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ECO-DESIGN IN ELECTRONICS - THE STATE OF THE ART

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Abstract. *An attempt is made to consider the basic problems and concepts of eco- and sustainable design of electronic products. The problem is stated first where data are given to confirm that interaction of the electronics with the environment is no longer an unimportant issue. Than, the life cycle and the end-of-life management in electronics are considered in order to create statements and definitions related to the subject of eco- and sustainable design of electronic products. Guidelines for electronic eco-design are gathered together. The mutual interaction of eco-design and end-of-life management is considered in detail. Finally, several examples of successful eco-design of electronic products are described including examples of end of life management in an attempt to describe the status of the art.*

Key words: *electronics, eco-design, preseruable planning*

1. INTRODUCTION

The production of electrical and electronic equipment is one of the fastest growing domains of manufacturing industry in the Western world [1]. Electronics as a human activity becomes more and more influential. There is hardly any part of life where electrical and electronic equipment are not used. This includes home appliances, entertainment, telecommunication, industrial applications, automation, military, space applications etc. The number and weight of electronic components and equipment in use becomes so high that makes electronics comparable with other much "heavier" industries. In the year of 1988 the amount of electronic equipment reaching end-of-life measures 6 million tones and is expected to double in 2010 [2]. This means that about 20% of the municipal waste stream will be related to WEEE (Waste Electrical and Electronic Equipment).

In addition, the growth of the production of electronic equipment is directly related to the rise of use of virgin materials giving no opportunity to the nature to regenerate this

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kind of resource. This is especially related to rare elements being used in modern electronic components.

Finally, electronic equipment is using energy for its work. Some of the appliances are mostly in "stand-by" position being ready for function but not functioning. The amount of energy spent by electronic appliances both active and stand-by is enormous and any optimization leads to significant savings. One should have in mind that electronic components are produced in billions what may be stated for many types of equipment, too. Savings energy during function of these components and equipment may lead to a great benefit to the environment in many respects.

This is why the electronic engineers and especially electronic designers are to accept that they are playing an exceptionally important role in the world economy and the eco-system. Slowly but surely they become part of the most influential people in the world. Here, inter alia, we will show what are the benefits of environmental awareness in the design process. As shown in Table 1 [3] these may be material, immaterial, and emotional and may influence the producing company, the customer using the company's product, and the society as a whole. Among other we will stress here that cost reduction, better quality of life, and use of fewer resources are important benefits got by successful design being eco-aware.

Table 1. The benefit matrix

	Company	*Customer*	*Society*
Material	Cost reduction	Lower cost of ownership	Use of fewer resources
Immaterial	Simpler to produce simpler to sell	Easier More fun	Better compliance
Emotional	Better image	Feel good, Quality of life	We make progress in green

Before proceed we will first define what are electrical and electronic products being considered hereafter [1, annex I A]. Electrical and electronic equipment means equipment which is dependent on electric current or electromagnetic fields in order to work properly and equipment for generation, transfer, and measurement of such current and fields designed for use with a voltage rating not exceeding 1000 V for alternating current and 1500 V for direct current. Subcategories of these equipments are: large household appliances (refrigerators, washing machines, microwaves etc.), small household appliances (vacuum cleaners, toasters, coffee machines etc.), IT and Telecommunication equipment (computers, printers, copying machines, telephones, facsimiles etc.), consumer equipment (radio sets, television sets, audio amplifiers, musical instruments etc.), lighting equipment (luminaries, discharge lamps, etc.), electrical and electronic tools (drills, saws etc), toys, medical equipment systems (radiotherapy equipment, nuclear medicine, cardiology etc.), monitoring and control instruments (smoke detectors, heating regulators etc.) and automatic dispensers (for hot drinks, solid products etc.)

In this paper we will try to give an overview of the interaction of the electronic production and the environment and to give guidelines for eco-design of electronic products. These considerations should be taken into account as part of the worldwide efforts already described in publications having as a subtitle "green book" such as [4,5].

2. MAIN INTERACTION WITH THE ENVIRONMENT

The interaction of the electronic production and the environment may be considered as threefold: energy consumption, pollution by used electronic products, and pollution by toxic materials. Here, using a set of examples, we will try to highlight this interaction in every respect as mentioned above.

Let's start with energy consumption. In the year 1995 in the USA the computers spent a gigantic figure of 60 million MWh of energy [6], while one expect this figure to rise for 15% in the year 2015. According to this it is estimated that in the year 2000 the computers were spending about 10% of all energetic resources in the USA. Even the smallest improvement gained by effective design of serial products such as radio and TV receivers, VCRs, or computers, being multiplied by hundred of thousands and even millions, may lead to important energy saving during the exploitation phase of the product. It is estimated that thanks to lack of careful design the USA are spending about 10 GW while supplying home appliances and professional equipment being in stand-by (switched off functionally but not electrically). The TV sets in stand-by in the USA are spending around 1 GW. Careful design, as done by the newest generation of Sony's KV29FX66 TV set, may lead to significant savings. The mentioned set spends 20 times less energy in stand-by position then its predecessor of the year 1996. Thinking in this way one may only anticipate how large the saving may be for the equipment being switched on. Not to mention the ones being in on position but not in use.

The second example related to energy is about the diameter of wires distributing energy installed in residential and business buildings. The design philosophy applied here is based on saving material e.g. copper. In that way one gets design solutions being the cheapest in the moment of building. Building-in wires with twice larger diameter (four times the area), however, would diminish the heating the wires by factor of four meaning saving of 75% of dissipated power. The trick is in the fact that power savings are multiplied by the time of use of the building. In fifty years there are approximately 500.000 hours. A saving of 100 W in some industrial facility, big residential building, or a bank (with many air-conditioners and computers), for a period of 50 years, means saving of 50 MWh. The value of this spending, being unimportant at small time scale, becomes incomparably much larger than the price of the saved copper if long-term use is considered.

New electronic products usually are compact and equipped by most advanced technological achievements. The speed, however, of replacement of such products is astronomical. Unfortunately many of these products are substituted while in good functional and esthetic condition. Some of them are simply excellent. The need for compatibility with new generation products or, simply, the mentality of the consumer society takes them out of use no matter how good are they. This rises the electronic waste but un the same time gives clues for the concepts of eco-design. A question arises: can the product's life be extended? An often-overlooked consideration, but, a product that lasts 10 years makes less impact on the environment than an identical product that has to be replaced after only 5 years. This subject was mentioned above and will be considered in more details later on.

Finally, when one considers the pollution due to toxic and non-toxic materials one should have in mind the following. The very existence of the product means that some raw materials were used. This in turn means that some transformation of these materials were introduced in an irreversible manner meaning that such materials will be not available to the future generations. Best example of this kind are the fossil fuels being related practically to any industrial and agricultural product at all, at least because of the need of some transportation. The transformation of material, per se, is liable to produce substances potentially harmful to humans, animals, or vegetables. In addition, these transformation may transport harmful materials to places where they may influence the environment. As best example of the influence of the electronic industry to the environment, unfortunately one among many others, one may use the printed-circuit board (PCB) manufacturing. It is estimated that PCB manufacturing that uses lead/tin soldering is among the worst polluters. In this production in the pre-mounting phase only 7% of the material (copper) is retained on the board while 93% is pilled-of chemically, presenting a toxic waste. The importance of this datum comes clearer when one has in mind that (excluding home appliances) about 40% of the electronic waste is made up of printed circuit boards. Here we come to the conclusion that the minimization of waste in this (very important) production phase is to be left to the designers of PCBs. Their task is supposed to be: minimisation of the area occupied by the circuit for a given electronic function.

By mentioning the main conflict points between the electronic production and the environmental requirements we, in fact, introduced the main ideas and principles underlying the concepts of eco-design. We will define the eco-design as a system approach to the design of a product encompassing not only economic, functional, and esthetic aspect but protection of health (human, animal and floral), environment, and society during the whole life-cycle of the product. In the next the fundamental ideas related to eco-design will be elaborated and definitions will be given, first. Then, guidelines for eco-design of electronic product will be listed followed by examples of successful eco designs of electronic products.

3. ECO-DESIGN AND END OF LIFE MANAGEMENT

The 1980s concern with recycling has now given way to a more sophisticated understanding of how a product affects the environment. It is not just the waste left at the end that matters, but the effect of every stage of the product's life from the choice of raw materials, through manufacture, distribution, and use to the recovery or disposal. 'Eco-design' requires all these impacts to be considered from the start and weighed against each other to create a product that is 'greener' than its predecessors.

The complete life cycle of an industrial product is depicted in Fig. 1. [4]. Here on the top of the figure (above the dashed line) the product's life is fragmented in phases: raw material processing, component production, assembly, distribution, sales, and use. From the designer's point of view, every phase has its eco-aspect what is collected in the supertitle of the figure. Namely, in the raw material processing phase one should take care on the choice of the materials especially rare and toxic ones. It is up to the designer to develop technologies being capable to extract the materials needed with minimum industrial effort which includes minimum energy, water, and air consumption and minimum waste to be disposed.

The component production phase is typical industrial process in which no specific requirements are put from the ecological point of view. Of course, some specific components are designed in order to enable easy dismantling. In that way the price of the end of life management becomes lower. In addition, some components, generally not possible to be reused after end-of-life (such as some plastic parts) are to be carefully designed. Some plastic parts containing flame-retardants are extremely toxic if incinerated. These should be avoided. This will become a duty after the introduction of the WEEE directive in October 2002 in the EU.

The assembly phase seems to be less related to the environment. In this phase however one should think on the disassembly. Design product being easy to disassemble is an important issue when take-back is planned. Such products make disassembling cheaper and feasible as such.

Distribution and sale are related to the environment mainly through the packaging and the waste related to it. We are now faced with large amount of waste related to the packaging, which in turn is supposed to protect the product as much as possible in very difficult, even dangerous, circumstances.

When speaking on the use of a product, in classical terms, it has nothing to do with the price of the product. Having in mind its function, which means energy and water consumption, and use of chemicals etc., however, the use phase of the product's life becomes very important from the environmental point of view. Developing reliable products exhibiting good functionality in long period of exploitation means environmental friendliness, of cause, due to the delay of the end-of-life. In the same time, however, these products are supposed to produce minimum waste and to spend as less energy, air, water, and other materials, as possible. Such products are cheaper to the consumer in both respects: he or she is not supposed to buy new one and, in the same time, has less expenses in the exploitation phase with less environmental impact.

The bottom part of Fig. 1 (under the dashed line) is related to end-of-life management, hence the sub-title. Within this we recognize several activities: product take back, collection and sorting; product repair, refurbishing and reuse; disassembly and sorting; component reuse; and recycled material processing. Following the arrows one may find out three main loops of reuse. The first one, after take back, collection, and sorting is related to product reuse. It may be reused after repair or after refurbishing (if needed). The next user is, generally speaking, having lower requirements. Such products are frequently delivered to schools or exported to less developed markets. The producer himself mainly performs this activity. The second loop is related to component reuse. It follows disassembly. One should have in mind that some of the components extracted in this way may be crucial for use as spare parts of successfully functioning systems and, consequently, may reach high prices. When speaking on electronic components obtained after disassembly, in some cases high-tech equipment is needed to face with soldered multi-pin components on board. Finally, the third loop is related to recycled material processing. It is clear that materials obtained by recycling rarely are comparable by quality with virgin ones. Nevertheless, some of them may be useful for future use. On the other side, final disposal on landfills is supposed to obey rules especially related to toxicity. This stand for plastics containing flame-retardants for which incineration is not the final cure.

As an illustration of the process described above Fig. 2 depicts the end-of-life of a computer [2]. The importance of this example comes clear if one has in mind that one expects that by 2007 in the United States 500 million personal computers will become obsolete [2].

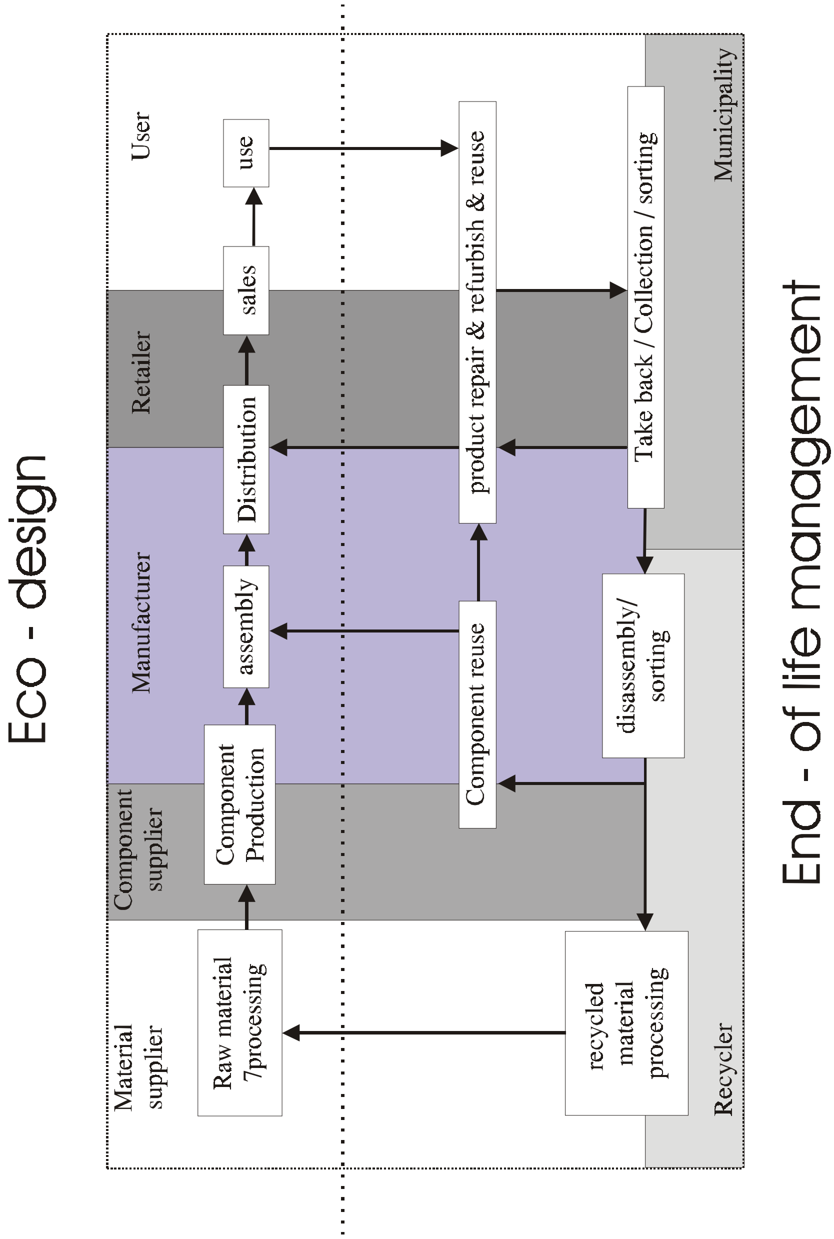

Fig. 1. Eco-designs and end-of-life management interrelation

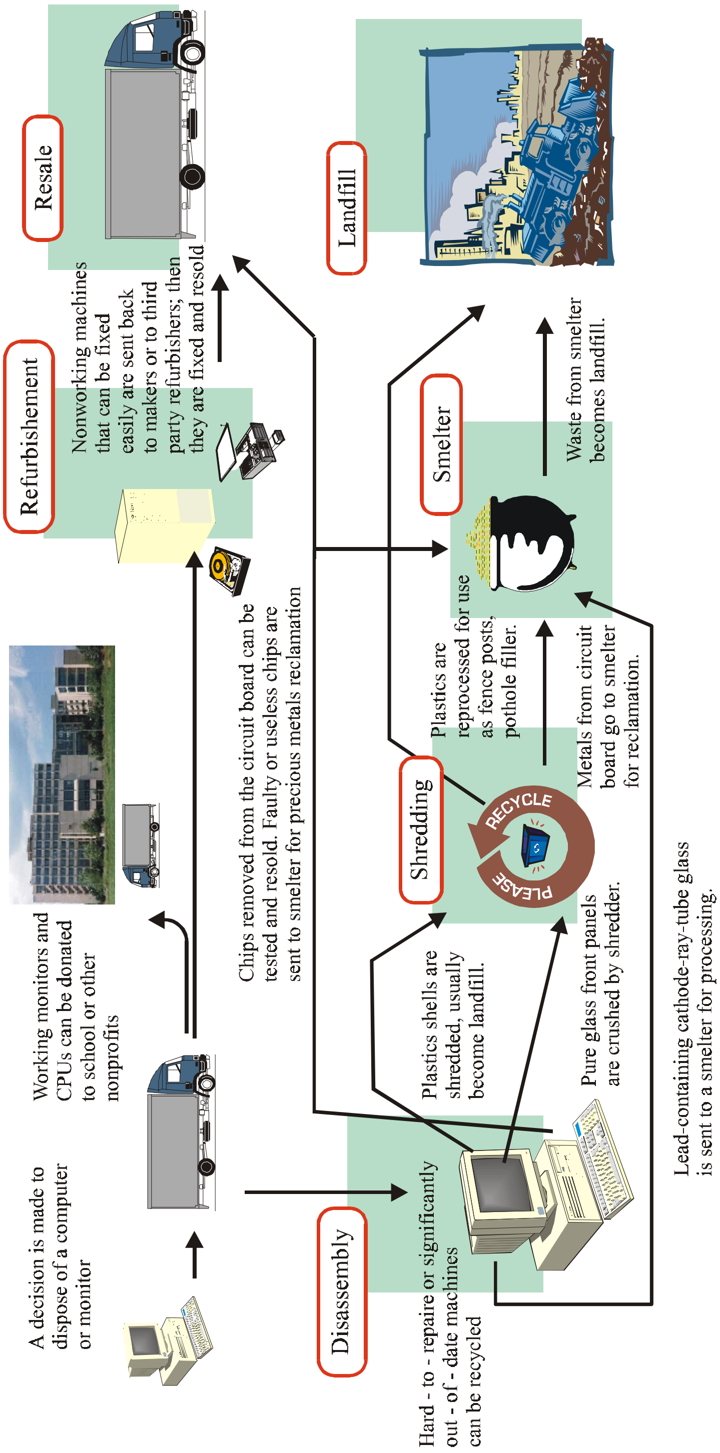

Fig. 2. End-of-life of a computer

Having in mind Fig. 1 and Fig. 2 and the discussion above we may recognize several points of interaction of the life cycle and the end-of-life management. These, as can be seen, are in raw (recycled) materials processing, in assembly (components reuse), in distribution (repair/refurbish) and use (reuse) of products. According to this several activities are emerging to get optimization to the whole interaction.

Design for reuse means shaping of the products in a way that enables reprocessing at the end-of-life. This is specially related to effective dismantling making easier the reuse of components. In the application of this concept sophisticated ideas are in use going as far as use of intelligent materials (shape memory plastics, photo-chromatic glasses [7]) or micro-electromechanical components.

Reduction of the amount of material needed for realization of the required functionality is of crucial importance. Products designed under such requirements will be cheaper, easier to transport, and will produce less waist at the end-of-life. In some cases these product will produce less toxic waste.

Design for recycling, in general, would mean use of smaller number of components and (especially) materials during the production phase. In that way the price of the product is reduced but, in the same time, the process of extracting valuable components and materials is made easier.

One should eliminate, as much as possible, the use of toxic materials. This is related to the production phase and to the final disposal. In recent time, having in mind the development of the public opinion, law initiatives arise in favor of forbidding some materials. In that respect one should go in front of time getting double benefits. There will be no need for further correction of the technology when the law is brought on power, and environmental friendliness will help better promotion of the new product. On the contrary, avoiding to obey environmental requirements may soon bring the producer in conflict with the law possibly leading to unwanted consequences.

Sustainable design is, per se, environmental friendly having in mind that it asks for reduction of use raw materials, energy and to prolong the life of the product. Of course the main aspects of sustainable design is development of such product that exhibit high durability, high reliability, high functionality, low production cost, and environmental friendliness during the whole life cycle. From the electronic design point of view one should rise the reliability and longevity of life of a product by careful tolerance design. By successful parameter optimization during the design one may reach such design that will keep the product's function even with large parameter changes (due to aging). Application digital instead of analogue solutions may lead to products less sensitive to tolerances, temperature and, in general, aging.

Finally, spending energy during production, and especially, during exploitation (stand-by and active mode) leads to better portfolio during the whole life-cycle but in the same time activates a chain effect. Smaller dissipation means smaller (cheaper) cooling equipment within the product, smaller energy for cooling, smaller volume of the product, smaller mass of the product,… This consideration stresses again the importance of careful design.

4. SUSTAINABLE DESIGN TOOLS AND GUIDELINES

It is obvious that the above described goals related to environmental friendliness and sustainable design need respective design methods and design- and evaluation-tools that will help designers and others to assess the product in any respect. According to [4] the tools that exist for assessing the products environmental attributes fall into two categories: tools that *evaluate* the environmental *impact* relating to a product, and tools which aim to improve environmental *product design*.

Evaluation tools create a product environmental profile from which it is possible to identify where environmental performance can be improved. These tools need information regarding the whole life cycle of the product. The results produced by such tools show where the designer has to react. Among such tools is LCA (Life Cycle Analysis) belonging to the so called quantitative tools, and The Matrix Approach belonging to the subgroup of qualitative tools.

On the other side, the improvement tools are used as help to the designer to find solution for a specific negative impact of a product to the environment. These tools provide guidelines and advice to the designer. Among such tools let mention Eco-Wheel developed at the Delft Technical University.

To make the subject clearer one of the tools will be discussed with some more details.

When a new product is to designed, according to the ISO 14040 standard, one should estimate its impact to the environment. This is done through LCA. For realization of this task one use software tools generating matrices with matrix-elements representing mutual relation between two type of quantities: material prices, production costs, testing costs, exploitation overheads, costs of maintenance, prices of reuse, dismantling, and recycling, from one side, and a list of impacts to the environment (energy needed, weight of the product, toxicity, use of rare materials) from the other. Thanks to such matrices one makes decisions related to materials and components to be implemented in the product.

Fig. 3 [3] exhibits a generic model of integrating environmental aspects into the product development process. We consider this figure self-explanatory in most parts. Our comments here intend to stress some aspects only.

Namely, a careful reader will find out that environmental aspects and sustainability are in fact incorporated in every phase of the design starting with planning and ending with product review. This is stressed by the feed-back loop. Even such phases as market launch are to be aware of the environmental properties of the product in order to check versus the existing laws and to promote the product's environmental friendliness.

Producer's responsibility is one of the main issues in the sustainable design. The producer (and the respective designers) takes key decisions concerning his product emanating his responsibility. The objectives of producer responsibility is that by making producer financially responsible for their products when these become waste, an upstream effect is created, which leads to design for the environment, considering the durability and reparability or upgrading, disassembly, and recycling of the product. In addition, thanks to the producer responsibility, through the eco-design, the reuse of resources and separate collection, hazardous substances contained in the product are prevented from entering into the environment in an uncontrolled way.

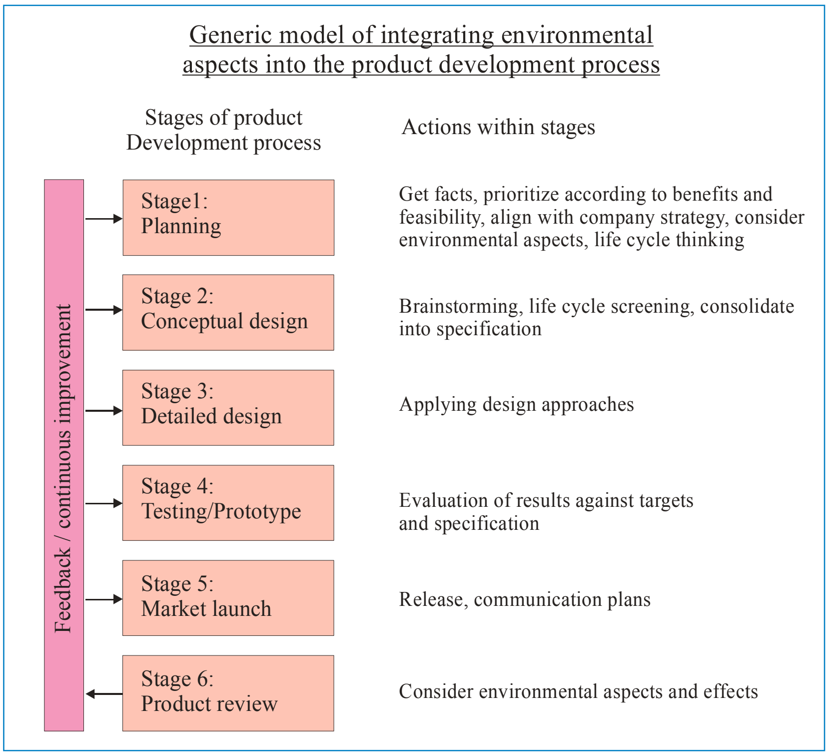

Fig. 3. Integrating environmental aspects into product design

Looking in that way on recognizes that eco-design is to be introduced and permanently supported at management level. Here are some management principles related to eco-design [3]:

– Active role of management rather than designer focus.
– Focus on business rather than technicalities
– Market driven
– Five focal areas: Energy, materials, packaging, chemical content and recyclability.
– Goes far beyond just environment "Look with fresh eyes at old problems"
– Functionality first, Embodiment second
– Frugal, resources reduction (cost down)
– Life cycle perspective (integral effects)
– Chain management with suppliers, users (common ground)

In the rest of these proceedings we will focus our attention to several examples of successful eco-design. These are chosen in a way to influence the design community to understand that eco-design is not only environmentally important challenge but, in the same time, may lead to significant financial savings.

5. EXAMPLES OF ECO- AND SUSTAINABLE DESIGN

In the recent years the awareness that eco-design is not only environmental friendly but may also be a profitable activity was risen thanks to many successful projects [8]. Here we will review several examples that, we think, are among the most interesting ones.

The first concern when one starts a electrical/electronic project is the functionality of the product to be. The next concern should be energy. The first efforts to spend energy in computer design were performed in the late eighties. Thanks to these results the recommendations (requirements) were generated in 1992, published by EPA (Environmental Protection Agency) in the USA. Based to these recommendation concepts were developed that leaded and lead now to energy spending in more and more effective ways.

When speaking on personal computers, for example, in order to spend energy when the computer is in the sleeping mode (stand-by), the following designer's recommendation were given [9]:

- Lower the clock speed on the motherboard to a slow mode, usually 8 MHz. Shut down all disks and stop all synchronization signals at the video controller.
- Stop the processor clock, putting the DRAM in slow refresh.
- Suspend to disk all DRAM and control registers, and then power off the entire system, leaving a small auxiliary power supply to some circuits to allow them to awaken the sleeping machine.

The awaking takes place by touch of the keyboard or the mouse or, if the computer is networked, by a signal coming from the network. In the later case the so called "magic packet" is used as part of the network protocol.

Of course, energy should be spend during the active phase of the computer work. One of the fundamental approach in that direction is rising efficiency of the computer. There is, however, an additional possibility. It is related to the power factor correction (PFC) [10]. Using AC power more efficiently through the broad use of power-factor correction ($\cos \varphi$) can create up to 30% excess generating capacity. The main idea is related to the fact that the supply current is not sinusoidal but pulse-shaped meaning that it contains considerable amount of harmonic components. The odd order components predominantly reduce the PFC of three-phase systems loaded by single-phase loads such as the computer. Using active PFC circuit one may reach acceptable power-factor far beyond 95% what is obtained with passive PFC.

Let's consider, now, reuse. As discussed above, many firms resell what they can to schools and late adopters. But when these customers outgrow their appetite for 486 PCs and bulky monitors, companies will need a way of preparing old components for new users. Reuse of materials if of special interest. Table 2 contains list of elements compounds and components being most interesting for reuse in the electronic industry. One of the main objectives of the present initiative of the EU [1] is to increase the recycling of WEEE. In general, increased recycling preserves resources and disposal capacities, in particular landfill.

In order to get materials from the electronic waste it should be recycled. Entering this activity, however, asks for two main goals to be achieved. Firstly, the materials obtained by recycling are supposed to have the characteristics of virgin materials. Secondly, the price of the materials obtained by recycling should be so low to make them competing with the virgin ones.

Table 2. Materials and components for reuse in electronic industry

Elements	*Compounds*	*Components*
Platinum, Gold,	ABS-FR plastic,	Integrated circuits,
Palladium,	Stainless steel,	Motors,
Silver, Nickel,	PVC,	Power supplies,
Copper, Zinc,	Polyethylene,	Displays,
Aluminum,	PCBs,	Lead acid batteries,
Mercury	Glass, Steel	NiCd batteries

The recycled materials may be used for production of products from whom they were extracted. One calls this a closed loop recycling. Open loop recycling means use of recycled materials in new products.

The process of recycling is connected to many problems. Namely, in spite of the positive effects, the recovery operation might add to the environmental pollution if the waste is not properly pre-treated.

Much more important version of reuse, however, is related to reuse of components. Among many companies performing this activity we will mention IBM. This company has established about twenty foundries for dismantling used computers and refreshing the extracted components. Within every foundry one performs the following: advices are given to the user who is sending the computer for dismantling, the old computers are accepted and verified, books are kept on what is the quality of the taken-back products, preparation and dismantling is performed, and, finally, sorting and refreshment of the components is done. In the period 1994-1997, on this way, IBM recycled 30,000 tones of computer products. In addition to the environmental protection achieved, financial effects are seen, too. Within the company 50 million of dollars are saved in use of refurbished components while 10 million dollars are gained from sale of used components to retailers around the world. Finally, materials extracted after recycling in the value of 5 million dollars were sold.

In this context one should reconsider the subject of *design for reuse*. It was stated that it represents a design making easier the dismantling of the product after end of life. A question arises, however, on whether the components obtained in that way are of any use. This is especially important for component whose aging depends on the time of active use and the conditions of exploitation (electrical stresses, high temperatures, to mention only two important parameters of aging). Such components are motors, power supplies, and monitors being less subject of obsolescence and technological innovation. In order to create the knowledge about the history of work of a motor, for example, one should keep a book or a log. A concept, named electronic data log (EDL) was introduced [11] enabling realization of design for reuse. Here are in brief the elements of this concept.

In order to build in the EDL into the electrical product, according to [11], one needs
- A PCB including a micro-controller and EEPROM memory,
- Sensors for measurement of temperature and current,
- A wireless interface to transmit data from EDL to an electronic reader,
- A power supply to provide DC voltage to the electronic circuitry.

The EDL system functionality includes:
- Counting the number of starts and stops of the motor,
- Storing the runtime of each individual use cycle as well as the accumulated runtime,
- Recording and compiling sensor information, such as the motor temperature and the

power consumption in each individual use cycle,
- Classifying and evaluating the record data, and
- Computing and storing peak and average values of all parameters of interest.

During the life cycle (if needed) and at the end-of-life via the wireless connection the data logged in the EEPROM are transferred to a computer as if one reeds a black-box used in airplanes. At the computer side a receiver is created connected via RS232 port. If one prepares a comprehensive database one may take decisions about the usefulness of the components inside the product in no time. The original project was applied to evaluating motors in drilling machines. It was found that the price of the machine was risen by two dollar. This lead to a conclusion that if 50% of the drilling machines was for further use, one would need to take back (after end-of-life) approximately 65% of the machines.

When speaking on-eco design from material point of view one should mention the project named: "lead free telephone" [12]. The goal here was to substitute the lead into the soldering compound. The final result achieved however, was a telephone without lead at all. Namely, even the components mounted in the telephone were supposed to be produced with no lead.

One use now [13] new tin/copper alloy with 99,3 % tin and 0.7% copper. The author claim that the melting point of the SnCu alloy is 227 ^{o}C, while it takes liquid phase at 242 ^{o}C meaning that the electronic components are supposed to sustain at their pins 260 ^{o}C. Alternatively one recommends tin/silver alloy with 96.5 % tin and 3.5 % silver.

One may expect that the exclusion of lead will change many things in PCB design the main being change of the design rules thanks to the higher temperatures needed for soldering.

Before proceed to the last example we will discuss here briefly the set of ISO 1400 standards. This system of standards is related to the following areas:

- Environmental management system (14001) gives specification with guidance for use,
- Guidelines for environmental auditing (14010) gives general principles of environmental auditing,
- General principles of environmental labeling (14020)
- Environmental management (14040) includes principle and guidelines for LCA,
- Terms and definitions (14050)
- Guide for inclusion of environmental aspects in product standard (14060)

This standard is related to organizations that want to improve the environment, that want to confirm to themselves that they are successful in the protection of the environment, that want to show to others that they are successful in protection of the environment, that want to get a certificate, etc. The important thing however is that every organization that wants to adopt the ISO 14000 standards is supposed to obey not only national but international regulations, too. In addition when the certificate is issued the organization will be expected to have an effective system of internal management that is accommodated to the application of the ISO 14000.

An example of application of ISO1400 was given in [14]. The authors from ST Microelectronics claim that they started the application of ISO 1400 during its definition. They adopted 16 principles for managing the protection of the environment. In that way implementation of ISO1400 was in fact only a byproduct of the efforts to obey the internal standards. Moreover, as for surprise to all (even to the leaders of this activity) not only environmental friendliness was achieved but the productivity and the company profit were risen. For example, investments in energy saving lead to diminishment of energy spending from 680 kWh per USD1000 of revenue, to 550 kWh. The water spending was diminished from 11.3 m^3 to 7.8 m^3 per USD1000 of revenue. Finally, the part of the product reaching end-of-life that were supposed to be disposed at landfill was diminished from 71% to 35%, while the water spent was diminished from 1200 to 800 tones per year.

6. CONCLUSION

The state of the art of eco-design in electronics is considered. It is shown that the electronic and electrical industry is no more light one, and that design for life cycle is an important issue in electronics. The life of an electronic product was followed and the life phases were analyzed from environmental, eco-design, and end-of-life management point of view. Basic concepts were discussed followed with a set of examples of successful eco-designs.

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EKO-PROJEKTOVANJE, STANJE I MOGUĆI RAZVOJ

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Razmatran je problem eko- i održivog projektovanja u elektronici. Date su osnovne postavke ovog koncepta i primeri nekih rešenja koja ukazuju na suštinu problema i ideje koje vode ka uspešnom održivom projektovanju.

Key words: *elektronika, eko-projektovanje, održivo projektovanje*