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CONCEPTS OF COMPUTER TAKE-BACK FOR SUSTAINABLE END-OF-LIFE

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Abstract. *Electronic computers have become the most frequent electronic product and, accordingly, from the point of view of sustainability, they are the most hazardous one. Recycling materials and components that constitute the nonfunctional and obsolete units of a computer has become the most secure and cheapest strategy of managing the end-of-life of a computer. In that way, the take-back of computers offers new opportunities in the reuse of raw materials and components, and effectively protects the environment. At the same time, a substantial reduction in cost related to disposal is avoided. Here comes in the importance of the organization of the take-back of computers as a crucial step in creating the conditions for the implementation of recycling technology. In this paper we consider the computer as an environmental risk and review the take- back procedures in order to identify the ones that will be most convenient for application in local communities.*

Key Words: *End-of-life of a computer, take-back, management*

1. INTRODUCTION

Obsolete computers represent hazardous waste, risky for the environment and human health. If disposed of without processing, they become a threat. This is why all developed societies have expressed their concerns related to the end-of-life of computers and other electronic appliances. In the year 1999, the European Commission produced a directive according to which demands are set that by the year 2015, the amount of domestic hard waste is to be reduced to only 35%, compared to the amount disposed of in 1995 [1]. In order to get a clearer picture of the subject, some data will be given below.

Every computer, including the monitor, on average, contains between one and two kilos of lead (20% of the weight of the monitor is lead, Figure1). Thus, according to data from the United States of America (USA), from the 315 million computers that have be-

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come obsolete in the period between 1997 and 2004, one could extract 340 000 tones of lead [2]. In Canada, on average, 363 tones of lead are disposed of per year without recycling. Simply throwing these monitors could have frightening consequences. Now, already 40 % of the lead found in the soil originates from electrical waste. In addition, 70% of heavy metals (including mercury and cadmium) found in the soil are of electronic origin. Table 1 represents a comprehensive list of the materials found in a typical contemporary computer along with the properties of these materials from a sustainability point of view.

Having all this in mind, the effective management of the end-of-life of a computer, has become an important social and business activity that encompasses take-back, dismantling, recycling, reuse, neutralization of toxic materials and the disposal of the rest in a sustainable manner. Among these activities, the crucial part is the collecting-back or take-back of the computers in societies and communities where no stringent regulations and environment-protective traditions exist. The organization of the service and the share of responsibilities are of crucial importance. Here we have a case where no recycling exists at all. This, however, by no means, make the take-back senseless. Collecting the hazardous waste is the first step that, we think, will get us a picture of the problem and press towards successful recycling and safe disposal. The US government researchers estimated that three-quarters of all the computers ever sold in the USA remain stockpiled, awaiting disposal.

In the following section, we will first consider the problem of take-back. Than we will go through the existing praxis, including an overview of the status in Serbia. Finally we will consider take-back schemes and discuss structure and applicability.

2. Take-Back of Computers

An awareness of the problems stated above on the part of society and especially the governmental institutions, we consider, is of paramount importance for setting up the solutions. Among these the take-back is of greatest importance, originating from the fact that it needs the participation of several subjects generally not connected among themselves and not being interested in doing something for the solution. The municipal and governmental authorities are, accordingly, expected to play a fundamental role in the matter. In the following text we will go through these considerations in more detail.

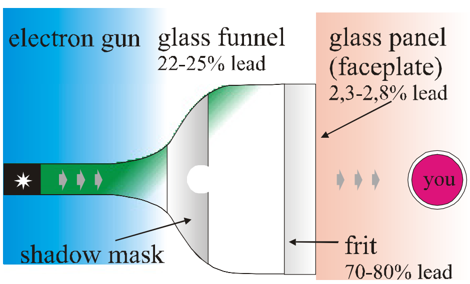

Fig.1. Content of lead in a typical television set or computer monitor

Table 1. Composition of a Desktop Personal Computer [1]

Name	% of total weight	Weight of material (kg)	Recycling Efficiency	Use/Location
Aluminium	14.1723	3.85	80%	Structural, conductivity/housing, Cathode ray tube (CRT), Printed Wiring Board (PWB), connectors
Antinomy	0.0094	<0.05	0%	Diodes/ housing, CRT, PWB
Arsenic	0.0013	<0.05	0%	Doping agents in transistors/ PWB
Barium	0.0315	<0.05	0%	In vacuum tube/CRT
Beryllium	0.0157	<0.05	0%	thermal conductivity/PWB, connectors
Bismuth	0.0063	<0.05	0%	Wetting agent in thick film/PWB
Cadmium	0.0094	<0.05	0%	Battery, blue-green phosphor emitter/housing, PWB, CRT
Chromium	0.0063	<0.05	0%	Decorative, hardener/(steel) housing
Cobalt	0.0157	<0.05	85%	Structural magnanimity/(steel) housing, CRT, PWB
Copper	6.9287	1.90	90%	Conductivity/CRT, PWB, connectors
Europium	0.0002	<0.05	0%	Phosphor activator/PWB
Gallium	0.0013	<0.05	0%	Semiconductor/PWB
Germanium	0.0016	<0.05	0%	Semiconductor /PWB
Gold	0.0016	<0.05	99%	Connectivity, conductivity /PWB
Indium	0.0016	<0.05	60%	Transistor, rectifier/PWB
Iron	20.4712	5.57	80%	Structural magnetivity/(steel) housing, CRT, PWB
Lead	6.2988	1.72	5%	Metal joining, radiation shield/CRT, PWB
Mercury	0.0022	<005	0%	Batteries, switches/ housing, PWB
Manganese	0.0315	<0.05	0%	Structural magnetivity/(steel) housing, CRT, PWB
Nickel	0.8503	0.23	80%	Structural magnetivity/(steel) housing, CRT, PWB
Niobium	0.0002	<0.05	0%	Welding allow/housing
Palladium	0.0003	<0.05	95%	Connectivity, conductivity /PWB
Plastics	22.9907	6.25	20%	Organics, oxides other than silica
Platinum	0		95%	Thick film conductor/PWB
Rhodium	0		50%	Thick film conductor/PWB
Ruthenium	0.0016	<0.05	80%	Resistive circuit/PWB
Selenium	0.0016	0.00043	70%	Rectifiers/PWB
Silica	24.8803	6.79	0%	Glass, solid state devices /CRT, PWB
Silver	0.0189	<0.05	98%	Conductivity /PWB, connectors
Tantalum	0.0157	<0.05	0%	Capacitors/PWB, power supply
Terbium	0	0	0%	Green phosphor activator, dopant/CRT, PWB
Tin	1.0078	0.27	70%	Metal joining, /CRT, PWB
Titanium	0.0157	<0.05	0%	Pigment, alloying agent/housing
Vanadium	0.0002	<0.05	0%	Red phosphor emitter/CRT
Yttrium	0.0002	<0.05	0%	Red phosphor emitter/CRT
Zinc	2.2046	0.7	60%	Battery, phosphor emitter /CRT, PWB

2.1 Who is responsible

There are different opinions as to who is the most responsible in the take-back scheme, including the activities that follow it in the end-of-life management of a computer. The European Union (EU) considers the electronic production industry responsible for supporting this activity in several respects. First, it is expected that the sustainable design of an electronic product should be implemented in order to avoid hazards at the end-of-life stage. Having this in mind, it puts the financial responsibility on the producers. They are expected to manage the end-of-life stage, including the reuse of the components and materials. Recycling technologies are expected to be developed in the design phase of the product. It is expected that the price of these activities will raise production costs for about 1 to 3% of the retail prices of the electrical and electronic products compared to avoiding any recycling and reuse.

The concept of Extended Producer Responsibility (EPR) [3] is based on the considerations that the waste generated during the production processes could be taken care of in a proper way, from an environmental and resource-saving point of view, and should primarily be the responsibility of the manufacturer. Before the manufacturing of a product is commenced upon, it should be known how the waste which is a result of the production process should be treated, as well as how the product should be taken care of when discarded.

This concept was first introduced in Sweden in 1979 and was related to aluminium cans for single-servings of beer and soft drinks. It is estimated that, thanks to the requirements of this legislation, more than 90% of these products are taken back when obsolete.

While there are many definitions of EPR, it is generally described as a pollution prevention policy that focuses on product systems rather than production facilities. Thus responsibility for the product is broadened beyond the emissions and effluents generated by the extraction or manufacturing processes to the management of the product once it is discarded.

The ultimate goal of EPR is sustainable development through environmentally responsible product development and product recovery. The following basic types of EPR may be recognized:

– *Liability* – the producer is responsible for the environmental damage caused by the product in question

– *Economic responsibility* – the producer covers all or part of the costs for collection, recycling or the final disposal of the products he manufactures, and may charge a special fee

– *Physical responsibility* – the manufacturer is involved in the physical management of the products or in the effect of the products. This can range from merely developing the necessary technology, to managing the total "take back" system for collecting or disposing of the products he has manufactured for which he may charge a fee

– *Ownership* – the producer assumes both physical and economic responsibility

– *Informative responsibility* – the producer is responsible for providing information about the product or its effects at various stages of its life cycle.

It is important to note that the take-back schemes generally combine both economic and physical responsibility.

In order for the ERP to be implemented, there are three categories of policy instruments that can be initiated by the government to encourage product responsibility.

– *Regulatory Instruments:* mandatory take-back; minimum recycled content standards; secondary material utilization rate requirements; rates and dates; energy-efficiency standards; disposal bans and restrictions; material bans and restrictions; and product bans and restrictions.

– *Economic Instruments:* advance disposal fees; virgin materials taxes; removing subsidies for virgin materials; deposit/refund systems; and environmentally preferable product procurement.

– *Informative Instruments:* seal-of-approval types of environmental labeling (Green Seal, Blue Angel); environmental information labeling (energy efficiency, Chlorofluorocarbon (CFC) use, recycled content); product hazard warnings; product durability labeling.

2.2 What are the costs

The estimated cost of recycling of a computer is between $10 and $60. This is less then needed for its disposal as waste. It is estimated, also, that the disposal of a computer would cost more then $25 and less then $50. In the later case, however, there are additional overheads related to decontamination of the landfill due to e-waste. According to [2] the minimal expenses for recycling E-waste in the USA in the next ten years will exceed $10 billion. It is, of course, clear that neither the municipalities nor the consumers can afford such large amounts of money.

One of the concepts implemented by the producers is to incorporate the recycling cost into the retail price of the electronic equipment, which should be paid when the computer is purchased. Thus, many cases that lead to nonadequate recycling and disposal are a consequence of a lack of insight and influence of the consumers on the end-of-life stage of the product. Even illegal disposal was reported.

In some countries a tax was introduced to be paid immediately upon purchase of a computer. The state of Alberta (Canada) for example, charges CAN$45 per computer for end-of-life management by the state.

In most cases, however, municipalities and governments are covering the costs of recycling E-waste that was not taken back properly.

2.3 The computer take-back campaign

The National Safety Council in the USA reported in 1999 that only 11% of discarded computers were recycled, compared with 28% of overall municipal solid waste. [4] Other estimates of computer recycling range from 5% to 15%, compared to a 42% rate for overall solid waste and a 70% rate for major appliances like refrigerators, washing machines, and dryers. While there is limited information on where and if these computers and televisions are recycled, some studies tracking E-waste shipped overseas find that lax practices pose serious environmental and human health threats. In the United States, growing public and government attention to the problems posed by E-waste has prompted a few manufacturers and retailers to announce plans for some small-scale take-back programs. Dell, Hewlett Packard (HP), International Business Machines (IBM) and other market leaders all have programs of one type or another, mostly focused on their customers. But none claims to receive or recycle more that 10% of their annual sales. Considering that not enough, a Computer Take Back Campaign (CTBC) was established. It is aimed at supporting the policy of producer responsibility in the USA for electronic products at the end of their useful lives, wherein brand-name manufacturers/producers work with consumers and state and local governments to properly collect and manage electronic products in an environmentally responsible fashion. As for products sold in the past ("legacy" electronic waste, including "orphan" products for which the relevant producer/brand owner is no longer in business), one can advocate that all due measures should be taken to allocate primary responsibility to those who manufactured and sold these products in the first instance. For that orphan waste which cannot be allocated to past producers, one could suggest the application of the principle that current electronics producers as well as those entering the market in the future should share in the responsibility of managing this electronic waste based on an equitable cost allocation related to a historical market share. In addition, the producers are supported to improve the design of their products to minimize their life-cycle impacts on the environment.

2.4 The state-of-the-art in Serbia

There are many reasons why the situation related to E-waste management in Serbia is different compared to the developed world. First of all, the absolute quantity of the obsolete (and non-obsolete) equipment and appliances is smaller. Then, thanks to lower living standards again, the criteria for pronouncing equipment obsolete is less restrictive. In other words, the life cycle of equipment is extended beyond the usual expectations. On the other hand, however, the uncontrolled import of used equipment being almost at its end of life in the period just after the NATO Campaign against Serbia in 1999, led to a practical shortening of the average lifetime of electronic equipment in Serbia. To prevent further negative trends on April 19, 2004 [5] governmental restrictions were imposed on the import of used computers. For now, that is the only effective measure aimed at the reduction of E-waste.

Note that, to our knowledge, there are no demanufacturing facilities for electronic equipment in Serbia. Furthermore, there is no awareness of the importance of the problem and the need for emergent solutions.

A specific aspect should be considered when discussing the subject of the take-back of computers in Serbia. Namely, there are no computer producers in the country. Accordingly, no EPR is applicable. The CTBC has to target different subjects. Among them we recognize the importers and the government.

The wholesale importers of computer equipment in Serbia may be seen as producers, being the ones that first have the product. They are the only ones that have direct contact with the original producer. Having in mind, however, the fact that the possibility of forcing the real producer to take back (import) the obsolete computers is negligible, we come to the conclusion that the importer is the one to be targeted by the CTBC.

Of course, the government, while issuing import licenses, is to share the responsibility with the importer. At this moment, to our knowledge, the following measures are planned to be implemented by the Serbian Government [5]:

– Creating an action plan for the management of E-waste according to the EU regulations.

– The prevention of waste production by the implementation of cleaner production, the reduction of dangerous properties of waste and the introduction of European standards for the reduction of toxic substances (such as heavy metals, for example). Encouraging recycling. The introduction of methods and tools for the evaluation of environmental indicators and the evaluation of the life cycle of electronic products.

– The establishment of a complete scheme and system for E-waste management from the moment of take-back until disposal.

– The establishment of an information system describing e-waste.

– The development and implementation of economic instruments (such as subventions, taxes and the like) for encouraging proper waste management and preventing waste generation and improper disposal.

Note that no take-back strategy is mentioned. It is our opinion that take-back is a crucial step for the start of any treatment and, accordingly, the government should pay much more attention to this activity. Here, not only regulations but also concrete actions for the implementation of the regulations are expected to be undertaken.

3. TAKE-BACK PROGRAMS

Here we will try to make a short overview of the implementation of existing take-back concepts in the US and in Europe, to look for the accumulated experience, to make comparisons, and try to draw conclusions and recommendations applicable to domestic circumstances.

According to [6] the following are to be the prerequisites and needed actions for a successful take-back campaign:

– Identify a common format for data collection for materials and cost;

– Evaluate and aggregate existing collection and demanufacturing materials and cost data sets;

– Identify common opportunities and barriers for different collection and transportation models;

– Define the advantages and disadvantages of different collection and transportation models;

– Identify commodities that are most viable economically (positive revenue) for collection and demanufacturing;

– Identify successful motivators and strategies for marketing collection events;

– Identify key issues and motivators for various groups that have or may participate in electronic equipment collection including consumers, local government officials, small businesses, recyclers, demanufacturers, shippers, etc.;

– Identify data gaps and infrastructure needs to increase residential participation; and

– Analyze what motivates the public to participate in collection events.

As for the United States, several computer manufacturers are beginning to include the take-back of old systems as part of a sales package for marketing new systems to commercial and government customers. And while most manufacturers rely on third parties to handle the collection, processing and recycling of old personal computers, some companies have established recycling facilities to handle waste reclaimed from the company's customers. Some examples of take-back programs for consumers include companies like Dell (Dell Recycling (formerly Dell Exchange), enabling customers to order the home pickup of unwanted electronic products), HP-Compaq (by introducing HP Planet Partner e-Coupon given for an obsolete electronic product no matter who the producer was, and a program that includes transportation coordination) and Lexmark (printers only). While some of these larger manufacturers are starting to provide take-back services, these services fall short of a suitable solution.

A 2004 study of the options for recycling a desktop system found "high cost, relative lack of convenience and substantial time commitment." The average price was $68, far more than most consumers are willing to pay to recycle E-waste. [7] On average, it took nearly two hours to do the tasks involved in the recycling and 6.5 days of waiting for the recycling information or materials. The report concluded that these programs "do not offer the easy, low-cost options desired by consumers." Other than mail-back programs, there are infrequent one-day voluntary collection programs in scattered locations around the USA. Xerox and Pitney Bowes offer, for a variable fee, a take-back program for office equipment to their business-leasing customers. These programs demonstrate that there is a significant cost associated with recycling or properly discarding E-waste.

The EU's approach, known as EPR in policy circles, creates incentives for manufacturers to reduce the environmental impacts of high-tech products throughout their life cycle. Instead of issuing regulations for an industry in constant flux, the EU has set clear goals for electronics collection and recycling, and has given the industry flexibility in how to meet them. Rather than trying to make the law catch up with technology, the EU is making the technologists catch up with the code.

The first European Union directive on E-waste requires producers to take responsibility for the entire life cycle of their products. By 2005, companies will either have to take back products directly from consumers or fund independent collectors to do so. Waste that was generated prior to the enactment date will be the responsibility of all existing companies, in proportion to their market share. Future waste is to be the individual responsibility of each company, thereby creating an incentive to redesign products for easier and safer recycling and disposal. No E-waste will be allowed in municipal waste streams. The public will be able to return E-waste without charge.

The second directive phases out the use of key toxic materials by 2006, including lead, mercury, cadmium, hexavalent chromium, and the brominated flame-retardants polybrominated diphenyl ether (PBDE) and polybrominated biphenyl (PBB).

Intensive research was supported in order to evaluate different models for the implementation of various phases of E-waste management [8].

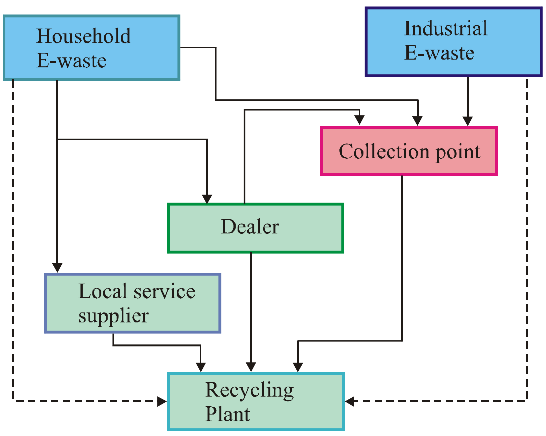

Fig. 2. Collection system of obsolete computers

Figure 2 depicts one of the possible take-back schemes advised in [8]. The heart of the system is the so-called collection point. It is accessible directly by both households and industrial product users. At the same time, however, the computer dealer has access to it. It is not a simple matter of deciding who is to be the owner of the Collection point. Should it be the dealer, the municipality or an independent proprietor? Note that a Collection point is necessary if refurbishing, dismantling and other reuse intended activities are expected. Accordingly, for products supposed to be of no use an opportunity to be transported directly to recycling plant is allowed.

Table 2 represents an overview of pro's and con's, barriers and advantages, for different models offered for managing E-waste at the end of life [9].

Table 2. Summary of the Advantages and Barriers to Collection Models

Collection Model	Barriers	Advantages
Drop-off Events	• Ineffective or insufficient publicity can result in low participation • Conflicts with other events may affect participation • Resident's unfamiliarity with drop-off events can affect participation	• Low up-front costs • Short time-frame but high collection amount
Regional Approach	• Potential unequal distribution of costs among communities	• Economies of scale over single community drop-off event models • Planning for the events is shared • Larger base of residents to participate
Permanent Collection Depot	• Not effective for every community size • Need for staff may increase operational costs	• Year-round collection of equipment • Convenient for most residents • Economies of scale are possible
Curbside Collection	• Potential for theft of equipment for parts, and then abandonment • Operational costs can be higher than other models	• Easy for residents used to curbside collection • Residents without transportation can participate more easily
Point of Purchase (Retail) Collection	• Retailer's active participation is essential • Retailer may not be able to collect the data on participation • Logistical issues	•Low up-front and operational costs for the collection agency Promotion of the program by retailers ensures high visibility
Combined/ Coordinated Collection Methods	• The economies of scale are uncertain. • Requires large population to be viable	• The gaps created by one model can be filled by another model • Year-round collection • Good if inhabitants are spread over a large area

The implementation of any scheme as well as the one depicted in Figure 2, in our opinion, requires at least tree actors besides the governmental/municipal participation. These would be the organizer, the collection point and the recycling plant. No such actors are sought in Serbia at the moment. That may become a serious obstacle for the implementation of any such scheme.

4. CONCLUSION

The importance of the organization of the take-back of computers as a crucial step in creating conditions for the implementation of recycling technology is considered. Here we have tried to make a short overview of the implementation of existing take-back concepts in the US and in Europe, to look for accumulated experience, to make comparisons, and have tried to draw conclusions and recommendations applicable to domestic circumstances.

We consider the computer an environmental risk and review the take-back procedures in order to get the ones that will be most convenient for application in local communities.

REFERENCES

1. M. Pennock, "Creating an electronics equipment take back program in light of current European Union directives and possible U. S. legislation", A Research Paper submitted in partial fulfillment of the requirements for the MSc, University of Wisconsin-Stout, May, 2003.
2. http://www.svtc.org/
3. T. Lindhquist, Extended Producer Responsibility as a Strategy to Promote Cleaner Production, Proceedings of an invitational expert seminar, Sweden, May 1992.
4. http://www.svtc.org/cleancc/pubs/sayno.htm.,
5. http://www.ekoserb.sr.gov.yu/dokumenti/index.php
6. -, "Residential Collection of Household End-of-Life Electrical and Electronic Equipment: Pilot Collection Project", Common Sense Initiative – Computer and Electronics Sector, U.S. Environmental Protection Agency, Region I, EPA-901-R-98-002, February 1998.
7. -, "Test of Manufacturer Mail-Back Programs," a report prepared for the Snohomish County Solid Waste Management Division by PRR, January 3, 2003.
8. Eco-design subgroup, "Environmentally improved product design case studies of the European electrical and electronics industry", ECOLIFE Thematic Network, July, 2002.
9. US Environmental Protection Agency, "San Jose Computer Collection and Recycling Pilot: Draft, prepared by Vista Environmental for the Common Sense Initiative – Computer and Electronics Sector, Region IX, San Francisco, CA, February 1998.

KONCEPTI SAKUPLJANJA RAČUNARA NA KRAJU ŽIVOTNOG VEKA SA STANOVIŠTA ODRŽIVOG RAZVOJA

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Elektronska oprema i računari postaju, sve više, najčešće korišćeni elektronski proizvodi, tako da, saglasno tome, sa stanovišta održivosti, to su istovremeno i najveći zagađivači. Recikliranje materijala i komponenti koje ulaze u sastav nefunkcionalnih i zastarelih jedinica u računaru predstavlja najbezbedniju i najjeftiniju strategiju rešavanja problema odlaganja računara na kraju životnog veka. Sakupljanje računara nudi nove mogućnosti ponovnog korišćenja kako sirovina tako i komponenata, pri čemu se vodi računa o zaštiti prirode okoline. U isto vreme, izbegnuti su značajni troškovi skladištenja i odlaganja štetnog otpada u za to predviđenim objektima. U ovom radu analiziran je računar na kraju životnog veka sa stanovišta zagađenja prirodne okoline i ukazano je na postojeće koncepte rukovanja računarima na kraju životnog veka u svetu. Naglašena je važnost same organizacije prikupljanja računara kao najvažnijeg koraka u procesu stvaranja uslova za implementaciju tehnologija recikliranja elektronskih proizvoda i predloženi koncepti sakupljanja.

Ključne reči: *Kompjuter na kraju životnog ciklusa, preuzimanje otpada, menadžment otpadom*