices.
2. ENVIRONMENTAL LEGISLATIVE FRAMEWORK

The production industry of electrical and electronic equipment constitutes one of the most rapidly developing economic sectors, mainly due to technological innovation and market broadening. Technological development, consuming patterns and income increase have resulted in the production of huge quantities of waste of electrical and electronic equipment (WEEE). It is calculated that in EU member states about six million tones of WEEE are annually generated and there are forecasts for an annual increase of 3-5%. More than 90% of WEEE is landfilled, incinerated and recovered without any pre-treatment.

Electrical and electronic equipment contains a significant number of hazardous substances, such as heavy metals (mercury, lead, cadmium, chromium). The magnitude of the environmental problems that are related to the existence of such substances is determined by their toxicity and the existing management practices. All the above factors render WEEE as an issue of high environmental priority, while the production of electrical and electronic equipment comprises one of the most important economic sectors.

The European Union (EU) introduced the Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment, targeting to prevent the generation of electrical and electronic waste and to promote reuse, recycling and other forms of recovery in order to reduce the quantity of such waste to be eliminated, whilst also improving the environmental performance of economic operators involved in its management. The main measures of the European Directive are the following:

- involves the total of commercial and domestic electrical and electronic appliances,
- forces all the Member States to adequate WEEE collection and recycling networks, so that the owners and the distributors of such equipment can return their waste without economic burden,
- sets the producers in charge of organizing certified collective or individual systems for the collection, and treatment of WEEE,
- ensures that the producers have special labeling on their products that certifies their management after the end of their life,
- sets specific quantity targets for the collection and recycling of WEEE,
- highlights the importance of public information and awareness in the success of collection systems.

It is clear that the WEEE Directive requires producers of electrical and electronic equipment to provide financial arrangements for collecting products at the end of their life, whether such products are reused, recovered, recycled or disposed. Most important, it creates minimum standards for the EU and provides substantial latitude to each member state to determine its own system for measuring and allocating disposal costs among producers and commercial end users. As a result, whether and to what extent a producer or commercial user of a product may be required to pay fees associated with disposal of discarded EEE in a particular country will depend on the national laws adopted there.

The categories of EEE covered by the WEEE Directive are:
- Large household appliances
- Small household appliances
- IT and telecommunication equipment
- Consumer equipment
- Lighting equipment
- Electrical and electronic tools
- Toys, leisure and sports equipment
- Medical devices (with the exception of all implanted and infected products)
- Monitoring and control instruments
- Automatic dispensers

In addition, in order to contribute to the recovery and elimination of equipment waste and the protection of human health, the EU is also taking measures to restrict the use of hazardous substances in this type of equipment. For this purpose, Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003, on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive), was introduced.

The RoHS Directive was adopted as a complimentary measure to minimise the volume and toxicity of electronic waste by restricting the use of hazardous substances used as constituent components in electrical and electronic equipment.
In particular, the RoHS Directive prohibits, with limited exceptions, the use of the following substances above threshold levels in electrical and electronic equipment put on the EU market after 01/07/2006: 0.1% by weight in lead, mercury, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ethers, and 0.01% in cadmium.

The Directive provides that additional substances may be regulated as scientific evidence becomes available and indicates that the precautionary principle should be considered in making such determinations.

The RoHS Directive applies to the same category of producers as the WEEE Directive and covers the same scope of EEE, although with no distinction between household and commercial EEE, with the exception of medical devices and monitoring and control instruments, which are still under review.

A very recent European Directive that concerns electrical and electronic equipment is 2005/32/EC of the European Parliament and of the Council of 6 July 2005. This Directive establishes a framework for the setting of eco-design requirements for energy-using products, with the aim of ensuring the free movement of those products within the internal market.

The Directive provides for the setting of requirements which the energy-using products covered by implementing measures must fulfil in order for them to be placed on the market and/or put into service. It contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply.

Other legislative measures that directly affect telecommunication products include the Proposal for a new Directive on Batteries and Accumulators and Spent Batteries and Accumulators (expected to be adopted in 2006), the Commission Proposal for a new EU regulatory framework for chemicals, the proposed new system called REACH (Registration, Evaluation and Authorisation of Chemicals) and the Council Regulation (EEC) No 259/93 on the movement of waste within, into and out of the Community. Particularly the shipment of hazardous waste is restricted and subject to control procedures (a new Shipment Regulation to replace the present one from 1993 is currently in the legislative process).
3. ECODESIGN BACKGROUND

Ecodesign is a systematic way of incorporating environmental considerations into product and process design together with performance, cost, legal, health and aesthetic requirements. All these requirements shape the design of the final product or process, and the environmental considerations must fit into the design process with these other factors. There are three unique characteristics of Ecodesign:

• The entire life cycle of a product is considered
• Ecodesign is applied early in the product development process (although continuous improvement of all processes is recommended)
• Decisions are made using principles such as "industrial ecology" and integrative "systems thinking"

Ecodesign considers the potential environmental impacts of a product, process or service throughout its entire life cycle. A product, process or service’s potential environmental impacts range from the release of toxic chemicals into the environment to consumption of non-renewable resources and excessive energy use. The life cycle of a product includes the extraction of resources needed to manufacture the product, use of the product, its reuse or recycling and finally its disposal.

Ecodesigners design a product life cycle, not just a product. Knowledge of your product’s life cycle will help your designers prevent environmental accidents and liabilities by designing products to minimise environmental impacts.
The diagram above shows an example of an idealised, simplified design process. The designers start with a large design “space” which diminishes throughout the design process. The diamond shapes represent the generation of options and subsequent selection during each phase.

### 3.1 Ecodesign Strategies

Ecodesign may be interpreted in different ways. Each company has different environmental problems linked to their products/services and will have to approach ecodesign using different strategies.

For example, external factors, such as compliance with new environmental laws, may set the strategic agenda for ecodesign. Internal factors, such as energy consumption, also play a leading role in setting ecodesign priorities.

A company should examine the processes or materials present within their specific product system before choosing which strategy to implement. Using the correct strategy will allow the company to integrate all their requirements into the design process.

The following general strategies may be followed to design a *"green" electronic product*:

- New concept development
- Physical optimisation
- Material selection
- Production optimisation
- Distribution optimisation
- Product use optimisation
- End of life management

Implementing just one single strategy will not produce a "green product" and therefore a range of strategies should be adopted.

#### 3.1.1 New Concept Development

Design for the Environment involves new concept development by the designer of the product. This means integrating innovative strategies such as immaterialization,
dematerialization, life cycle design, and new services development into the new product design whilst ensuring that it meets the same consumer needs.

Immaterialization is the replacement of a physical product with a non-physical product or service. Dematerialization on the other hand means using fewer and/or new raw materials to produce the same products. Dematerialization may also lead to redesigning products so that components can be recaptured for reuse or recycling at the end of their useful lives, thereby reducing the raw materials needed for the next generation of products.

Designers should conduct an analysis of consumer needs to identify the service that a product provides and its true value before exploring new product concepts which involve immaterial solutions. Providing a service means that value is created and measured by the product function offered, and for the manufacturer the product increasingly becomes a means of delivering this function.

Designers should not just design "green" products. Instead, they should design environmentally sound product life cycles. This takes into account all processes that occur during the life cycle, from cradle to grave. Or when the materials used are also recyclable during end of life management, the term "cradle to cradle" may be used.

Finally, a new concept strategy may include shared use of a product. This means that a product is no longer the property of a single consumer, but instead a company provides the product to all users. Photocopiers and laundry equipment are typical examples of shared use products.

3.1.2 Physical Optimisation

Physical optimisation is the design of a product to increase reliability and enhance functions to result in an improved environmental profile. To do this, the following aspects must be investigated:

- **Increase of product life and reliability**
  Extending the life of a product can directly reduce environmental impacts. Longer lived products save resources and generate less waste because fewer units are used to satisfy the same consumer needs. Life extension means prolonging the useful life of the product. Useful life can be measured by the
number of times a product is used, length of operation or even shelf life for products that degrade as time passes.

A durable product will continue to satisfy consumer needs over a long useful life by resisting wear, stress and environmental degradation. However materials should only be durable as needed. Designers should not choose long-lived materials for short-term functions, unless there is an intention to recover them during the end of life management of the product. Enhanced durability and reliability can form part of a broader marketing and sales strategy.

Life extension can also be achieved by designing the product to be adaptable. Adaptable designs either allow continual updating or they perform several different functions. An adaptable structure makes it possible to revitalise a product from a technical or aesthetic point of view. This enables the product to keep pace with the changing needs of the end-user. A modular structure allows the benefits of a new technology to be incorporated into an older product. As a result, an adaptable product may undergo several upgrades in components over its life span, reducing the need for new products to be purchased on a more frequent basis. Products with several and interchangeable parts are the best candidates for adaptable design.

Environmental impacts are also related to the reliability of a product. Unreliable products quickly become waste causing greater environmental impacts and increased costs. Reliability should be ensured in the initial design of the product by reducing the number of parts or by simplifying the design.

- **Optimisation and integration of functions**
  Materials and space can be saved when designers integrate several functions or products into a single product by taking advantage of common components. Multipurpose machines that combine the functions of printing, copying and sending faxes in one single product are typical examples. Function integration, or optimisation, can open up markets for new environmentally designed products, thus giving manufacturers opportunities for increased sales.

- **Easy maintenance and repair**
Maintenance includes periodic and preventive repairs as well as minor servicing. Proper maintenance will conserve resources and prevent pollution. Designers should develop products that can be easily maintained by relatively unskilled users who can access all the necessary parts and components. Procedures for maintenance should be simple and all necessary information (frequency of maintenance, trouble-shooting procedures, tools required, life expectancy of components etc.) should be given to the product user. A designer should design a product so it can be repaired when necessary. Product life will be extended for an easily repaired product that relies on interchangeable and standard parts. The repair of the product should be inexpensive; high costs associated with the repair of some products, or the replacement of some parts, can make it an unrealistic option. Repairable products should be provided with complete after care service. Easy maintenance and repair not only reduce environmental impacts, they reduce costs and can be used as marketing tools.

3.1.3 Material Selection

Selecting the correct materials during the ecodesign of a product will reduce environmental impacts associated with resource depletion or end of life management. The objectives of this strategy are material life extension, minimisation of material use, and generally, use of low impact materials. The choices that will be made depend largely on the product characteristics and its life cycle. Life Cycle Assessment (LCA) is a tool that can be used to study alternative scenarios that use different materials and various disposal or recycling options. In most cases, substitutes can readily be found that reduce life cycle impacts but do not conflict with either cost or performance requirements. Material substitutions can be made for products as well as process materials, such as solvents and catalysts. Reformulation of material use can be a less drastic alternative to substitution of materials. Rather than entirely replace one material with another, the composition can be altered to achieve the same result. More information is available on the following materials types:
• **Recycled and recyclable materials**

Recycling can be a very effective resource management option. However, design for recyclability is not the ultimate strategy for minimising all the environmental impacts of a product. Using recyclable materials can reduce the amount of waste going to landfill but the environmental impact of recycling itself must also be examined. Life Cycle Assessment must be used to determine the best options in terms of materials selection and end of life management.

Applying ecodesign principles enhances recycling by:
• making the product easy to disassemble
• providing material identification
• simplifying and consolidating the product parts
• providing an opportunity for material selection and compatibility checking

The quality of the recovered material plays a major role in viable recycling. There is no demand for low quality material so recycling is not possible even if it is delivered to potential users free of charge. Good quality recyclable material can be obtained by carefully sorting and segregating the different materials before they are collected, or during disassembly of the product.

Ecodesigners should consider incorporating recycled materials such as steel, aluminium, paper, cardboard, plastics, rubber and glass into their product design.

• **Renewable materials**

Renewable materials are those that are easily regenerated by the environment. These include materials from plants or animal sources. When considering the use of a renewable material, the full environmental impact during the life cycle should be examined.

For instance, a plastic bag may be a better environmental choice than one made of paper. Producing plastic bags creates less air, water, and solid waste pollution than producing paper bags. And because plastic is considerably lighter than paper, it takes less energy to transport and uses less landfill space. Also, in many modern landfills, even biodegradable materials, such as paper, degrade very slowly or not at all. However plastic is far from perfect.
Unlike paper it comes from a non-renewable resource, petroleum, and is not biodegradable.

- **Less material use**
  Designers should aim to minimise material use when developing environmentally friendly products. Reduced resource and energy use means lower manufacturing costs and less waste to be recycled or disposed of at the end of the product's life cycle. Designers should ensure that the volume and weight of materials used are optimised so that less energy is consumed during production, transport and storage. Minimising packaging materials will also reduce the overall material content of the product. Moreover, when a product and its packaging are reduced in size and volume, more products can be transported in a given vehicle.

- **Low energy content materials**
  This strategy refers to the use of materials that are produced using the lowest amount of energy to extract, process and refine them before their use in product manufacture. This amount of energy is also referred to as "embodied energy". Wherever possible material from the most energy efficient suppliers should be included in the design. Materials produced using greater amounts of energy will be generally more expensive. Using environmentally friendly materials can therefore lower production costs.

- **Use of low impact materials**
  Hazardous materials can cause major problems during their end-of-life management, for example toxic materials may cause poisoning, respiratory problems, cancer or other health problems.

3.1.4 *Production Optimisation*

Production processes should be optimised to minimise material use, energy consumption and waste production. This can be accomplished by redesigning existing processes to increase efficiency or by eliminating unnecessary production steps.
More information is available on the following production optimisation techniques:

- **Alternative production processes**
  Processes that cause environmental impacts should be replaced with alternatives that cause fewer impacts. However the effect of such process changes on cost and performance must also be assessed. Designers should be familiar with the best available technologies and equipment to complete a processing step. Process alternatives should always be evaluated within the life cycle framework to make sure that total impacts are reduced. Engineers and designers should also consider chemical, biological and mechanical alternatives.

- **Fewer production steps and improved process layout**
  Process optimisation involves reducing the number of production steps and improving process layout to increase process efficiency.

- **Process control**
  Control systems are an integral part of process design. Well-designed process controls can prevent pollution and conserve resources. The production of off-spec items can generate a significant amount of waste. Setting appropriate tolerances improves accuracy, thus directly reducing environmental impacts. Improving regulatory compliance will reduce the likelihood of incurring environmental fines and therefore will reduce costs. Simple actions may also reduce impacts, for example installing control devices that switch off equipment when not in use.

- **Less energy consumption**
  Energy consumption can be minimised through process design. Waste heat, for example, could be used to preheat process streams. In addition, energy for pumping may be reduced by using larger diameter pipes to cut down frictional losses. Significant amounts of energy can be saved by the use of more efficient process equipment, for example high-efficiency motors and fans. Adequate maintenance and use of the right size equipment also greatly affect energy use.
• **Lower waste production**
  Process optimisation minimises waste production by increasing the efficiency of material use and therefore decreases the amount of material sent to landfill. This can also be referred to as reducing the "non-product output" per unit of production.

• **Renewable energy utilisation**
  Solar thermal systems can be used for heating processes in the low to medium temperature range. This will reduce fossil energy consumption and therefore develop a more environmentally friendly way of production. Unlike conventional energy systems, the use of solar energy requires a comparatively large investment at the beginning, leading to reduced costs during the operating period. Current low energy prices can lead to long payback periods, but benefits like emission reduction or freedom from the uncertainties of the fossil energy markets should be valued alongside economic considerations.
  Wind energy is another example of an alternative to electricity production with much lower environmental impacts.

3.1.5 *Distribution Optimisation*

Optimisation of product distribution, by using more efficient transport and packaging systems, can reduce costs and minimise environmental impacts.

**Packaging**
Products should be properly packaged for damage free distribution. The following strategies may be used to design efficient packaging:

- Packaging reduction
  - elimination: suitable products could be distributed unpacked
  - use of reusable packaging
  - changes to products
  - material reduction
- Material substitution
- use of recycled materials
- use of degradable materials
- use of less hazardous materials
- use of materials that are more easily handled as waste

**Transportation**
Life cycle impacts of transportation can be reduced by:
- using energy efficient modes of transportation
- reducing air pollutant emissions (for example, by properly maintaining the vehicles)
- optimising vehicle capacity
- ensuring proper containment of hazardous materials
- optimising the routes to reduce distance travelled
- reducing the size of the product

3.1.6 *Product Use Optimisation*
High use of energy and other consumables during the life of a product greatly contribute to its overall environmental performance. Optimisation of energy efficiency and consumable consumption will minimise emissions and waste production. More information on the following product optimisation techniques is available:

- **Cleaner energy sources**
  Using renewable energy sources will lower fossil fuel consumption, resulting in lower emissions. Rechargeable batteries and kinetic energy may also be used in applications where appropriate. For industrial products or machinery, the use of cleaner energy such as natural gas, or low-sulphur energy sources, will also have a positive effect. When there are no options to use other forms of energy, increasing energy efficiency will be the only solution to lower energy consumption.

- **Lower energy consumption**
  Energy efficiency reduces electricity or fossil fuel consumption and lowers emissions to the environment, especially for energy-intensive products.
Energy consumption has already become a marketing tool for manufacturers of home appliances such as refrigerators or washing machines. Standby power, the energy used to maintain an appliance in readiness for operation, can often be significant. Improving insulation will decrease the energy consumption of products that are used for heating or cooling.

- **Reduction of consumables**
  Reduction, or more efficient use of consumables can be achieved by:
  - designing products for reduced use of consumables
  - providing and following advice about the right amount to use, or dosage
  - providing and following information on correct maintenance

- **Cleaner consumables**
  Consumables should be designed for reuse, remanufacture or recycling, for example rechargeable batteries that are managed properly during their end-of-life. Disposal of filters, cartridges and dispensers should be minimised. Producers should always provide consumers with information on the disposal (recycling, material information etc.) of consumables.

- **Reduction of consumables waste**
  If reuse or recycling is not possible the designer must ensure that the amount of consumable waste to be landfilled or incinerated is minimised.

3.1.7 **End of Life Management**

Environmentally friendly alternatives for the management of products and materials at end-of-life include recovery of the product for reuse or re-manufacturing, recycling of materials and responsible disposal. Selection of a product management technique is influenced greatly by the mix of products, recovery techniques and economics. The technique must be evaluated both in terms of its environmental impact and how sustainable it is. The ecodesign of the product is a major factor in the implementation of an environmental friendly strategy for end of life management.
• **Reuse of product**
  Products must be designed so they can be quickly and easily taken apart and the separated components used again in the production of another product. These products can be manufactured and brought to market more quickly than products made from all new parts. Consequently, the company’s profits will increase. Design for reuse is not only beneficial to the environment, it also helps decrease production costs and increase profits.

• **Re-manufacturing**
  Re-manufacturing includes collection of product parts by type, cleaning them, and inspecting them for repair and reuse. Re-manufactured products are reassembled using recovered and new parts where necessary.

• **Design for disassembly**
  Design for Disassembly ensures the product and its parts are easily reused, re-manufactured or recycled at the end of their useful lives. The following strategies may be used:
  • use of materials that can be easily recycled, re-manufactured or reused.
  • use of fasteners and connectors that enable easy and quick disassembly.
  • design of the product’s structure so it can be disassembled quickly and cheaply without damaging any of the parts.

• **Recycling of materials**
  Recycling reclaims useful materials that can be used again in new products. Separation of different materials increases the value of the recycled materials by removing contaminants, hazardous materials, or high value components. The components can be separated manually or automatically.

• **Design for safe disposal**
  If disposal is the only option available to the consumer the designer must ensure:
• the use of toxic or hazardous materials is avoided
• safe disposal instructions are provided
• biodegradable materials are used wherever possible

3.2 Life Cycle Assessment Principles

As environmental awareness increases, companies have started to assess how their activities affect the environment. Society has become concerned about the issues of natural resource depletion and environmental degradation. Many businesses have responded to this awareness by providing “greener” products and using “greener” processes. The environmental performance of products and processes has become a key issue, which is why some companies are investigating ways to minimise their impact on the environment. Many companies have found it advantageous to explore ways of moving beyond compliance using pollution prevention strategies and environmental management systems (EMS) to improve their environmental performance. One such tool is called Life Cycle Assessment (LCA). This concept considers the entire life cycle of a product.

According to the Society of Environmental Toxicology and Chemistry (SETAC), LCA provides a way of assessing the environmental burdens associated with the whole life cycle of a product or service, from its cradle to its grave. “Cradle-to-grave” begins with the gathering of raw materials to create the product and ends at the point when all materials are returned to the earth. The LCA methodology evaluates all stages of a product’s life from the perspective that they are interdependent, meaning that one operation leads to the next.
LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). By considering impacts throughout the product life cycle, LCA provides a comprehensive overview of the environmental characteristics of that product or process and a more accurate picture of the true environmental trade-offs in product selection.

**Advantages of LCA**

There are a number of advantages of carrying out LCAs. These can be summarised as:

1. **Improved product design**
   
   LCA can be used to aid decision-making during product or process design or re-design. Businesses can use LCA to compare the environmental impacts of different design options and assess whether any have potentially significant environmental advantages or disadvantages. In this way, LCA will enable a systematic evaluation of the environmental impacts associated with a specific product.
2. **Provision of environmental information**

With an increasing focus on life-cycle thinking throughout the supply chain, it may often be necessary for companies to provide information about the environmental impacts of their products to others in the chain. This information may be required, for example, by the government, other producers or by the public. By using LCA, the industry will have a ready source of data. LCA quantifies the inputs to and outputs from each life cycle stage of production. It will then relate these inputs and outputs to environmental impacts and specific environmental areas of concern.

3. **Marketing**

LCA can be used as a marketing tool. The fact that LCA has been applied to a product's development process indicates that the resulting product is likely to be less polluting to the environment. This account of the use of the LCA tool could be a driving force for consumers to prefer environmentally friendly products.

4. **Financial benefits**

LCA examines a product's life cycle and identifies where the main environmental impacts arise. These environmental impacts can be reduced by increasing the efficiency with which material and energy inputs are used. Increasing the efficiency of resource use will lead to a reduction in the quantity of inputs used and waste produced, thereby reducing costs.

5. **Life Cycle Assessment links with other environmental management tools.**

The LCA framework can be incorporated into environmental management systems (EMS) and environmental labelling schemes. There are both competitive and economic advantages of doing so.

   o **Environmental management systems (EMS)**

   The LCA methodology can be used within an environmental management system. For example, one aim of a company environmental policy may be to reduce the environmental impacts associated with its products. LCA provides the means of achieving this as it enables an assessment to be made of the impacts associated with the product across its entire life cycle.

   o **Environmental labeling**
All of the national environmental labeling schemes operating within the EU use LCA as the basis for setting the criteria that products must meet if they are to be eligible for an environmental label.

Applications of LCA

LCA is a technique that assesses the environmental performance and potential impacts associated with a product, process or service. This is done in a very analytical manner that can help a company to assess all of the inputs to and outputs from their production process. The LCA provides a comprehensive overview of environmental impacts via a stepwise process of:

- compiling an inventory of relevant energy and material inputs and environmental releases (e.g. emissions to air, solid waste disposal, wastewater discharge);
- evaluating the potential environmental impacts associated with identified inputs and releases;
- interpreting the results in order to make a more informed decision.

The main applications of LCA are in:
- investigating the source of problems related to a product or service;
- comparing options for improving a product or service;
- designing new products or services, or choosing between a number of comparable products or services.

The following table shows examples of LCA application within an organisation:

<table>
<thead>
<tr>
<th>Application</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment of Environmental Focus</td>
<td>Identification of areas for improvement</td>
</tr>
<tr>
<td></td>
<td>Product-oriented Environmental Policy</td>
</tr>
<tr>
<td></td>
<td>Environmental Management</td>
</tr>
<tr>
<td>Design Choice</td>
<td>Concept Selection</td>
</tr>
<tr>
<td></td>
<td>Component Selection</td>
</tr>
<tr>
<td>Material Selection</td>
<td>Process Selection</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Environmental Documentation</td>
<td>ISO 14000 Certification</td>
</tr>
<tr>
<td></td>
<td>Eco-labels</td>
</tr>
</tbody>
</table>

Product-oriented environmental policy is guided by a life-cycle approach: by describing the product life-cycle ‘from the cradle to the grave’, all of its environmental consequences can be analysed and all relevant actors identified.

Environmental management systems (EMS), like ISO14000 or EMAS, are concerned with meeting a company’s environmental goals. LCA, on the other hand, is concerned with assessing environmental consequences at all stages of a product or service’s life. Thus, by integrating LCA and EMS the producer satisfies environmental stakeholders at each life cycle stage of the company’s products and services.

LCA also makes a significant contribution to providing a scientific and transparent basis for establishing ecological criteria for the EU eco-label scheme. Eco-labels may be awarded to products which are in compliance with specific ecological criteria. The criteria must be set using a cradle-to-grave approach and should consider all relevant environmental aspects at each stage of a product’s life.
4. ECODESIGN CASE STUDY OF ELECTRONIC PRODUCTS

The case study of a ISDN modem and a fixed telephone device, both produced by Intracom S.A., will be used as examples of the implementation of ecodesign strategies.

4.1 Life Cycle Considerations

4.1.1 Fixed telephone devices

The LCA study of the telephone device took into consideration the investigation of the production cycle, including the assembly of the telephone device and component manufacturing. Material and energy consumption, emissions to the environment and disposal problems were also recorded.

The sales package of an IRIS 6001 telephone device generally consists of the IRIS telephone device, the device requisites, and the packaging material. The telephone device includes the plastic covers and bases, a printed circuit board and other electronic components. Electronic devices have a very complicated structure and material composition. The IRIS telephone device consists of more than 170 components. Most of these components are made up of large variety of materials and substances. In the device, the mechanical components like housing are mostly made up of polymers, and the electrical and electronic components mainly of metals.

The IRIS telephone consists of the following components:

- The plastic base of the device
- The plastic cover of the device
- The PCB component
- other components (e.g. loudspeakers, keypad, hook-switch, screws, labels etc.)

Figure 4.1.1 presents the contribution of the IRIS package components to the total environmental score and Figure 4.1.2 their relative contribution to the impact categories. The IRIS telephone device has by far the greatest contribution (78.11%)
to the total environmental score. The IRIS requisites and packaging material contribute by 12.40 and 9.49% respectively to the total environmental impact score.

**Figure 4.1.1: Environmental scores of the IRIS package**

The IRIS 6001 telephone device presents environmental impacts related to the production of the various components that comprise the device. The biggest part of the device is made up of plastic, paper (as a packaging material), and stainless steel.

**Figure 4.1.2: Environmental scores of the IRIS package components**
Other materials that the device is composed of are bakelite, copper, aluminium, steel and ceramic. The total weight of the IRIS product is 891 grams.

The electronic components of the device weight less than 80g, thus less than 10% of the total weight of the materials. The chemical content of each electronic component is shown in Figure 4.1.3. The basic materials that make up the components are aluminium, copper, nickel, epoxy resin, polyamide, polyester and polyphenylene sulphide.

**Figure 4.1.3: Chemical content of the IRIS telephone device**

The plastic components that constitute the base and the cover of the telephone set and the handset of the device, present a very high environmental impact compared to the rest of the components (Figure 4.1.4). This happens due to the fact that the above components constitute the biggest part of the telephone set. The energy used for the manufacture of the various components has also a significant impact to the environmental score of the device. The printed circuit board is the third component with a large contribution to the environmental impact score of the device. The electronic components packaging and some steel parts of the device also have a negative impact to the total score.
The results of the life cycle assessment study have shown that the IRIS 6001 telephone device presents environmental impacts related to the production of the various components that comprise the device. Acidification and the release of heavy metals constitute the major part of the environmental effects of the production phase. Carcinogenic substances, winter smog formation and photochemical oxidant formation also contribute to the total environmental score. Eutrophication and global warming potential have a small contribution.

4.1.2 Modem devices

The LCA study of the modem device included the investigation of the production cycle including the assembly of the telecom device and component manufacturing. The study also investigated the impacts regarding the use phase of the electronic
product. Material and energy consumption, emissions to the environment and disposal problems were also recorded.

The sales package of a NETMOD device generally consists of the NETMOD device (NETMOD GREECE V.5), the installation material, device requisites, and the packaging material. The NETMOD device represents 62% of the total weight of the product. The requisites represent 25% of the total weight, the packaging materials the 12% and finally the installation material only 1%. Internally the NETMOD consists mainly of two printed wiring boards with active components like Integrated Circuits (ICs), and passive components like capacitors and resistors mounted on it.

Figure 4.1.5 presents the total environmental score of the NETMOD package and the environmental scores of the various impact categories. Acidification and heavy metals appear to be the most important environmental effects of the package. Carcinogenic substances, global warming potential, eutrophication potential and photochemical oxidant formation have much less effect to the environment.

![Figure 4.1.5: Environmental scores of the NETMOD package](image)

Figure 4.1.6 presents the contribution of the NETMOD components to the total environmental score and Figure 4.1.7 their relative contribution to the impact categories. The NETMOD device has by far the greatest contribution (97.5%) to the
total environmental score. The NETMOD requisites and packaging material have a very small contribution by 1.25 and 1.14% respectively. Acidification contributes to the total score by 31.6% while heavy metals by 28.4%. Winter smog creation and carcinogenic substances contribute much less by 16.7 and 11.7% respectively. Global warming potential contributes to the total by 6.9%.

Figure 4.1.6: Environmental scores of the NETMOD package components

Figure 4.1.7: Percentage contribution of the NETMOD package components to the EI95 environmental scores
The biggest part of the modem device is composed of plastic, iron, copper, cardboard (as a packaging material), and phosphor bronze. Other materials that the device is composed of are bakelite, liquid crystal, epoxy resin, aluminium, ceramics, aluminium, various alloys and metals (Figure 4.1.8).

The environmental impact of the substances that are included in the device could be generated either during their production phase, or during their final disposal. These include chemicals, such as lead, molybdenum, antimony, manganese compounds, PVC, and metals. The metals include silver and gold. The environmental impacts of these metals are generated during their production phase.

Lead can be found among the electronic components of the NETMOD device in resistors, in the form of lead monoxide. It can also be found as additive in PVC in certain capacitors. Lead as a solder (wave and SMT soldering) exists in a total amount of 0.30% of the total weight of the package or 0.35% if the packaging material is excluded.

PVC can be found in specific capacitors. In these components the percentage of PVC is around 4%. The total amount of PVC is less than 0.08%.

Molybdenum can be found only in some diodes in a total of 0.046% of the device.

**Figure 4.1.8: Chemical content of the NETMOD device**
The results of the life cycle assessment study have shown that the NETMOD device presents environmental impacts related to the construction of the various electronic components that comprise the device. Acidification and the release of heavy metals to the environment constitute the major environmental impacts of the production phase while winter smog formation, carcinogenic substances and global warming potential also contribute to the total environmental score. Eutrophication, photochemical oxidant formation and ozone depletion have a very small contribution.

4.2 netMod Redesign

4.2.1 Minimisation of heavy metals & Component suppliers’ selection

In accordance with Directive 2002/95/EC, the improvement suggestion No 4 recommends the minimisation of the use of heavy metals in the netMod product. Heavy metals include lead, mercury, cadmium, and hexavalent chromium. The heavy metal that is present in netMod in a quantity / percentage higher than the defined thresholds is lead. Lead can be found among the electronic components of the netMod device in resistors, in the form of lead monoxide. It can also be found as additive in PVC in certain capacitors. PVC can be found in specific capacitors. In these components the percentage of PVC is around 4%.

In order to eliminate lead in the product, it was necessary for the company to review and adjust its supply chain around the product. The following activities were performed to achieve this.

- The device was analysed down to the component level.
- The components (approximately 320) were then distributed to the responsible component engineers according to their component type.
- The component engineers communicated with the corresponding suppliers in order to get the new ROHS compliant part numbers.

This effort was quite successful, as the component engineers managed in the majority of the cases to acquire the requested information. There were cases however, that they encountered several problems, such as:
• Some manufacturers did not have at that moment a determined policy regarding planning and scheduling the conversion of non-RoHS compliant components.

• Some manufacturers would provide RoHS compliant components but would not change their part number. This raised the need for the company to implement a way to identify this RoHS compliant component from the corresponding non RoHS compliant one.

Following this process, the netMod components were classified into the following categories:

- Components that were converted by the manufacturer to RoHS compliant components with change in the part number
- Components that were converted by the manufacturer to RoHS compliant components without changing the part number
- Components for which the manufacturer supplied a conversion schedule
- Components that were revoked and replaced by RoHS compliant components without pin-to-pin correspondence (implying in this way the need for redesigning the corresponding card)

4.2.2 Minimisation of the product mass

In order to minimise the netMod mass, the company had to investigate alternatives for minimising the mass of the various product parts and components.

netMod is composed by two different boards:

- the motherboard that is used to supply power to the device
- the daughter board that is the processing unit of the product where all processes of netMod operation are executed.

The examination of the possibility to minimise or reduce the mass of the motherboard indicated that no significant changes to its total weight or mass could be achieved. The main reason behind this is the standard technology used that does not allow of alternatives.

The company efforts then were focused on the daughter board where significant changes were achieved at component level. Various components were replaced by alternative ones that are smaller and lighter. The replacement was performed based on the technology available in the market, the suitability of the technology for netMod
operation, as well as on the company efforts to have RoHS compliant components on the product (according to improvement suggestion No4).

The redesign of the daughter board was performed mainly by engineers of the R&D division including hardware (VLSI, PCB designers) and software engineers, mechanical engineers, engineers of EMC (Electromagnetic Compatibility) and safety test laboratory. Their efforts were supported by a component engineer and a production testing team. The redesign lasted for six months.

Figure 4.2.1 presents the one side of the daughter board of netMod version 5 and the corresponding side of the redesigned daughter board. The components that were replaced are highlighted. Each of these components is further described in the following paragraphs.

Figure 4.2.1: The upper side of the daughter boards of netMod V5 and of the redesigned product.

The Dual Codec (Table 1) is used to convert the analogue interface to digital interface and the opposite. It is called dual because it is referred to two subscribers.
Table 1. Dual Codec

<table>
<thead>
<tr>
<th></th>
<th>Version 5</th>
<th>Version 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Dual Codec</td>
<td>Dual Codec</td>
</tr>
<tr>
<td>Weight</td>
<td>0.95 gr</td>
<td>0.28 gr</td>
</tr>
<tr>
<td>Dimensions</td>
<td>17.2x17.2 mm</td>
<td>12x12 mm</td>
</tr>
<tr>
<td>Mass</td>
<td>724.808 mm$^3$</td>
<td>172.8 mm$^3$</td>
</tr>
</tbody>
</table>

The Subscriber Line Interface Circuit (SLIC) (Table 2) is used to control the high voltages needed for operating the terminal equipment connected to the telephone line.

Table 2. SLIC

<table>
<thead>
<tr>
<th></th>
<th>Version 5</th>
<th>Version 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Subscriber Line Interface Circuit (SLIC)</td>
<td>Subscriber Line Interface Circuit (SLIC)</td>
</tr>
<tr>
<td>Weight</td>
<td>2.02 gr</td>
<td>0.16 gr</td>
</tr>
<tr>
<td>Dimensions</td>
<td>14.2x16 mm</td>
<td>10x6 mm</td>
</tr>
<tr>
<td>Mass</td>
<td>840.64 mm$^3$</td>
<td>96 mm$^3$</td>
</tr>
</tbody>
</table>

The next component is a static Random Access Memory (RAM) organized as 131,072 words by 16 bits and operates on low power supply voltage from 2.7V to 3.3V.

In netMod version 5, there were two Static RAMs that were replaced by a smaller one according to Table 3.

The microcontroller (Table 4) is a fully integrated controller for ISDN/IDSL terminal equipment applications with advanced data communications features, offering integrated USB interfaces. It has been specifically designed for control and interface functions between ISDN access devices, and other terminal functions, such as analogue interfaces. It incorporates an ARM7TDMI RISC core, which can perform all of the terminal control and data flow management functions required in software. It can thus form the core of an Intelligent NT, or ‘NTplus’ unit, as well as being the core of router/multiplexer equipment for data applications.
Table 3. Static RAM

<table>
<thead>
<tr>
<th></th>
<th>Version 5</th>
<th>Version 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Static Ram</td>
<td>Static Ram</td>
</tr>
<tr>
<td>Weight</td>
<td>0.72 gr (x 2 components)</td>
<td>0.46 gr</td>
</tr>
<tr>
<td>Dimensions</td>
<td>20x8.40 mm (x 2 components)</td>
<td>18.40x11.76 mm</td>
</tr>
<tr>
<td>Mass</td>
<td>201.6 mm3 (x 2 components)</td>
<td>259.66 mm3</td>
</tr>
</tbody>
</table>

Table 4. Microcontroller

<table>
<thead>
<tr>
<th></th>
<th>Version 5</th>
<th>Version 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Microcontroller (MTC-20285)</td>
<td>Microcontroller (MPC870)</td>
</tr>
<tr>
<td>Weight</td>
<td>5.44 gr</td>
<td>1.83 gr</td>
</tr>
<tr>
<td>Dimensions</td>
<td>32x32 mm</td>
<td>23x23 mm</td>
</tr>
<tr>
<td>Mass</td>
<td>3584 mm3</td>
<td>1322.5 mm3</td>
</tr>
</tbody>
</table>

Figure 4.2.2 presents the bottom side of the daughter board of netMod version 5 and of the redesigned one. The difference in the two versions is obvious. The redesigned one is much simpler and straightforward than the one used in version 5. In addition, several small components were combined and replaced by fewer and smaller ones. Due to the very small weight of these components, we will not analytically present them here. Furthermore, it should be noted that the two Flash memories and the integrated circuit are now placed in the upper sided of the redesigned daughter board. The above described changes lead to a decrease of the weight of netMod daughter board of 10 gr.
4.2.3 Use of recycled material in product packaging

According to the improvement suggestion No 6, the use of recycled material in product packaging should be promoted. INTRACOM Telecom had already started considering the use of recycled material in product packaging wherever this is feasible.

In the redesigned netMod, 90% of the product packaging is made of recycled material. Each netMod device is packaged in layers. All the interior layers used for packaging product parts are made of recycled material. Regarding the exterior layer, it is a demand of the company’s customers, to be of high resistance. In addition, the material used for the exterior packaging should allow for printing on it. Consequently, in order to meet this two main requirements, the exterior package of the netMod device is made of non recycled paper.

Finally, a bigger box is used for packaging ten (10) ten packaged netMod devices. This box is also made of recycled material. The product manual is made of non-recycled material due to the high cost required for using recycled material. As it has already been mentioned, netMod is a highly...
cost sensitive product and at the current state of its life cycle such high product-related costs couldn't be recovered.

4.2.4 Product Manual update with guidelines for recyclers and end users

INTRACOM Telecom plans to update product manual with:

- Information on the materials used in the product and guidelines for separating the materials. The target of this update is the recyclers and the goal is to facilitate the process of material separation at the end of the product's life.
- Information on how to properly dispose the product at the end of its life. The target of this update is the end users of netMod and the goal is to increase awareness on recycling and facilitate the recycling of the product and its components.

For appropriately performing this update, INTRACOM Telecom anticipates the guidelines and the appropriate templates from the National Body of Recycling. As soon as these guidelines are available, the company will proceed with the implementation of the above update.

4.3 Redesign of the Production Cycle

The redesign of the production cycle received as input intermediate and final results of the LCA study, as well as first results of the product (netMod) redesign. According to the LCA study, the major environmental effect during the production phase of the product is the release of heavy metals. The heavy metal that is released in quantities higher than the defined thresholds is lead. Furthermore, according to the improvement suggestion 5 “Elimination of the use of lead as a solder. Proper capacitors should be used that allow the use of lead-free solder.”

Consequently, the redesign of the production cycle focused on moving / transforming to a lead-free manufacturing process. For achieving this transformation in an efficient and cost-effective way, it was necessary to perform a series of tests and trials aiming at improving INTRACOM Telecom's experience and knowledge, locating all weaknesses of the company's
equipments and materials, identifying upgrade requirements for them, and evaluating (ROHS compliant) solder pastes, solder alloys and solder fluxes proposed by the company’s suppliers.

These tests were performed in two phases:

- During the first phase, the existing manufacturing process was used for testing new ROHS compliant components based on preliminary results of Action 1.
- The objective of the first phase was to ensure that the new ROHS compliant components are compatible with the existing manufacturing process and thus allow us to focus on the process issues during the phase of testing.
- The second phase of testing aimed at evaluating alternatives options for the to-be ROHS compatible manufacturing process.

The production cycle redesign lasted for almost a year and was performed mainly by the working team from the Manufacturing in close collaboration with the Quality Assurance.

In accordance with the results of the LCA the action of redesigning the production cycle focused on moving to a ROHS compliant process. For successfully implementing such a transformation, it was necessary to perform a series of tests and trials aiming at improving INTRACOM Telecom’s experience and knowledge, locating weaknesses of the current infrastructure and materials, identifying requirements for upgrading them, and evaluating (ROHS compliant) solder pastes, solder alloys and solder fluxes proposed by the company’s suppliers.

The trials performed indicated that the printed circuit assemblies manufactured with the lead-free soldering technology experience higher processing temperatures than boards assembled using the standard lead-containing soldering process. Currently, most of the electronic industry supports the SnAgCu family of alloys to replace Sn-Pb solders. There are several concerns related to the high melting temperature of the new alloys, which represents an increase of about 40º C compared to the Sn-Pb alloy. Due to the higher temperature of the lead-free process, some equipment, like the SMT reflow ovens, can reach or exceed the borders of their technical capability.

Also, due to the demanding conditions of the new process, the use of nitrogen is beneficial for the soldering process. Using the nitrogen atmosphere instead of the air atmosphere when soldering may reduce oxidation, improve the solder joint quality and reduce dross production, thus save money and lessen maintenance requirements.
In order to address the needs identified, INTRACOM Telecom had to improve the already available infrastructure (Wave Soldering machine) and upgrade the machine in order to be able to use nitrogen. In this context, two systems were purchased and installed in the Wave Soldering machine:

- Wave Soldering Retrofit System (ALIXTM IN2ERTWAVE)
- Solder Pot made by titanium

Furthermore, a new SMT Reflow Soldering System (SMT Quattro Peak L N2) was purchased and incorporated in the new manufacturing process in order to perform soldering of SMT components using lead free technology.

Regarding the PCB finishes, it is clear that each one has its own set of pro's and con's and that the selection has to be made considering issues as cost of product, flat surface coplanarity requirement, shelf life and product assembly process requirements.

Figure 4.3.1: The new reflow soldering system implemented in the new manufacturing process.

4.4 End of life management pilot programme

The end of life management pilot programme proceeded to the recycling of 200 NETMOD appliances, 200 PC towers and 200 telephone appliances. The first two
categories of appliances originated from the end of life appliances storage area of INTRACOM Telecom (appliances that have been withdrawn because of worn out technology or damage), while the telephones provided by the responsible Greek Collective Alternative Management Scheme of Waste Electrical and Electronic Equipment “RECYCLING APPLIANCES S.A”.

The transport of appliances from the storage area of INTRACOM Telecom and the warehouses that collaborate with the RECYCLING APPLIANCES S.A., were carried out by the Environmental Protection Engineering S.A. (mother company of Polyeco S.A.).

When the appliances transferred to the installations of Polyeco S.A. at Aspropyrgos, they were weighted per type and stored in a specifically licenced for WEEE storage warehouse.

With regard to the process of recycling of appliances, forklift vehicles transferred the appliances from the stocking area to the area of disassembly. Polyeco S.A. had set up work lines in an industrial building of its installation, where well educated personnel begun the disassembly of appliances. The education of personnel in appliances disassembling was carried out by Polyeco.

During the disassembly process the different parts of the appliances were collected and stored in separate special containers properly labeled.

For big volume items like plastic cases of netMod’s shredding was carried out. The plastic cases transferred to a shredder where they were cut into small pieces.

The resulted materials stored properly depending on its type, hazardous or not, and following, they will be disposed at proper Greek companies (e.g. steelwork companies) or at the responsible Collective Schemes of Alternative Wastes Management (for example batteries will be disposed at the collective scheme of batteries management called AFIS, printed circuit boards will be disposed at RECYCLING APPLIANCES S.A. e.t.c.). These companies issued the certification of final disposal.

During the process of disassembling, certain critical parameters as disassembly time, weight and volume were recorded, in order useful conclusions to be made.

These conclusions could help for the re-designing of appliances and the management of appliances at the end of their life cycle.

The following tables present the results of disassembly for netMod, fixed telephone devices and PCs towers:
## NETMOD

<table>
<thead>
<tr>
<th>Total disassembly time: 51 min</th>
<th>Plastic: 54.7 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean disassembly time: 15.3 sec/item</td>
<td>Printed Circuit Boards: 166.2 kg</td>
</tr>
<tr>
<td>Number of personnel: 3</td>
<td>Cables: 20 kg</td>
</tr>
<tr>
<td>Man-hours: 1h and 33min</td>
<td></td>
</tr>
</tbody>
</table>

### Fixed Telephone devices

<table>
<thead>
<tr>
<th>Total disassembly time: 358 min</th>
<th>Plastic: 84.6 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean disassembly time: 107.4 sec/item</td>
<td>Ferrous parts: 14.4 kg</td>
</tr>
<tr>
<td>Number of personnel: 3</td>
<td>Screens: 0.6 kg</td>
</tr>
<tr>
<td>Man-hours: 17h and 54min</td>
<td>Printed Circuit Boards: 9.6 kg</td>
</tr>
<tr>
<td></td>
<td>Cables: 12.8 kg</td>
</tr>
<tr>
<td></td>
<td>Headphones - sound-boxes: 9.8 kg</td>
</tr>
<tr>
<td></td>
<td>Batteries: 0.3 kg</td>
</tr>
</tbody>
</table>

Note: The disassembly time for the IRIS 6001 telephone device was 145-165 sec.

### PC towers

<table>
<thead>
<tr>
<th>Total disassembly time: 468 min</th>
<th>Plastic: 124 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean disassembly time: 140.4 sec/item</td>
<td>Ferrous parts: 1062.3 kg</td>
</tr>
<tr>
<td>Number of personnel: 4</td>
<td>Printed Circuit Boards: 160.2 kg</td>
</tr>
<tr>
<td>Man-hours: 31h and 12min</td>
<td>Cables: 43.2 kg</td>
</tr>
<tr>
<td></td>
<td>Power suppliers: 192.8 kg</td>
</tr>
<tr>
<td></td>
<td>Batteries: 0.57 kg</td>
</tr>
<tr>
<td></td>
<td>Drivers: 170.1 kg</td>
</tr>
</tbody>
</table>
Consequently the total volumes of the materials are:

<table>
<thead>
<tr>
<th>Total volumes of materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic: 263.3 kg</td>
</tr>
<tr>
<td>Ferrous parts: 1076.7 kg</td>
</tr>
<tr>
<td>Printed Circuit Boards: 336 kg</td>
</tr>
<tr>
<td>Cables: 76 kg</td>
</tr>
<tr>
<td>Power suppliers: 192.8 kg</td>
</tr>
<tr>
<td>Batteries: 0.87 kg</td>
</tr>
<tr>
<td>Drivers: 170.1 kg</td>
</tr>
<tr>
<td>Headphones - sound-boxes: 9.8 kg</td>
</tr>
<tr>
<td>Telephone Screens: 0.6 kg</td>
</tr>
</tbody>
</table>

The whole process is presented schematically in Figure 4.4.1.

**Analysis of the recycling findings**

As far as the disassembly time is concerned, it is highly depended on the type of the appliance. In the cases of complicated or old technology appliances, more time is needed for them to be disassembled. The shorter time was recorded during the netMod disassembly, around 15-20 sec, while for the telephone devices the time was 1.8 - 2.5 min. The longest disassembly time was recorded during the disassembly of the PC towers, 2.5-3.0 min.

Although re-use is not applicable in the case of netMod, INTRACOM TELECOM had adopted the suggestion with the goal to achieve a higher level of recyclability. Valuable feedback on this issue would be given by the pilot programme related to the end-of-life management and better insight and knowledge would be gained in order to further improve the product’s recyclability.

The results of the pilot programme indicated that the netMod device is designed to be easily disassembled. The personnel managed to disassemble 200 devices in 1 hour and 33 minutes.

The working team of INTRACOM Telecom and more specifically the Research and Development (R&D), Component engineering and Purchasing teams, collaborated in order to examine all the possibilities to further improve the product’s recyclability through a proper redesign. Taken into account the results of the disassembly
process, the knowledge and their experience it was decided that the product recyclability it is in a high level and no further improvements can be made.
The pilot recycling programme confirmed that the product can be easily disassembled.

Figure 4.4.1: End of life Management activity flow
Important results related to the recovered material were also recorded. More specifically, 70% of the total weight of netMod recovered materials (plastic, boards and cables) are Printed Circuit Board parts. Due to the fact that the boards contain silver, cold and platinum, their exploitation is considered to be very profitable.

Printed Circuit Boards have to be transported abroad for final disposal in an approved area. In Greece there are no such units as the quantities of boards in the Greek market are quite low. That is why an investment on developing such unit cannot be justified. An indicative sell price for boards is 800-1200 €/ton. However, there is also a cost for transporting the materials abroad which is estimated to 100-200 €/ton.

With regard to the fixed telephone devices the results were different. 65% of the total weight of the recovered materials (plastic, ferrous parts, boards, screens, headphones - sound-boxes, cables and batteries) were plastic parts.

One problem that is recognized in the case of the plastic materials is that there is a big variety of plastics which have to be separated before their disposal. Segregation is the procedure that it is usually followed for plastic materials before its disposal and sale to an approved plastic recycling unit. If no segregation is performed, plastics are used as a secondary alternative fuel. An indicative sell price for plastic materials (polypropylene or polythene) is 70-130 €/ton.

PC towers were the third type of appliances that were recycled. As it has already been mentioned the recycling of such devices would allow the consortium to come to more general conclusions applicable to a wider spectrum of WEEE (Waste Electrical and Electronic Equipment). 60% of the total amount of the recovered materials (plastics, ferrous, boards, cables, power suppliers, hard disks-drivers and batteries) were the ferrous parts. Ferrous parts are disposed and sold to steel mills. Their price depends on the quality of the metal. More specifically indicative price for rustless ferrous is 1.200-2.000 €/ton.

4.5 Ecolabel criteria

Ecolabeling, or environmental labeling, is a guide to consumers which helps them make informed environmental choices about the products and services that they
require. Ecolabeling makes a positive statement that identifies products and services as being less harmful to the environment than similar products or services used for a specific function. It is also different from the minimum product standards or requirements; the key difference is that ecolabeling is intended to reward environmental leadership.

Ecolabeling is based on life cycle assessment which considers the impact on the environment at every stage of the product’s life cycle from cradle to grave. Criteria are established on the key environmental effects and identify products that have a substantially lower environmental impact. Criteria are also established on performance, in order to ensure that ecolabeled products are fit for use and their performance is of the same standards as other products in the category. The criteria are reviewed and possibly made more stringent at regular intervals (usually three years) to allow for improvements in the environmental performance or technology improvement.

The European Commission’s ecolabeling scheme, EU Flower, is part of a broader strategy aiming at promoting sustainable production and consumption. Being a market-based instrument, the primary function of the EU Ecolabel is to stimulate both the supply and demand of products with a reduced environmental impact. With respect to supply, the EU Ecolabel has a clear objective of encouraging businesses to market greener officially licensed products. On the demand side, the scheme gives the European consumer the means to make informed environmental choices when purchasing.

The objective to "provide guidance to consumers" has considerable implications with regard to economic efficiency and the flow of information. In fact, the “EU Flower” reduces costs for consumers, manufacturers and retailers by lowering the time and effort needed to obtain and provide reliable information on life-cycle considerations, green products and specific European know-how on Integrated Product Policy, IPP.

At the same time, products eco-labeled in the EU scheme can give the consumer the guarantee that their compliance with established ecological criteria has been tested by independent third parties, the national and regional Eco-label Competent Bodies.

Information, as used by the scheme, is one key character of a market-based environmental policy. Diffusing information about the environmental impact of a product during its whole life-cycle will be essential in order to support sustainable consumption patterns.
Based on the Life Cycle Analysis, which has been conducted in the framework of the IPP-Tel project, ecolabel criteria have been developed under the European scheme concept and are being proposed for fixed telephone devices and ISDN modems. These criteria concern all the stages of the products life cycle. However, they particularly emphasize on the manufacturing (minimization of heavy metals, prohibition of the use of certain flame retardants in plastic parts etc.) and the end-of-life stage (free-of-charge take back, easy disassembling, user instructions, high percentage of recycled material in packaging etc.), which are the main phases of environmental concern for the particular products.

An objective of the EU ecolabel is to encourage manufacturers to market devices with reduced overall environmental impacts, with the aim of helping consumers make informed choices based on sound environmental information. In order to be awarded with the EU Ecolabel, a fixed telephone or a modem needs to comply with criteria, developed from life cycle considerations, which particularly emphasize on the manufacturing (minimization of heavy metals, prohibition of the use of certain flame retardants in plastic parts etc.) and the end-of-life stage (free-of-charge take back, easy disassembling, high percentage of recycled material in packaging etc.).

4.5.1 Environmental issues of a fixed telephone

4.5.1.1 Manufacturing phase

The impact on the environment due to the assembling of the fixed telephone is minor in relation to others phases like extraction of raw materials and manufacturing of materials / components. In the selection of the materials that will be used for the assembling of the fixed telephone, the following issues should be taken into account:

**Flame retardants**

Fire safety is an integral part of fire precautions. Fire precautions minimise the number of, and damage from, fires by reducing their initiation and limiting their propagation, meaning that life, health and property are protected. Flame retardants are chemicals which are added to combustible materials, like plastics, to render them more resistant to ignition. They enhance the fire safety level of combustible materials and are used in the circuit boards and cabinets of electronic equipment. However,
careful design of such equipment can reduce the possibility of a fire starting inside the equipment, and also the possibility of a fire spreading outside the equipment.

There are more than 175 different types of flame retardants, which are generally divided into five classes (Source: L.S. Birnbaum and D.F. Staskal, Brominated Flame Retardants: Cause for Concern?, Environmental Health Perspectives Volume 112, Number 1, January 2004):

- Brominated flame retardants
- Chlorinated flame retardants
- Phosphorus-containing flame retardants
- Nitrogen-containing flame retardants
- Inorganic flame retardants

Different types of flame retardants are better suited for different types of applications. Their suitability depends on factors such as the material to be flame-retarded, the fire safety standards with which the material must comply, and cost considerations. Brominated flame retardants are often the most cost effective flame retardant when both performance and cost are considered. In addition, the lower concentrations of brominated flame retardants required for most applications means that they are less likely to affect the physical and mechanical properties of the materials they are added to than other types of flame retardants (Source: BSEF - Bromine Science and Environmental Forum, An introduction to Brominated Flame Retardants, 2000).

Brominated flame retardants (BFRs) are a family of 75 chemical substances with different properties, characteristics, and performance and are mostly used in electronics and electrical equipment (these account for more than 50% of their applications). In the electrical and electronic equipment, BFRs are used in four main applications: in printed circuit boards, in components such as connectors, in plastic cover and cables (Figure 4.5.1).
Brominated flame retardants are often the most effective flame retardant when both performance and cost are considered. In general the presence of bromine in a typical flame retardant molecule offers the highest activity in combination with cost effectiveness. The choice of flame retardant systems one can use for a particular application will depend on how the material decomposes in a fire as well as the physical properties required. As BFRs, do act in the flame, they can be used in just about every application, indeed in some plastics and uses they may be almost the only choice. (Source: Bromine Science and Environmental Forum, BSEF)

However, brominated flame retardants (BFRs) have attracted considerable interest over the past few years because of their alleged persistence in the environment. Especially, two groups of brominated flame retardants, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) have been targeted by RoHS legislation as they are suspected to be carcinogenic. They can harm the human reproductive system, may be transformed into highly toxic compounds in the body and may cause tumours. They are toxic in aquatic environments, where they also accumulate and persist rather than breaking down into harmless compounds.

Due to the environmental and human risk, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) must not be contained in any part of the products, in accordance to the Article 4.1 of the Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment. This criterion is adopted both for fixed telephone devices and ISDN modems.

Recent revisions of ecolabel criteria for other electrical and electronic products have included a requirement that plastic parts weighing more than 25 grams shall not contain flame retardant substances or preparations that are assigned any of the following phrases: R45 (may cause cancer), R46 (may cause heritable genetic
damage), R60 (may impair fertility), R61 (may cause harm to the unborn child), R50 (very toxic to aquatic organisms), R50/53 (very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment), R51/53 (toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment) as defined in Council Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labeling of dangerous substances and its amendments.

**Heavy metals in materials**
Materials must not contain cadmium, lead or mercury except for impurities which cannot be avoided technically in accordance to EU Directive 2002/95/EC (RoHS). The maximum allowable concentrations of impurities in homogenous material are:
- Cadmium 0.01 w-%
- Lead 0.1 w-%
- Mercury 0.1 w-%

**Batteries**
According to the Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators, batteries accompanying the fixed telephone devices, whether they are incorporated into the devices or not, shall not contain more than 0,0005 % of mercury by weight; and more than 0,002 % of cadmium by weight (only for fixed telephone devices).

**Other**
- Plastic parts over 25 grams must not contain chlorinated polymers.
- Fluoro-organic additives, which are used to improve the physical properties of plastic, will be accepted provided they are not present in concentrations greater than 0.5 weight %.
- Plastic parts must have a permanent marking identifying the material, in conformity with ISO 11469:2000.

**4.5.1.2 Use phase**
Given that for most electrical and electronic devices, the energy consumption during use is usually the main environmental impact, it becomes obvious that this is not the case for a fixed telephone or a modem. Generally, the impact on the environment due to the use of these products is not considered to be very important, since the device have minor energy consumption (Source: “Life Cycle Assessment study of the IRIS 6001 telephone device” and “Life Cycle Assessment of the NETMOD device”, July 2005, IPP-Tel).

In the case of a fixed telephone device, the energy consumption is mostly dependent on the telephone network, with which the device is connected, and less with the device itself.

On the other hand, there is noticeable energy consumption for an ISDN modem. The ISDN modem uses power supply both from the telephone line and electrical network. The extra electrical power is needed so that the device can gain full advantages from the ISDN technology. Analysis for the NETMOD modem has shown that its energy consumption is about 0,576 kWh/day in normal operation mode and 0,01 kWh/day in stand by mode (Source: User Manual for ISDN Netmod, INTRACOM TELECOM). This consumption is considered to be relatively low even though it is constant, however it cannot be reduced due to the ISDN technology.

The most important issue that must be taken into account concerns the provision of information to the consumer about the device.

User instructions for environmental use

The following information must be specified in user information:

- Warranty period
- Information about the time period, in which spare parts will be available and guaranteed.
- Information about the design specifications of the telephone device, in order to enable proper reuse of parts and recycling
- Information about where used products and packaging can be deposited in accordance with local legislation (Information about the return system for electronic equipment, packaging, batteries in accordance with local legislation).
- Recommendation that the device should be turned off when not in use, in order to zero energy consumption (only for the ISDN modem)
4.5.1.3 End-of-life phase

The production industry of electrical and electronic equipment constitutes one of the most rapidly developing economic sectors, mainly due to technological innovation and market broadening. Technological development, consuming patterns and income increase have resulted in the production of huge quantities of waste of electrical and electronic equipment. (Source: Techno-economical Study for end-of-life management options of electrical and electronic equipment, May 2007, IPP-Tel)

Electrical and electronic equipment contains a significant number of hazardous substances, such as heavy metals (mercury, lead, cadmium, chromium). The magnitude of the environmental problems that are related to the existence of such substances is determined by their toxicity and the existing management practices. All the above factors render Waste of Electrical and Electronic Equipment (WEEE) as an issue of high environmental priority, while the production of electrical and electronic equipment comprises one of the most important economic sectors. (Source: Market & Consumer Behavior Analysis about end-of-Life management of telecom devices and Eco-Design, September 2005, IPP-Tel).

The environmental aspects and impacts from the end-of-life phase depend on how the device is managed at the end-of-life. If the device is mismanaged, then this phase results to significant environmental impacts, such as depletion of natural resources, land contamination, water and air pollution due to leaching of metals. The following issues must be taken into account under the end-of-life phase:

Reduction of ecological damage related to the use of natural resources by encouraging product upgrading and recycling.

The following issues must be taken into consideration:

- The device must be designed so that it is easy to dismantle and disassemble by one qualified person alone. This criterion has been proved to be very critical for the economical sustainability of the end-of-life management of the specific devices (Source: Market & Consumer Behavior Analysis about end-of-Life management of telecom devices and Eco-Design, September 2005 & "End of Life Management Strategy of the NETMOD and the IRIS telephone device", December 2005, IPP-Tel)
- 90% by weight of plastic and metal materials used must be recyclable on the basis of existing recycling technologies for the manufacture of high-quality long-life products.
- Plastic parts shall have no added lead or cadmium, nor metal inlays that cannot be separated easily, be of one polymer or compatible polymers (except for the cover), and have permanent marking identifying the material in conformity with ISO 11469:2000 standard.
- To reduce the multitude of materials, plastic casing parts that weigh more than 25 grams must consist of a single polymer or polymer blend. Polymer blends are permitted.
- At least one part over 25 gram must be made of reused plastic or recycled plastic (post-consumer recycling).

**Life-time extension**

Generally, there is a remarkable gap between the maximum technological life-time of electronics and the real time of use, due to consumer pattern favouring the newest, most advanced devices. However, a long life-time for a product will reduce environmental damage in relation to the use of natural resources by encouraging maintainability and later recycling of the product. Clearly, from a life-cycle perspective, repairing a product reduces the environmental impacts attributable to resource depletion; rather than buying a replacement product, the consumer simply buys a new component.

The life-time extension of a telephone can be increased from the design phase, if the devise is designed so that the display and buttons (there are the parts which are more vulnerable to damage) can be easily displaced. (only for fixed telephone devices).

Another factor that can increase the life-time extension of a telephone device is the guarantee of availability of compatible replacement parts and service for a time period of three years after the production of the specific device has ceased.

**Limitation of solid waste**

In order to limit the solid waste generating from the end-of-life phase of fixed telephones, the manufacturer must offer, free-of-charge, the take-back for recycling of the product and must provide information regarding the take-back policy applied at
national level in the user manual. In addition, the product shall meet the following criteria:

- The device must be designed so that it is easy to dismantle by one qualified person alone
- All packaging components shall be easily separable by hand into individual materials to facilitate recycling
- Cardboard packaging shall consist of at least 80% recycled material.
- The variety of the packaging materials must be minimized.

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