INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES
SEVILLE
W.T.C., Isla de la Cartuja, s/n,
E-41092 Sevilla

"Towards a European solution for the management of waste from electric and electronic equipment"

A Report prepared by the IPTS for the Committee on Environment, Public Health and Consumer Protection of the European Parliament

Final Report

EUR 19628 EN

Demosthenes Papameletiou,
European Commission, Joint Research Centre,
Institute for Prospective Technological Studies (IPTS)
Seville, June 2000

Printed in Spain

Table of contents

Executive Summary

This report presents the results of the analysis of current environmental policy options on waste from electric and electronic equipment (WEEE) conducted by IPTS at the request of the European Parliament. In order to address the environmental problems associated with the treatment and disposal of WEEE the Commission has proposed in June 2000 two Directives. The first – the draft Directive on WEEE – deals with the management of waste. The second seeks to harmonise national measures on the restriction of the use of certain hazardous substances in electrical and electronic equipment. These two Directives will be accompanied by a further proposal on the design and manufacture of electrical and electronic equipment later this year.

The discussion of the potential environmental impacts from WEEE has shown a wide agreement that the major problem is related to the hazardous substances contained in products. These hazardous substances include constituents such as cadmium, lead, lead oxide, PCB - (poly chlorinated biphenyls), TBBA - (tetra-bromo-bisphenol A), octa- and deca-BDE - (octa- and deca-bromo diphenyl ether), chloroparaffins, etc. The recovery, re-use or recycling of non-hazardous materials, such as iron, copper, glass, ceramics, plastics, which are the major constituents of Electric and Electronic Products (EEE), is of priority as well.

Concerning the systematic assessment of the WEEE quantities in the EU, there are presently only few recent experiences from pilot projects carried out in several countries. Rough estimates were generated in the frame of the EC priority waste stream project. According to these estimates the total WEEE is with about 6 million tonnes per year only a small part in the range of 1% of the total wastes in the EU. Nevertheless it already amounts to 4-6% of the municipal waste. In general, the “theoretical” calculation of WEEE on the basis of sales statistics and of average lifetime data does not deliver comparable results with the “real” quantities identified in the different collection experiments. The trend is that **theoretically calculated WEEE data in the range of 12-20 kg/inhabitant/year** are higher than those measured in the pilot projects. On the other hand, measured data deviate substantially from each other depending on geographic location and the particular test conditions.

With progressing awareness about the size of the WEEE problem, it is generally accepted that in the long-term the competitiveness of the electronics and of the electric appliances industries will depend on their ability to minimise waste on a life cycle basis to attract consumers through environmentally friendly products. Developments may be introduced by industry on a voluntary basis or induced indirectly through regulation. From information available to date, it appears that in the USA a "wait and see" attitude is prevailing, at least regarding the implementation of country-wide WEEE take-back regulation. Contrary to the US, faster regulatory developments are anticipated in the EU. This could accelerate the adoption of solutions in the EU and reportedly European companies could obtain competitive advantage. Current proposals include **prevention, collection and treatment provisions.**

The preventive measures basically consist of **phasing out hazardous substances from EEE**, such as lead, mercury, cadmium, hexavalent chromium and halogenated flame retardants by the 1st January 2008. Some applications of lead, mercury, cadmium and hexavalent chromium are exempted.

It has been demonstrated that attributing the economic responsibility for the treatment, recovery and disposal of WEEE to producers constitutes an important incentive to improve the design of electrical and electronic equipment which takes waste management aspects into

account. Contrary to that, there is no evidence that attributing the collection of WEEE from private households to producers would have an impact on the design of the equipment. Therefore, the **responsibility of producers** is limited to the actual treatment, recovery and disposal of this waste. For practical reasons producers will have to pick up the waste from designated collection points. Member States will have to ensure that appropriate **collection** systems are set up.

The re-use and recycling targets of the current WEEE proposal are in the range 50-80 %. These levels reflect to some extend achievable and demonstrated results, which were obtained until now in different pilot trials across the EU.

The main recommendation of the study is that the regulatory approach should include as a first priority the provision of a common **guidance** to the producers, to the operators of take-back schemes and to the controlling Authorities on the acceptable processing practices and on the achievable performances. Performance targets should be technically, economically and ecologically meaningful and most particularly demonstrated at an industrial scale. On this basis, the legislator can develop the so-called **"best practices"**, which can be used as benchmarks for the production of EEE with preventive measures and for the certification of collection, recycling, recovery and disposal activities.

Finally, there are several **financing models**, which have been in use to raise funding for the management of packaging waste. Theoretically these models could also be applied to cover WEEE management costs. However, it is also clear that differences in the product characteristics between packaging and EEE, in particular concerning life-time, and the special problem of the "historical waste" make it **necessary to develop and operate new concepts**.

In conclusion, within an appropriate legislative frame it seems feasible to keep ecology standards as high as possible and to achieve at the same time better economy by stimulating

- development of new product designs that lower recycling cost,
- competition among producers to improve the overall efficiency of take-back schemes.

1. Introduction

The Chairman of the Environment Committee of the European Parliament requested IPTS to perform a study that critically examines the different options available for the establishment of a European concept for the management of waste from electric and electronic equipment.

The Committee expects an analysis of the key issues, the main impediments and the potential solutions, which could be introduced to speed up the improvement of the current situation.

Waste from electric and electronic equipment (WEEE) represents a waste category for which, despite systematic efforts[1], no conclusive regulation could be established until now at EU level. This situation creates considerable problems[2] regarding the protection of the environment, quality of life and the conservation of resources. On the other hand it affects industrial competitiveness[3], due to the uncertainty resulting from the extraordinary length of the debates already started in the beginning of the 90's.

Under the pressure of the present "non regulated" situation, it appears that all actors concerned, including environmental authorities and industry, are willing to find, as soon as possible, a constructive solution. Several European countries have already started regulatory initiatives in combination with several recent pilot WEEE management exercises. In the same time, companies and most particularly the big global players are developing corporate strategies and pilot WEEE take back schemes.

Co-ordinating the current regulatory developments, towards a European WEEE solution, is generally perceived as a difficult undertaking. This is mainly due to the complex nature of the WEEE, which consists of a wide variety of products with a wide distribution of life cycle expectations. Furthermore, particular difficulties arise from the fact that long-life equipment has been accumulating in households over the past decades without any rules regarding its end-of-life fate. However, the recent pilot exercises in several Member States appear to offer a unique way of "learning by doing" in order to test and adopt potential solutions. In this light, the present study provides review of the available experiences and analyses key issues regarding the large scale deployment of WEEE management systems across the EU.

[1] Environment DG/EC, priority waste stream project on WEEE,1995
[2] Chapter 3 summarises available data about the size of the problem
[3] Environmental issues are of increasing strategic importance for the commercial success in domestic and global markets

2. World-wide regulatory trends

A comprehensive overview and comparison of the currently applied WEEE management practices in the EU, USA and Japan has recently been carried out (see summary Table 1). The study concludes that Western Europe is leading the developments when it comes to environmentally conscious processing of end-of-life appliances. United States are taking a wait- and –see position while Japan is found to be progressing since a few years.

Table 1

Currently applied WEEE management practices[4]

Issue	Japan	Europe	USA
Collection	Each municipality has its own policy. Drop-off systems are free of charge, while pick-up systems are operational with a charge varying from $2 to $15.	A collection infrastructure is present in most communities. Services are usually free of charge, and paid for by local taxes.	Most cities have pick-up services for large appliances. Services are usually free of charge, and paid for by local taxes.
Disassembly	Little or no disassembly is done	Disassembly as a step prior to shredding is done at a number of recycling facilities	Little or no disassembly is done[5]
Processing	Appliances are only shredded for recovering iron. Plastics are usuall landfilled. Small appliances are incinerated.	Many different product categories are shredded	Some shredding operations exist for appliances with material value. Still the majority of small appliances is landfilled. However, the majority of large appliances are recycled.
Regulatory initiatives	Appliance Recycling Law, 1998	Proposed EU Directive/National Decrees (see Table 2)	No existing nor proposed regulations

An overview of current legislative activities in Member States of the EU is presented in Table 2 and shows the great variety of the WEEE management models, which are under consideration.

[4] Casper Boks et al. : An international Comparison of Product End-of-Life Scenarios and Legislation for Consumer Electronics, IEEE International Symposium on Electronics and the Environment, Oak Brook, Illinois, May 4-6, 1998

[5] This statement is being questionned by Mrs. Holly Evans, IPC, USA. Reportedly several pilot experiences are available in the USA. In addition many private companies have begun to get into the electronics recycling business.

Table 2
Current WEEE legislative initiatives in Europe

Country	Status and key characteristics of WEEE legislation
Austria	Legislation only on refrigerators and lamps
Belgium	Law adopted in Jan. 1998 in Flanders; Effective for white goods in July 1999. Producer responsibility
Denmark	Regulation adopted on 22 December 1998 ; covers IT, telecom, white and brown goods; consumer and professional goods; shared responsibility; last owner pays for professional waste; consumer WEEE collected and managed by municipalities
France	
Finland	
Germany	Proposed ordinance, covers brown and white goods, and ICT equipment
Ireland	
Greece	
Italy	Draft Decree; computers and white goods; shared responsibility
Luxembourg	Proposed legislation on CFC containing equipment and mercury lamps
Norway	In force July 1999; all EE products; producer responsibility; levy on new price
Portugal	
Spain	
Netherlands	Decree in force January 1999; covers IT, telecom, white and brown goods; shared responsibility; ban of incineration of whole products; no targets; levy on new price
Sweden	Draft ordinance; proposed to enter into force on 1 January 2000; covers IT, telecom, white and brown goods; consumer and professional goods; producer responsibility; municipal responsibility for refrigerators and freezers;
Switzerland	In force July 1998; IT, telecom, consumer electronics, white and brown good; producer responsibility; obligation to give WEEE back
UK	

At EU level there is presently a proposal[6] by the European Commission for two separate Directives concerning the environmental problems associated with the current methods for the treatment and disposal of WEEE. The first – the draft Directive on WEEE – deals with the management of waste and is based on Article 175 of the Treaty. The second, which seeks to harmonise national measures on the restriction of the use of certain hazardous substances in electrical and electronic equipment, is based on Article 95 EC Treaty. These two Directives will be followed by a further proposal on the design and manufacture of electrical and electronic equipment later this year. The key characteristics are the following:

WEE Directive

Scope: covers a wide range of Electric and Electronic Products new and "historical[7]" waste, including consumer and professional[8] goods.

- **Separate collection of WEEE:** Requests Member States to set-up systems, so that last-holders and distributors can return WEEE from private households free of charge. Distributors, when supplying a new product will be requested to offer to **take back free of charge** similar WEEE from private households provided that the equipment is contaminant free.

[6] Proposal for a Directive on Waste Electrical and Electronic Equipment and for a Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment, European Commission, 13. 06. 2000
[7] Equipment placed on the market before the entry into force of the Directive
[8] EEE mainly in professional use and of small or medium size is in general subject to the provisions of the current proposal. In weight terms, the vast majority of professionally used equipment is not subject of the proposed regulation. The excluded equipment includes vehicles, aircraft, vessels and associated transport equipment or large industrial appliances.

- **Implementation targets:** Introduces collection[9], re-use and recycling targets.

- **Financing:** Member States are requested to ensure that holders of WEEE from households can return this waste **free of charge**. The costs for treatment, recovery and environmentally sound disposal are to be borne by producers either by collective systems or by individual systems for the products of their brand only.

Hazardous substances Directive:

- **Measures to improve prevention and recycling:** introduces phasing out of certain uses of substances such as lead, mercury, cadmium, hexavalent chromium, halogenated flame retardants[10] by 1 January 2008. The rate of component, material and substances re-use and recycling shall reach a minimum of 50-80 %[11] by weight of the appliances.

In the USA there is currently no planned nation-wide WEEE tack-back legislation. However, it has to be stated that various States have introduced legislation on specific groups of WEEE. In addition, several initiatives of the US EPA are focused on WEEE, seeking on a **voluntary non regulatory basis**[12], to encourage companies to implement cleaner technologies. Of particular importance are the following:

- Common Sense Initiative,
- Design for the Environment (DfE) Programme,
- DfE Printed Wiring Board (PWB) Project,
- Project XL (Excellence in Leadership).

In Japan, a bill on WEEE recycling was passed by the diet on 29th May 1998, and was promulgated as the "Specified Household Equipment Recycling Law" on 5th June 1998. This law was to be enforced within 6 months after the day of promulgation. Imposition of take-back and recycle obligation on manufacturers and retailers is to be carried out within 3 years after the promulgation day will cover 4 product categories only: **TVs, Washing machines, Refrigerators and Air conditioners**. According to Japanese experts the Japanese frame is based on a **"last owner pays"** approach[13]. The main contents of the law are as follows:

- Manufacturers or importers are responsible for taking back and recycling of WEEE.
- Each manufacturer can set up the recycling cost of its product by itself.
- End user has to pay a recycling fee which includes logistics costs (around 2500-5000 Yen) to dealers at the moment of take-back.
- Dealer is responsible for transporting WEEE to manufacturers.
- Municipality can support manufacturers for collection of WEEE.

Of particular relevance for the WEEE management in Japan is a project for the development of an integrated treatment and recycling system for post-use electric home appliances carried out by AEHA (Association for Electric Home Appliances) with the support of MITI (Ministry of

[9] Member States shall aim at achieving a minimum rate of separate collection of four kilograms per inhabitant per year

[10] Polybrominated biphenyls and polybrominated diphenyl ethers

[11] Depending on the type of appliances: for example 75 % for large household appliances, 70% for all appliances containing a cathode ray tube, etc.

[12] Except for the Project XL, which is an enforcement experiment concerning the flexible regulation of emissions from production facilities

[13] Source: Mr. Takashi KITABA, Office of Recycling Promotion, Water Supply and Environment Sanitation Department, Ministry of Health and Welfare, Tokyo, Japan, personal communication to IPTS 23 June 1998,

International Trade and Industry). In this context, AEHA is developing and testing a 150.000 units per year pilot plant (51.000 TV's, 36.000 refrigerators, 39.000 washing machines and 24.000 air conditioners). Total cost is about $40 million and the test operation was due to start in 1998.

3. Environmental issues related to WEEE

Waste from Electric and Electronic Equipment can cause environmental problems through inappropriate treatment and uncontrolled disposal. These problems appear to be primarily associated with the nature of hazardous materials contained in WEEE, and to a lesser extent with the total quantities of this type of wastes.

3.1 WEEE arisings

While there are no doubts about the annual equipment sales in the EU, our knowledge about the resulting WEEE quantities arising presently is particularly poor.

Rough estimates were generated in the frame of the EC priority waste stream project. **According to these estimates the total WEEE is with about 6 million tonnes per year only a small part in the range of 1% of the total wastes in the EU[14].** More recent calculations by the EC[15] found the WEEE to already amount 4% of the municipal waste[16].

The EC priority waste stream project estimated for WEEE an expected average growth rate throughout the 15 Member States in the range of 3-5%. However, due to the lack of WEEE regulation there is presently no constant flow of WEEE, which could be taken as a reference point for future developments. Secondly, the growth rate of WEEE will also depend on the way and the timing end-of-life EEE products, presently accumulating in households and business, will become waste. This will depend on the final outcome regarding the regulatory provisions on historical waste and most particularly on the prices which will have to be paid by those who will be called to assume responsibility for the historical waste.

Concerning the systematic assessment of the WEEE quantities, there are presently only few recent experiences from pilot projects carried out in several countries (see Chapter 4). In general, it has been found, that the “theoretical” calculation of WEEE on the basis of sales statistics and of average life-time data does not deliver comparable results with the “real” quantities identified in the different collection experiments. The general trend is that **theoretically calculated WEEE data in the range of 12-20 kg/inhabitant/year[17]** are higher than those measured in the pilot projects, which also deviate substantially from each other depending on geographic location and the particular test conditions.

Examples of data measured in pilot projects are given below:

[14] The total waste stream primarily consists of agricultural, mining, municipal and construction waste. Comparative data of waste arisings per year in the EU are known for the following categories of materials: a) waste paper 55 million tonnes, b) waste plastics: 17.5 million tonnes, c) construction waste: 500 million tonnes (see L. Bontoux, F. Leone, M. Nicolai and D. Papameletiou**:** “Impediments and Prospects of the European Recycling Industry”; EUR 17271 EN, Final report to the Environment Committee of the European Parliament, IPTS, Seville, 1996).

[15] Mr. F. Ermacora, Environment DG/EC, personal communication to IPTS, 9 September 1998. See also the explanatory memorandum of the July 1999 WEEE proposal.

[16] According to UK data provided by CECED, the Large Appliances in the UK are less than 1% of the municipal waste and 0.3% of total waste.

[17] CECED suggests that measuring arisings per household (instead per inhabitant) would be preferable

All white and brown household appliances:

- Weiz (Austria) 3 kg/inhabitant/year
- Bregenz (Austria) 4.5 kg/inhabitant/year
- Klingau (Switzerland) 5.1 kg/inhabitant/year

Large white appliances:

- Eindhoven (NL) 0.9 kg/inhabitant/year
- Rhone Alpes (France) 3.2 kg/inhabitant/year
- Bregenz (Austria) 1.8 kg/inhabitant/year
- Weiz (Austria) 2.1 kg/inhabitant/year

Television sets:

- Eindhoven (NL): 0.43 kg/inhabitant/year
- Weiz (Austria): 0.42 kg/inhabitant/year
- Rhone Alpes (France): 0.46 kg/inhabitant/year

Table 4 shows that the available data about WEEE quantities arising presently in some European countries and about their further management are extremely poor. In this respect, CECED suggests that a definition of "waste arisings" and an agreed "Protocol" are needed in to get better insights into the current situation.

Table 4:

Available data on WEEE quantities[18] (10^3 tonnes) and their further management in some European countries

Country	Total Arisings	Landfill	Incineration	RecoveryRe-use, Recycling	Export
Denmark[19]	120-130	n.a	n.a	8	80
UK	900[20]	n.a	n.a	n.a	n.a
Norway	144	76	20	38	10

3.2 Hazardous materials in WEEE

Concerning the characterisation of the hazardous potential of the WEEE arisings, there are several analyses available and their results have been recently reviewed by a study conducted on behalf of the Nordic Council of Ministers (see P. Hedemalm et al., 1995). The study found that a large proportion of the hazardous substances is concentrated in relatively few components and product groups in the Nordic countries, as follows:

- **Cadmium** - more than 90% in rechargeable batteries,

[18] IPTS has been explicitly requesting experts to provide quantitative information on WEEE arisings. Apparently there are no data readily available.
[19] Data provided by Mr. Anders Faber, Danish Environmental Management Center, 08 Jan 1999
[20] ICER: Arisings of end of life electrical and electronic equipment. Summary of Research Findings, London, March 1998

- **Lead** - more than 90% in batteries[21], [22], with small contributions from solders for PBAs, light bulbs and fluorescent tubes,
- **Lead oxide** (used in glass) - more than 80% from CRT's (Cathode Ray Tubes), with the rest coming from light bulbs and fluorescent tubes,
- **Mercury**[23] - more than 90% from batteries and position sensors, with small contributions from relays and fluorescent tubes,
- **Hexavalent chromium** is used as a corrosion inhibitor in the cooling system of absorption refrigerators
- **PCB**[24] - (poly chlorinated biphenyls) - more than 90% from PCB-filled capacitors,
- **TBBA** - (tetra-bromo-bisphenol A) - more than 90% from PBAs, in the PWBs and in components
- **Octa- and deca-BDE**[25] -(octa- and deca-bromo diphenyl ether) - more than 80% in computer enclosures, with small contributions from TV sets and domestic kitchen appliances
- **CFCs**
- **Chloroparaffins** - more than 90% in the PVC of cables.

Other materials or material categories of environmental relevance identified in WEEE include:

- silver, copper, barium and antimony

- PCN - plolychlorinated naphtalene - which has been used for impregnation of paper sheathed cables and in capacitors,

- liquid crystals- more than 2000 substances, many of them poisonous, can form liquid crystals,

- optical materials: indium, gallium, arsenide and cadmium,

- copper alloyed beryllium used for contact springs in small signal connectors,

- high temperature superconductors containing substantial amounts of mercury.

The size of the environmental problems that can be created by the above hazardous materials in WEEE depends on their toxicity and on the quantities that are released into the environment as a result of waste management operations. In this respect, the analysis of the problem and the

[21] Several actors stress that 90% of the lead have nothing to do with WEEE. The batteries are mostly used in cars. According to Dr. O. Frey, ZVEI e.V., personal communication to IPTS, 08. 10. 1998, the average content of lead in electrical products is 0.5 weight %. Lead in solders is estimated with max. 2% of the total lead consumption in Germany (1997).

[22] According to the Environment DG, in 1997 72% of lead was being used in batteries, mostly in industrially used batteries which are relatively easy to collect and treat. Other large uses, such as roofing sheet or cable sheating or lead ammunition are left in the environment untreated or returned to a scrap dealer. In quantity the main use of lead in WEEE is represented by lead in cathode ray tubes. Scientists say that this lead is bound in the matrix of the glass and normally not polluting the groundwater of landfills (in the short to medium term). As a consequence, the large majority of lead in landfills, which might be available to the, environment comes from lead in solders although the share of solders among the overall applications of lead is low.

[23] Hg has been largely substituted in EE products. Reportedly the substitution is not possible for: flat screens, Hg-lamps, very few battery types, special relays, fluorescent tubes

[24] this may be right for electrolytic capacitors that are more than ten years old

[25] The German Chemical Industry has signed a voluntary industry commitment not to produce PBDEs from 1986

conception of countermeasures must be based on a quantitative knowledge around the amounts of these materials. This knowledge may include

- the amount of hazardous materials cumulated in products in use by society,
- the amount of these materials that is currently introduced into the markets,
- and the environmental impacts that can result by the processing and disposal of the above WEEE amounts.

The amount of hazardous materials cumulated in products in use is a “historical” issue. This amount is difficult to be evaluated and remains unknown in most of the countries as it is also the case regarding the amount of hazardous materials which is introduced into the markets through new Electric and Electronic products. Data is available for the Nordic countries and represent an example of one of the most advanced contributions to the assessment of existing environmental risks by WEEE (see Table 5). This data, although approximate, show that significant quantities of toxic substances will be introduced in the mid-long term into the waste management chain of the Nordic countries.

Table 5
Hazardous substances in use and current annual inputs through new Electric and Electronic products in Nordic countries (DK, S, F, N)
[tonnes]

	Cumulated amount in products in use	Current annual input through new products
Cadmium	2 500	300
Lead[26]	180 000	60 000
Lead Oxide	11 000	2 000
Mercury	130	35
PCB[27]s	250	0

Source: P. Hedemalm et al., 1995

The assessment and analysis of the accuracy of such data should be a starting point of any WEEE management strategy and the present study will make corresponding recommendations for action at National or EU level. Furthermore, we suggest that monitoring the evolution of such data could provide a key for the conception and evaluation of waste prevention and management strategies[28].

The deployment of the environmental problems is delayed as long as the above substances are “fixed” into products in households or in business. **The direct threat for the protection of the environment starts not only through uncontrolled disposal in landfills but also at the**

[26] According to DANFOSS about 60% of lead used in electronics is shipped directly from the soldering process back to the supplier of tin/lead solder for recycling.
[27] poly chlorinated biphenyls
[28] According to Dr. O. Frey, ZVEI e.V., personal communication to IPTS, 08. 10. 1998, monitoring such data requires a huge administration, which cannot be afforded.

moment when human intervention is needed regarding the treatment and the disposal of the WEEE.

The drawbacks of the current “non regulated” situation are numerous, and can be summarised as follows:

- uncontrolled disposal of significant quantities of WEEE,
- ever increasing accumulation of the hazardous substances in the households and business,
- there is presently no large scale experience with WEEE management techniques and schemes to ensure minimisation of the environmental impacts through optimal partitioning of the hazardous substances into non-polluting streams (Chapters 4 and 5),
- future WEEE management techniques and schemes have to be designed and operated for old and outdated products.

In conclusion, it appears that implementation of a purely collection based WEEE management strategy is by far not sufficient to prevent environmental problems. The focus must equally be placed into the minimisation of the quantities of hazardous materials in products and into the minimisation of the release of these materials into the environment during treatment or disposal of WEEE[29].

3.3 Preservation of Resources

The discussion of the potential environmental impacts from WEEE has shown a wide agreement that the major problem is related with the hazardous substances contained in products. The recovery, re-use or recycling of non-hazardous materials, such as iron, copper, glass, ceramics, plastics which are the major constituents of Electric and Electronic Products is of priority as well.

From a life cycle point of view, the re-use and recycling of WEEE has a significant potential to reduce the consumption of resources and the waste generated during the production of EEE. A good example is given by the 522000 tonnes of copper, which are approximately contained in WEEE generated at EU level in 1998. EC[30] data show that the overall consumption of resources for the extraction of one kilogram of copper amounts to 1.176 kilogram. Accordingly, it is suggested that the recycling of the copper contained in WEEE could help achieving resource saving of more than 600000 tonnes of primary resources per year.

On the other hand, when evaluating the resource efficiency by extended product and component reuse one need to make calculations on a product life cycle basis, as well. In this way, it can be taken into account that new appliances are more efficient, compared to 15-year-old appliances, in the use of resources like energy, water, detergent etc.

Generally it is estimated that 90 % of the environmental impact of a house hold appliance occurs during use. Therefore, for many actors the reuse option appears to be not attractive regarding its potential to decrease the overall environmental impact. This is particularly the case, when the reuse option implies that old inefficient appliances remain in use for several additional years.

[29] CECED suggests that thresholds for hazardous materials are defined in standardisation bodies. Criteria for the certification of the disposal and recycling facilities are available from ZVEI/VDMA.
[30] See also the WEEE explanatory memorandum of the draft EC proposal, dated 13 June 2000.

4. WEEE management schemes

For the time being there are only experiences available from a number of trial WEEE management schemes which have been designed and operated at various pilot scale conditions during recent years in several EU Member States and to some extent also in Japan and the USA. As a consequence, the current WEEE initiative of the European Commission benefits from a certain richness of available models for action. However, as these trials were designed without a central co-ordination to meet several objectives, it is now be difficult to establish a consensus on a preferred European-wide solution.

Systematic evaluation of organisational concepts and of pilot results has been or is being carried out in Austria[31], France[32, 33], Germany[34, 35] and in the UK[36].

The Austrian study[37] distinguishes three potential organisational models:

- **Municipal systems:** local communities are obliged to collect WEEE, to transfer it to a recycling or a disposal agent and to undertake the entire financing of the operation

- **Distributor-based systems:** the obligation for the collection lies with the actors who have placed the EEE into the market. Brand (products sorted according to brand) or retailer systems (anonymous products) are further options for these systems. Collection can be brand specific or mixed.

- **Pool systems:** are commissioned by their members to organise and to finance the WEEE management. Community pool systems and retailer pool systems are further options.

Combined Municipalities-Retailer-Manufacturer systems appear to offer promising solutions for efficiently sharing responsibilities and existing infrastructures. Municipalities could primarily be involved in the collection WEEE from households and from retailers and undertake its separation from municipal solid waste. The Retailers and the Manufacturers could be involved in the establishment and operation, of the entire chain of treatment, recycling and disposal operations. Of key importance is to establish clear and efficient rules to optimise the interface

[31] Comparison of Systems for Collection/Recycling/Disposal of End-of-Life Electrical and Electronic Equipment (EEEE), Economic Impact. A study by FEEI (Austrian Electrical and Electronic Industries Association) produced at the Institute of Industrial Research (Economic University of Vienna), July 1996

[32] Jean-Pierre Desgeorges, Proposals for organising the collection and valorisation circuits for end of life electrical and electronic products, Report on behalf of the Ministry for Environment and the Ministry for Industry, France, 21 November 1994

[33] FIEE: Produits Electriques et Electroniques non portables en fin de vie en region Rhone-Alpes, Rapport Final, Paris, Janvier 1997

[34] Erfassung von Elektro-Haushalt-Kleingeräten aus Haushalten mit verschiedenen Erfassungssystemen, INFA, Endbericht im Auftrag des Zentralverbandes Elektrotechnik-und Elektronikindustrie e.V (ZVEI), August 1995

[35] Kommission der Niedersächsischen Landesregierung zur Vermeidung und Verwertung von Abfällen, Niedersächsisches Umweltministerium, Abschlußbericht des Arbeitskreises 13 “Elektronikschrott”, Hannover, März 1998

[36] ICER (Industry Council for Electronic Equipment Recycling): Report on the UK Industry for Recycling End of Life Electrical and Electronic Equipment, First Draft, London, April 1998

[37] Comparison of Systems for Collection/Recycling/Disposal of End-of-Life Electrical and Electronic Equipment (EEEE), Economic Impact. A study by FEEI (Austrian Electrical and Electronic Industries Association) produced at the Institute of Industrial Research (Economic University of Vienna), July 1996

between Municipalities and Manufacturers. Open questions are of the type **"who pays what"** and about criteria for the design of the post collection WEEE management chain. In this contexts, it is conceivable that different industrial pools, according to different product clusters, can be established and co-operate in parallel in order to make best use of market forces, of product characteristics, of the WEEE collection logistics and of the existing treatment, recycling and disposal capacities.

Distributor based systems, excluding totally the municipalities do not make sense because they are associated with duplication of existing collection infrastructure.

Brand systems make only sense when the competitiveness of the producer is strengthened through proprietary treatment recycling or reuse practices.

4.1 Municipal schemes

The following pilot municipal schemes for the WEEE management have been identified to date by IPTS:

- Pilot Project Bregenz, Austria[38]
- Pilot Project Flachau, Austria[39]
- Pilot Project Weiz, Austria[40]
- Rhone Alpes, France[41]
- Pilot Projects Stadt Dortmund, Stadt Bocholdt, Kreis Recklinghausen, Germany[42,43]
- Pilot Project Interseroh, Germany
- National pilot project, for collecting, recycling and repairing electrical and electronic equipment in the district of Eindhoven, Apparetour[44], The Netherlands

[38] R. Gabriel und S. Salhofer: Bregenz Pilot Project - Waste From Electric and Electronic Equipment. , Universität für Bodenkultur Abteilung Abfallwirtschaft, Institut für Wasservorsorge, Gewässerökologie und Abfallwirtschaft. Summary Document prepared for the Bundesministerium für Umwelt, Sektion III-Abfallwirtschaft, Wien, April 1996

[39] R. Gabriel und S. Salhofer: Pilotproject Flachau zur Sammlung und Behandlung von Elektrogeräten. Universität für Bodenkultur Abteilung Abfallwirtschaft, Institut für Wasservorsorge, Gewässerökologie und Abfallwirtschaft, Endbericht, erstellt im Auftrag der Salzburger Landesregierung, Abteilung 16-Umweltschutz, Wien, Februar 1998

[40] Elektronikschrott Projekt Weiz, Band 4, Informationsreihe Abfallwirtschaft des Landes Steiermark, Graz, März 1996

[41] FIEE: Produits Electriques et Electroniques non portables en fin de vie en region Rhone-Alpes, Rapport Final, Paris, Janvier 1997

[42] Erfassung von Elektro-Haushalt-Kleingeräten aus Haushalten mit verschiedenen Erfassungssystemen, INFA, Endbericht im Auftrag des Zentralverbandes Elektrotechnik-und Elektronikindustrie e.V (ZVEI), August 1995

[43] Kommission der Niedersächsischen Landesregierung zur Vermeidung und Verwertung von Abfällen, Niedersächsisches Umweltministerium, Abschlußbericht des Arbeitskreises 13 "Elektronikschrott", Hannover, März 1998

[44] Ploos van Amstel Miieu Consulting B.V.: Back to the beginning: National pilot project, for collecting, recycling and repairing electrical and electronic equipment in the district of Eindhoven, Apparetour, Eindhoven, September 1997

- LEEP Collection trial, UK
- Bilbao Trial, Spain
- Pilot Projects in Sweden

Operational parameters of the above WEEE trials like size of collection area, duration of pilot experiments, number of inhabitants, types of goods covered, collection, treatment, recycling and financing approaches vary considerably.

There is a clear need for a systematic comparison of the available results, which have been summarised in a study[45] on behalf of the EC (AEA Technology, June 1997) and discussed in a recent workshop[46], organised by the Enterprise DG. The conclusions of such a comparative study could be the starting point for action planning at EU level. Along this line, Table 6 specifies the information, which needs to be obtained directly by the operators of WEEE management schemes at communal and at corporate level.

Table 6
Information profile for data collection on Pilot WEEE management schemes at communal and corporate level

Name of WEEE management project
Main operator
Region/country
Number of inhabitants
Period of operation
Types of WEEE covered
Legislative issues
Responsibility issues: consumer, community, producer, retailer
Operator(s): collection, treatment, recycling and disposal
Collection approach
Treatment, recycling and disposal approach
Financing approach
Total collected WEEE quantities
Total treated WEEE quantities
Total recycled WEEE quantities
Total disposed WEEE quantities
Cost of collection, treatment, recycling and disposal
Environmental impact of the WEEE collection, treatment, recycling and disposal

4.2 Corporate schemes

The term corporate schemes covers all industry led initiatives to establish WEEE collection, treatment, recycling and disposal networks.

[45] see also Carsten Nagel: Take IT back-European approaches for setting up reverse logistic systems, International Symposium on Electronics & the Environment, May 4-6,1998, Oak Brook, Illinois
[46] Brussels, July 10th 1998

The following pilot corporate schemes for the WEEE management have been identified to date by IPTS:

- British Telecom
- Cycle Working Group, Germany
- ICER collection trial, UK
- EMERG, UK
- ECTEL, UK-Sweden
- Electrolux
- Deutsche Telekom, Germany
- VOBIS/Covertronic, Germany
- Phillips
- Sony
- IBM
- Apple
- Xerox
- DEC
- Hewlett-Packard/Noranda Metallurgy, USA
- San Jose, USA
- SWICO

5. Technology and industrial issues

This Chapter reviews technology demonstration results with the aim to evaluate the availability of proven concepts and the needs for further development work at EU scale.

In general the applied pre-treatment techniques can be:

- non-destructive disassembling,
- partially destructive disassembling,
- completely destructive treatment.

and the key issue is that they determine the choice of follow-up processing options of the treated WEEE including the economics and environmental impacts of the entire post-collection WEEE management chain.

There is wide agreement, that the starting point for the **post-collection WEEE management chain** will be so-called **WEEE processing centres** operated by industrial actors with the scope to treat and disassemble the WEEE into structural elements to be reused, recycled or disposed. The type of these structural elements depends on the hazardous content of different components, their market value for reuse, and from the available recycling and disposal options, which often are subject to local conditions.

Presently, disassembly work is being executed mostly manually. In the future it is expected that automation and robotisation will increasingly be introduced as the result of progress in DFE (Design for the Environment) and with the support of novel instruments, such as the so- called "Green Port Identification Unit".

In general, alternative treatment and processing options are of the type **"disassembling + component reuse[47] versus shredding[48] + smelting/incineration for metal/energy recovery".**

Key questions are about the optimum disassembling level prior to shredding and about acceptability of the environmental consequences resulting from energy recovery and metal smelting.

5.1 Large domestic appliances

The question whether large domestic appliances (washing machines, dryers, dishwasher, centrifuges, ovens, combined washer/centrifuge) should be processed in existing car shredders or in special shredders for domestic appliances has been investigated systematically in Germany, Austria and in the Netherlands. According to the Dutch study, in the case of the car shredders the required pre-treatment is limited to the dismantling of PCB (polychlorinated

[47] According to Mr. E. Redondo, Lucent Technologies, Spain, personal communication to IPTS, 23. 10. 1998, component reuse cannot be considered as a long-term alternative. Rapid change in technologies might render many components obsolete. Reuse of components could also create trade barriers for products manufactured abroad.

[48] to separate metals in a follow-up step by means of magnetism, eddy current, electrostatic air separation, flotation

biphenyl) containing condensers[49] in order to prevent contamination of the shredder fractions. On the other hand, the shredders for domestic appliances require complete dismantling of components such as drums, electromotors, counterweights, condensers, plastics, clocks etc. prior to the shredding operation. The dismantling can lead to the need for recycling of plastics contained in large household equipment. According to the Environment DG, this is an important point, in view of the fact that plastic is more and more used in large household equipment.

The available operational experiences show superior **material reuse possibilities of about 90%** in the case of the domestic shredder per appliance at substantially higher cost compared to **the car shredders[50] where material reuse rates of about 75%[51] can be achieved**. Despite the economic advantages of the car shredders[52], the experiments have shown that the combined treatment of cars and of domestic appliances affects negatively the overall material separation efficiency and that it increases the amount of shredder residue, which has to be disposed in landfills.

Information[53] about the management of end-of-life refrigerators and freezers is available from Germany, where installed capacities for recycling 3.2 million items are evenly distributed all over the country. The current practice is to export about 30-70% of the discarded freezers and refrigerators. As far as recycling is concerned, there is a requirement to drain all CFCs[54] containing refrigerants before shredding. Following the shredding operation, the resulting fluff from polyurethane insulation materials contains still considerable amounts of CFCs, which can further be reduced by applying degassing techniques. Polyurethane fluff containing more than 0.5% CFCs cannot be further recycled and is sent to municipal waste incineration plants.

According to the White Goods Industry[55], the term "Design for Environment" might be misleading if used only in the context of Waste Management. As already mentioned, the main part of the environmental impact of large household appliances happens during its use. Though being aware of their responsibility for the end of life of the appliances, the success of Design for the Environment (DfE) will therefore be decided along parameters like the energy consumption or the water consumption. Therefore, it would probably be more adequate to also use the terms Design for Recycling or Disassembly. In this light, CECED suggests that DfE measures need to be applied in parallel to an end of life strategy (option) available or predicted to be available:

- A fridge/freezer constructed of foam filled cabinetry and doors will need significant design changes to enable the product to be easily dismantled and at the same time may compromise Energy Efficiency during the use phase. This product and its materials (mainly plastics and rubbers) will also be in contact with food and other substances during and after its normal use, a variable that is not able to be predicted, is imposed by the user and one that cannot necessarily be designed out. In order to design this product with the

[49] The Dutch study found, that presently 12.6% of all large domestic appliances contain condensers with Polychlorinated biphenyl (PCB). Based on the fact that condensers build after 1984 are PCB free, the study calculates that PCB – suspect WEEE will be a concern until about 2015. Prior to the shredding, condensers have to be removed and checked on eventual PCB content. Condensers containing PCBs need to be destroyed in special high temperature incinerators for hazardous waste.
[50] CECED recommends that In order to determine the effectiveness of shredding facilities, a substantial quantity of material needs to be reprocessed. In the UK it was recently recommended by the largest shredder operator that a minimum representative sample should be no less than 250 tonnes .
[51] According to CECED, car shredders in the UK do not achieve the 75%; this figure is thought to be far too high
[52] operate at 15-20% of the cost required by domestic shredders
[53] source: ISOPA (European Isocyanate Producers Association)
[54] about 115 g CFCs per refrigerator are removed in a first step
[55] CECED

Environment in mind, the largest impact (use phase) has to be regarded as the priority in the DfE process. For this product the recycling/End Of Life strategy might therefore only represent a limited choice (shredding) until alternative solutions can be found.

- A cooker on the other hand represents a product with much higher recycling possibilities owing to quite a different type of construction. The mainly ferrous content is in this case able to be recycled but again, only the shredding process applies and energy efficiencies in use are the highest Environmental Impact. DfD is therefore irrelevant as a design option.

- For a washing machine, some static components (balance weights, pulleys & in some cases motors) lend themselves to DfE or DfD but have problems as technology develops and components become obsolete. It is in the former case that parts are able to be designed such that re use / repair become possible recycling options but may not necessarily be the final option when the product is discarded. Again the prominent part of a washing machine's environmental impact is that of its energy & water consumed through use. Hence, particular attention and priority should also be applied to this part of the life cycle.

5.2 Small domestic appliances

The treatment options for small[56] domestic appliances were investigated by the German study, which concludes tentatively that about 20% of this equipment contains significant amounts of hazardous components and suggests several treatment alternatives with and without pre-separation of hazardous components. The study found that **59% of the small WEEE consists of metals (38% Fe and 21% non-Fe) which can be recovered** through mechanical processing techniques and subsequent treatment in metallurgical processes. Concerning the remaining 41% of non-metals, which consist mostly of mixed plastics, textiles, wood and glass, the study estimates that there is no feasible recycling option because of the high level of contamination (org. bromine compounds, PCB, Hg, Cd, Pb, Ni). The study suggests energy recovery for a part of this fraction that can be decontaminated to certain level and final disposal for the remaining material.

As far as **cellular phones** are concerned, the ECTEL project[57] made first comparative efforts to assess the options "Shredding + Smelting for metal recovery versus disassembling and component reuse". The study concludes that the environmentally preferable option is "components reuse". However, it also alerts that adoption of such a strategy may not be sustainable in the future, at least for the cellular phones, because the ever increasing technological sophistication may render the recovered components obsolete before they can be-reused. Along this line, many other actors[58] are of the opinion that "reuse" has no sense for their products that must have high reliability and long service life, which is impossible to guarantee with "reused" components.

[56] Which are usually deposited in the garbage bag
[57] End-of-life management of cellular phones - an industry perspective and response. Report of the ECTEL Cellular Phones Take-back Working Group, November 1997
[58] for example Danfoss,

5.3 Appliances with screens

The current lack of a steady flow of end-of-life **CRTs[59] (Cathode Ray Tubes),** due to non existing systematic collection activities of these items at an European scale, appears to constitute a major impediment to the development of appropriate large scale recycling facilities.

Potential solutions for the management of lead containing waste CRTs were tested in Germany, Austria, The Netherlands and have been investigated in several studies and R&D programmes[60]. The technical solutions considered as promising are the following:

- recycling into the fabrication of new CRTs
- recycling into other glass or ceramic applications
- use of CRTs as a fluxing agent in lead smelters

Concerning the recycling option into the fabrication of new CRTs, it appears that there are several technology barriers to an economic recycling. In particular this concerns the efficiency of the separation of the various types of glass, ceramic and metal components contained in CRTs (such as panel, funnel, neck, stem, gun mount and frit). The achievable purity in the separated glass components of the CRTs depends significantly from the type and the age of the screens. In the Netherlands, the so-called EcoRam[61] proprietary technique is applied for cone glass production by recycling a mix of screen glass and cone glass. It allows in the case of relatively recent CRTs recycling rates of about 95%. However, the recycling rate for old CRTs is about 55% and the remaining 45% are sent to the ceramics industry. In agreement to this, the German study calculates at European level the achievable total recycling potential of CRTs in cone glass production to be about 88.000 tonnes per year (total cone glass production: 176.000 tonnes per year).

Evaluations about the CRTs recycling potential in lead and copper smelters are for Germany in the range 6.000 tonnes per year. Whereas, the CRTs recycling prospects in the container glass industry are limited, promising solutions are being proposed for using CRTs in the ceramics and in the abrasive materials industries.

Evaluation results have also been obtained in the USA[62, 63, 64]. Reuse and refurbishment is estimated to have the potential to prolong the original life of monitors from about four years to a second life, which can last up to eight years. Recycling CRTs in lead smelters has been found to generate lead emissions to air, in the level of 0.06% of the lead processed. Another reported disadvantage of the lead smelters solution is that energy embodied in the glass and in lead oxide is lost. Smelters in the USA are reported to charge between $200 and $500 to accept the CRT materials. Energy advantages can be obtained when waste CRT glass is directly recycled to new CRT glass.

[59] it is estimated that the annual production of CRTs in Europe is in the range of 606.000 tones and that additional 80.000 tones are imported

[60] BRITE/EURAM 3, “RECYTUBE”: Integrated Recycling of End-Of-Life cathode Ray Tube Glass; start date 12/`996; end date 11/1998

[61] Philips Components BV, Eindhoven; similar techniques have been reported to be operated in the USA by Envirocycle Inc. in Binghampton, NY and by Converion Technologies,

[62] “Environmental and Economic Impact Assessment of Cathode Ray Tube Recycling”, ICF Inc., May 27 1997, draft, US EPA Office of Solid Waste, Washington, DC

[63] Colleen Mizuki et al.: CRT Disposition: An Assessment of Limitations and Opportunities in Reuse, Refurbishment and Recycling in the USA, 1997 IEEE International Symposium on Electronics and the Environment,

[64] D. Smith et al.: Computer Monitor Recycling: A Case Study, Sony Electronics Inc., August 1996

5.4 Printed Circuit Boards

Printed Circuit Boards are typically difficult to recycle in particular due to their content in plastics[65] and most particularly due to plastics containing bromine-based flame-retardants[66].

Printed Circuit Boards are constructed of thermo-set plastics, like epoxy-resin, with glass-fibre as a skeleton material. Different electrical components, e.g. semiconductors, resistors, chip-condensers, etc. mounted on them are interconnected with solders containing lead and other heavy metals. Typically metals like Cu, Ag, Au, Pd, Pt are recovered in metal smelters.

According to analyses carried out by Danfoss, the lead content by weight is about 0.14% for the populated Printed Circuit Boards and about 0.1% for the complete converter.

Regarding the recycling of Printed Circuit Boards, there is lacking documentation on "best practices". Danfoss proposes that investigations should be encouraged, in particular because recycling options must be known already at the product design stage.

5.5 Plastic materials

According to APME[67] (Association of Plastics Manufacturers in Europe) the current plastics content in WEEE is 15.5%.

The traditional **mechanical recycling** of plastics is still considered as the preferred method by many policy makers. However, this is justified only for a part of the waste plastics, which is relatively clean and easy to separate into mono-fractions. Furthermore, the mechanically recycled plastics the performance characteristics of which are “downgraded[68]” need to be absorbed by the market in competition to the virgin materials. A key issue for mechanically recycled plastics is to identify suitable outlets. Their less specified characteristics compared to the virgin materials may cause that there is no little demand for their use. In this context, there is need for alternative recycling techniques for a significant part of mixed plastics wastes, the separation of which into mono-fractions is costly, energy consuming and not necessarily environmentally advantageous.

There are presently operational technological breakthroughs[69] according to which **mixed plastics waste** can be treated in existing industrial processes as hydrocarbons. In the case of the use of this plastics wastes in the iron & steel industry the main aim is to take advantage of their hydrogen content as a reducing agent for the iron ores. In the case of the so-called feedstock recycling processes, plastics waste can be converted in refinery operations into several crude oil fractions from which virgin plastics are produced.

---

[65] Sara Stenhammar , Swedish Environmental Protection Agency.

[66] Oeko-Institut e.V., Dr. Volker Strubel, personal communication to IPTS, 13. 08. 1998. Progress is reported o have been achieved within the project "Green TV" funded by BMBF (Bundesministerium fuer Bildung, Wissenschaft, Forschung und Technologie). Most particularly within this project, the traditionally used duroplastics were replaced by thermoplastics, which are considered to be easier to recycle.

[67] APME: Plastics a Material of Choice for the Electrical and Electronic Industry. Plastics Consumption and Recovery in Western Europe, Brussels 1995

[68] compared to virgin plastic materials

[69] According to APME, Dr. Neil Mayne, Personal communication to IPTS, 16. 10. 1998, a total of 350.000 tpy waste plastics was recycled in Germany by using existing industrial processes. Two new dedicated processes developed by industrial consortia, are currently subjects of investment proposals for commercial applications.

Acceptability of recycling options, which can use mixed plastics, would mean that there is no need to minimise the number of plastics in products. To this end, the first priority is to evaluate objectively the conditions under which the term “feedstock recycling” is equivalent to the current EU definition of recycling. Here, the problems are given by the overlapping of the process characteristics with energy recovery. Crude oil is a fuel but also a raw material for the production of plastics, which represents only a few percent of crude oil consumption. The same is valid for the cases when the hydrogen content of waste plastics is used as a reducing agent. Hydrogen is both a chemical raw material and a fuel. The second priority is to evaluate the applicability of mechanical and feedstock recycling techniques for the treatment of WEEE. According to results obtained in a joint APME-VKE project[70] (Verband KunstoffErzeugende Industrie e. V.), a significant part of the mixed plastics dismantled from WEEE can be processed by applying feedstock recycling.

The part of plastics in WEEE that cannot be treated by mechanical or feedstock techniques may be contaminated with materials, which are not compatible with the specifications of these recycling processes. In this respect, a study[71] commissioned by APME concludes that energy recovery can be considered as an important recovery route for WEEE plastics. The conclusion is based on systematic experiments with WEEE plastics in

- a MSW pilot plant (TAMARA) at the Forschungszentrum Karlsruhe in Germany.
- a MSW incinerator in Wuerzburg, Germany.

Dioxin measurements were carried out and the reported results suggest that emissions can be kept below the German BimSchG, V 17th regulatory limits. Based on these results, the APME outlines that the energy recovery from mixed waste plastics by using state of the art incineration technology should not be inhibited by a pre-ordained hierarchy between the different recovery options.

5.6 Phase out of substances

The use of **lead-based solders** is a fundamental technology to all sectors of the global electronics industry and the current technology is compatible across all the different sectors of the industry, across the global electronics industry and across manufacturing, component supply and after-sales service activities. Currently there is development work taking place to identify suitable replacements for this technology[72] and several experts agree that there are interesting emerging alternatives to tin/lead solder. The most promising being other tin alloys and conductive adhesives.

However, a significant part of industrial representatives report, that the "ban issue" is their key concern regarding the emerging WEEE regulations in the EU. It may affect their products, which need to satisfy high safety and reliability standards and guarantee as well a long service life.

Actors from industry are particularly stressing that the alternative materials to lead solders will have to demonstrate same process capability and yield in production volume. Lower yield will mean generation of more WEEE. The alternative tin alloys have higher melting temperature than normal tin/lead solder. Consequently all processes and materials must be qualified to this higher temperature. This also includes <u>all</u> electronic components. Conductive adhesive is lagging full

[70] APME/VKE: Feedstock Recycling of Electrical and Electronic Plastics Waste, November 1997
[71] J. Vehlow and F. E. Mark: Electrical and Electronic Plastics Waste Co-Combustion. A technical Report from APME, February 1997

[72] for example the IDEALS project at Brite/Euram III

scale production capability and impact on recycling. There is no documentation regarding EMI, high tension voltage, and fire hazard properties. Both alternatives are lagging to demonstrate safety, reliability and service life on the same level as normal tin/lead solder. These investigations must be large-scale real time test as acceleration factors are unknown. They include mechanical tests as vibration, shock, temperature cycling and aggressive atmospheres known from the applications. Long term field tests must be run and evaluated at selected sites**.**

For the time being, **the key question** is whether the development status of the emerging alternative materials allows estimation of the time frame for their commercial availability.

On one hand research results[73] seem to be encouraging the Environment DG to estimate that phasing out lead solders will become feasible in 2008.

On the other hand the review of the available information[74] reveals that, at present, there is no commercially available drop-in replacement. Furthermore, according to the opinion of many actors (among others including Eurobit, Danfoss[75], IPC, American Electronics Association, Lucent Technologies, Electronic Industries Alliance (EIA), Japan Business Council in Europe), there are no current alternatives that are techno-economically viable.

Flame retardant additives are used to modify about 13% of the plastics used in electric and electronic equipment to meet product specifications[76].

According to Environment DG, one of the main impediments for the recycling of plastics is the risk of dioxin and furan generation by certain brominated flame-retardants. Reportedly, it has

[73] Among others results obtained by ITRI (www. itri.co.uk)
[74]

Study by the National Center for Manufacturing Science (NCMS) in the USA

Miller, J. : Why There Is No Pending Ban on Electronic Lead Solder
CIRCUITS ASSEMBLY, 1998, VOL 9; NUMBER 2, 128

Whitten, G. : Lead Free Solder for Automotive Electronics
SAE SP 1998; Feb, NUMB 1342 ,p. 53-60

Manko, H. H. : Lead Free Solder - A Status Report
National electronic packaging and production conference
NEPCON East `95; proceedings of the technical program , Boston; MA, Jun 1995, p. 347-353

Maguire, J. F. : Evaluation of Alternatives to Lead Solders for Printed Wiring Assemblies
Symposium on Design and reliability of solders and solder interconnections (Editor Mahidhara, R. K.)
Orlando; FL 1997; Feb , pp 145-154

No Lead Without Solder: One manufacturer found the use of COB techniques cut its solder, and therefore lead, usage
ELECTRONICS MANUFACTURE AND TEST
1997 , 1, p. 23-26

Anderson, I. E. Tin-Silver-Copper: A Lead Free Solder For Broad Applications
NEPCON WEST, 1996. //2, p. 882-890

Guy, J. : Dealing with the Issues of Lead Solder Replacements
National electronic packaging and production conference
NEPCON West 95, Anaheim; CA, 1995; Feb, //2, p. 1066-1076

[75] In Danfoss' opinion the suggested time frame is too short for these investigations and proposes a more realistic one of 7-10 years after final political decision of the WEEE directive.
[76] APME

been shown that polybrominated biphenolethers (PBDE) formed toxic furans (PBDF) and dioxins (PBDF) during the extruding process, which is part of the recycling.

PBB and PBDE[77] are two flame-retardants with characteristics[78].

EBFRIP[79] (European Brominated Flame Retardant Industry Panel) recommends the application of a case by case approach concerning the risk assessment of halogenated flame retardants, because HFRs are a structurally diverse group of substances. Their major point in common is not their chemical structure but rather their use as flame retardants. EBFRIP reports about a joint BASF-ZVEI pilot project which is aiming at demonstrating[80] the suitability of pyrolysis as a recycling method for typical used WEEE from the capital goods sector, such as switchgear, control systems, etc.. It was shown that halogenated flame retardants containing material can be recovered in an environmentally sound manner. Furthermore, it is worth noting that EBFRIP is currently undergoing a feasibility study of the recovery of bromine from BFR-containing waste plastics (e.g. housings, Printed Circuit Boards) to close the bromine loop and reverse the supply chain.

5.7 R&D needs

Better integration of R&D and Environment Policies in the early 90's and pro-activeness for targeted inclusion of WEEE management research in the EU R&D programmes could have been beneficial for a timely adoption of WEEE regulation.

Most actors agree that technologies will certainly change, in particular due to WEEE legislation. However, it is understood that most new concepts are in their infancy and that intensive R&D efforts in the following areas need to be supported by industry and by the public:

- Eco-design of new products (Design For the Environment or Design for Recycling)
- Dismantling technology and Design for Disassembly
- Replacement of lead soldering
- Design and pilot operation of large scale WEEE schemes
- Environmental impact analyses of WEEE schemes
- LCA models for Electronic Products, Modules and Components (Life Cycle Analysis)
- Material characterisation, separation and environment impact of materials
- Information and Communication technology for product information exchange (Green Port Identification Unit)

[77] Systematic risk assessment activities are being carried out at EU level. These assessments include also deca-BDPE and octa-BDPE

[78] According to Sara Stenhammar , Swedish Environmental Protection Agency, Personal Communication to IPTS, 15. 10. 1998, the levels of PBDE in human breast milk in Sweden are increasing

[79] EBFRIP, Dr. D. Drohmann, Personal Communication to IPTS, 14. 07. 1998. See also: EBFRIP: Brominated FlameRetardants and WEEE - An Industry Perspective - June 1999 (www.ebfrip.org).

[80] Christill & Jansen, Kunststoffe, 87, 1997,10 p 1385-1387

- Carrier and transport systems
- Economic and financing models
- Employment and socio-economic aspects.

5.8 WEEE and industrial competitiveness

It is generally accepted that the global competitiveness of the electronics and of the electric appliances industry will depend in the long-term on its ability to minimise waste and the environmental impacts of its products on a life cycle basis.

In anticipation of faster implementation of WEEE regulation in the EU it has been reported that European companies could obtain competitive advantages[81].

The American Electronics Association stresses that there is a need to ensure that any WEEE management framework will guard or at least minimise any external trade affects on non-EU manufacturers. Given the global marketplace for many electrical/electronic equipment, product requirements and targets in the EU could inhibit the free flow of trade.

The White Goods Industry[82] is particularly pointing out the significance of the cost of collection. They estimate that in the UK the logistics cost represents 42% of the total recycling process costs. Attributing the logistics costs to the manufacturers could generate significant pressures on the prices.

Eurobit[83] estimates that meeting the implementation costs of the current WEEE proposal of the European Commission will impact negatively on the profitability of the IT companies in general, including the taxes they pay, the amount they invest in research & development, and on the size of their work forces.

Of particular concern are the costs for the collection and treatment for historical IT equipment which are estimated to be approximately BECU 5. In addition to these historical costs, Eurobit estimates that meeting the administration costs of the proposal -- collection, transportation, auditing, regulatory compliance, etc costs -- will lead to an increase in 5% of the factory price of a new IT product.

Other questions addressed by industrial actors are related with the capability of SMEs to bear the costs associated with WEEE regulations.

[81] MCC: Environmental Consciousness: A Strategic Competitiveness Issue for the Electronics and Computer Industry, March 1993
[82] CECED
[83] Source: EUROBIT, http://www.fvit-eurobit.de/EUROBIT/POSITION/Pos025.html

6. Regulatory approaches

The ultimate scope of any WEEE regulatory framework is to maximise prevention, to ensure avoidance of uncontrolled disposal and to minimise environmental impacts across the entire waste management **"collection"**, **"reuse", "treatment", "recycling or energy recovery" and "disposal".**

It appears that the uncontrolled disposal of WEEE, which is today a common practice, cannot be regulated alone by conventional landfill legislation, especially because it does not provide an adequate frame for attributing responsibilities to the polluters. At least in Europe, there is wide agreement that such a frame should be introduced by a WEEE-specific regulation. Following the experiences with the Packaging Directive, which was introduced in 1994 as the first example of a product-specific waste management Directive, the discussion today around WEEE can only benefit from the lessons learned during the recent years. Provided that appropriate financing models can be applied, it is today certain that funding can be raised to cover waste management costs. However, it is also clear that **differences in the product characteristics between packaging and EEE, in particular concerning life-time, make it necessary to develop and operate new concepts**.

Compared to the situation of the waste packaging materials, which is managed rather centrally by a relatively small number of economic operators, in the case of WEEE there is a risk that a multitude of WEEE management schemes will emerge in the EU. This is associated with a **high probability that significant variations in their operational efficiencies will cause distortions to the Internal Market**.

Such WEEE management schemes can be established and operated by single producers, groups of producers, retailers, municipalities and specialised waste management industries. EU-wide co-operation between these actors is desirable to ensure that equally high ecological and economical operation of these management schemes can be achieved throughout Europe. To this end, there is a clear need for well-founded and acceptable "rules of the game" in order to achieve **harmonised conditions for the management of WEEE in the EU.**

The alternative options available to the European legislators are many and their choice will determine how fast and how efficiently the WEEE management will be established. These options reflect current opinions concerning

- the list of the equipment categories that should be covered,
- the waste prevention provisions,
- the acceptable waste processing measures,
- the organisation of take-back systems,
- the attribution of responsibilities,
- the application of financial models
- and the timing according to which WEEE should be regulated in Europe.

Available policy options considered in the present study are the following:

- to cover all categories of electrical and electronic equipment, including domestic and commercial equipment, regardless of the date this equipment was put on the market,
- to start with relatively "easy" products, in particular with large appliances and to cover progressively the remaining categories,
- to focus only on domestic equipment and to exclude commercial WEEE,
- to focus only on new products and to exclude "historical" WEEE,

- to phase out certain substances such as heavy metals from new products
- to set numerical targets for the collection, re-use, recycling and energy recovery
- to introduce a “best practices” approach for the WEEE management
- to promote producer responsibility or shared responsibility
- to define financing models such as “levy on the price”, “last owner pays”, waste bills etc.

In our view there is no reason that can justify the exclusion of waste categories, such as the commercial and the “historical” waste from European WEEE regulation[84]. Depending on the different characteristics of these WEEE categories and on the various degrees of difficulty associated with their management, appropriately **diversified and progressive implementation approaches** could be developed and adopted by the EU regulation.

In particular, there is a real need to evaluate our preparedness to operate efficient take-back systems for all the different WEEE categories. This should be carried out in a systematic and transparent way in order to contribute to the establishment of consensus at EU level about a feasible **implementation timing** and about the appropriate levels for the prevention, collection, treatment, reuse, recycling, recovery and disposal of WEEE.

In this light, the present study provides an analysis of key conceptual issues with particular reference to:

- Measures for the prevention, collection, treatment, reuse, recycling, energy recovery and disposal of WEEE.
- Responsibility and financing models.
- Adoption of “best practice” driven approaches.

6.1 Measures for the prevention, collection, reuse, treatment, recycling and energy recovery

The key available option for introducing **prevention measures** is to promote DFE (Design For the Environment) which can also include **the ban of the use of harmful substances**. In this way it can be expected that disassembly will become more efficient and that material-recycling rates will be increased. Concerning the phase out of substances from electric and electronic products the key issues lie in the answers of following questions:

Can substances be replaced in foreseeable dates?

What are the ecological and economical consequences?

In the case of proposals for phasing out lead from solders, which have caused firm and strong opposition from industry, there is presently no clear evidence of technological breakthroughs and reliable information that could answer the above questions (see Chapter 5.7). Although it can be understood that regulatory pressure to phase out lead solders by 2008 could accelerate technological developments, it is not advisable to proceed to implementation before having objective data.

[84] According to the AEA (American Electronics Association) there are important policy considerations in favour of excluding historical and commercial waste from the scope of a European WEEE regulation. Personal Communication to IPTS, 19 November 1998.

The main implementation problem is related to the uncertainty of being able to achieve desirable research and development results within a given date. In this light, an elegant solution would be to introduce a **"best practice"** driven regulatory frame that requires ban of harmful substances whenever this is ecologically justified, technically and economically feasible (see Chapter 6.3).

Several **collection options** are possible involving municipalities and retailers. Collection systems could be operated in parallel including pick-up at the households and bring systems to waste collection points controlled by municipalities and/or retailers.

Depending on how financial responsibilities will be attributed to municipalities and retailers (see next Chapter 6.2), market forces will determine their respective roles in the collection of WEEE. From the present point of view many actors perceive that municipalities have the advantage of operating existing waste collection infrastructures, which can be, relatively easily and economically, adapted to the specifications of the separate WEEE collection. On the other hand, the advantages of the WEEE collection by the retailers are linked to preferences of part of consumers that end-of-life equipment is picked up or brought to the selling points in exchange with new purchases.

Regarding the geographical distribution of the collection points, it is suggested that there is a need for further evaluation of the cost-effectiveness of using centralised disassembly points rather than country specific sites[85].

In our view, the prevailing WEEE collection solutions will be based on synergy between municipalities and retailers. This synergy needs to be flexible and to make possible that the existing collection infrastructures are used as optimal as possible.

The requirement to separately collect WEEE from normal household waste is undoubtedly the correct way to go, in particular in order to avoid high separation costs and **to ensure that small domestic appliances are not landfilled or processed without appropriate pre-treatment**.

There are several problems with the definition of **collection targets**. The main reason for establishing collection targets is to introduce a legislative requirement that obliges all National Administrations to establish collection systems of comparable efficiencies. One approach to the definition of collection targets, which was adopted by the first draft WEEE proposal of April 1998 is to determine **product lifetimes** and to base collection targets on these figures in combination with sales data. The drawback of this approach is that product life times are not predictable because they depend on consumer behaviour patterns. Any effort to prescribe life-times or maximum allowed "residence times" for products in households is obviously unacceptable and therefore the value of calculating WEEE arisings through life-time assumptions is only appropriate for orientation purposes. However, such assumptions are not sufficiently reliable for attributing responsibilities to actors for the management of WEEE take-back schemes and many experts, in particular from industry[86], believe that life-time based collection targets cannot be implemented efficiently.

The proposal request that Member States shall aim at achieving a minimum rate of **separate WEEE collection of four kilograms per inhabitant per year by 2006**. It appears that this target is indicative and non-binding. As such it does not introduce implementation problems but on the other hand it does not offer clear advantages for attributing responsibilities[87]. Another

[85] American Electronics Association, Stephanie Holmgren, Personal Communication to IPTS, 19 November 1998
[86] ORGALIME – Position Paper, 11 June 1998
[87] According to SWICO, Dr. W. Zimmermann, personal communication to IPTS, 09. 10. 1998, the target of 4 kg is inappropriate. It will be too small in some countries and too big in others. The target should be

approach to the definition of collection targets that seems more promising would be to **impose a take back obligation and a total landfill ban** on all separately collected and **untreated WEEE**. According to this approach all WEEE would be submitted to municipal or industrial WEEE collection systems. Apart for forwarding WEEE to subsequent treatment, recycling and disposal steps, these systems would be legally required to weigh and keep records on the amount of waste they collected and processed.

The current WEEE proposals for **re-use and recycling targets, which are as high as 50-80%** reflect achievable and demonstrated results (see review in Chapter 5 of the present study). However, according to our analysis the results obtained until now in the different pilot trials is far from optimum and there is little information about their applicability at a large scale.

Therefore, it is suggested[88] that **further pilot experiences** and systematic evaluation work are carried out to understand how and which optimum levels of **reuse, recycling, energy recovery and disposal** can be achieved. These optimum levels should not only be described in terms of numerical re-use and recycling targets but also in terms of an **integrated assessment of the resulting environmental impacts and benefits.** In this context, **consensus** should be established through a standardised evaluation procedure about measurable and ecologically meaningful targets. The key results would be descriptions of “best practices” for all types of WEEE (see Chapter 6.3).

In conclusion, the regulatory approach of choice should include as a first priority the provision of a common **guidance to the operators of take-back schemes and to the controlling Authorities on the acceptable processing practices and the achievable performances**.

6.2 Responsibility and financing issues.

The on-going discussions are focused on concepts such as “producer responsibility” or “shared responsibility”[89]. Ideally, responsibility must cover both financial and practical responsibility and **it seems that most actors concerned are prepared to agree on a model for sharing responsibility** in a transparent and systematic way, according to the draft WEEE proposal:

- Separate collection of WEEE underlies the responsibility of Member States

- Treatment, reuse, recycling and final disposal of WEEE underlies the responsibility of producers /retailers/importers.

Under this model the actors involved must raise funding to finance the WEEE management activities resulting from the above distribution of the responsibilities.

There is today certainty, that funding can be raised through appropriate financing models, according to the following principles:

- Internalisation of the waste management costs into the price of products.
- Application of a levy on the price,

replaced by the obligation to give old equipment back (as is the case in the Swiss WEEE regulation VREG).

[88] Similar proposals are available from many actors including EUROBIT, ORGALIME, CECED, AMERICAN ELECTRONICS ASSOCIATION,

[89] According to the Oeko-Institut e.V., Freiburg, the consumers should also be attributed with responsibilities, in particular regarding the separation of WEEE from MSW and for refurbishing EEE to obtain maximal lifetime of the products

- “Last owner” pays
- Waste bills
- Tradable Certificates[90]
- Insurance[91]

As far as **new products** are concerned, at first glance it appears that the “internalisation” concept is a good candidate for raising funding in a straightforward way. However, many issues need systematic discussion before consensus about the emerging new situation can be established. Some of these key issues are listed below:

- **The still unknown cost of recycling:** the internalised cost must reflect true recycling costs which at the present stage is largely unknown because of our limited experiences with large scale WEEE take-back schemes.

- **Time gap between fund raising and execution of the WEEE management:** the large life-time of many of the products under consideration means that WEEE fees raised at the moment of purchase will be spent with a considerable delay which can be in the range of 10-20 years. This fact does not favour the consumer because within such long periods new technological developments are most likely to decrease costs. On the other hand, paying the WEEE fees at the moment of purchase can also be seen as a contribution of the consumer to the development of such technology.

- **Effect on sales and distortion of Markets:** Increasing prices[92], to cover WEEE management costs, could depress sales. Market distortions are the most probable consequence if different fund raising models, such as the “last owner pays” and the “internalisation” model are applied in parallel for new products in the EU. Further distortions could occur if the ecological and economic efficiencies of WEEE take-back schemes differ substantially.

Attributing retrospectively responsibilities for the management of **“historical” WEEE** is obviously difficult. In general, producers and retailers would be prepared to accept take-back responsibility but not financial responsibility. An exception has been negotiated in Sweden, where a **producer responsibility** driven concept is being enacted. According to this concept producers take back old equipment free of charge when the customer buys new[93],[94]. In most other countries, two different fund raising mechanisms of applying a “levy” on the price of new products or of applying the “Last Owner Pays” principle are presently under discussion.

Applying a “levy” on the price of new products to finance management of historical WEEE could contribute to fund raising. However, recent discussions have shown that this solution

[90] Report prepared by ERM on behalf of the EC, Enterprise DG. Reportedly the idea of using tradable certificates for WEEE management attracted little industry enthusiasm (for more information see ENDS report 293, June 1999, page 46)

[91] first experiences are currently emerging in Sweden

[92] According to Eurobit estimates expected average price increases will be in the range of 5% of factory gate prices.

[93] Only parts of the historic products will end up in the producer systems and the municipalities have the responsibility for the rest of WEEE from the households. S. Stenhammar, Swedish Environmental Protection Agency, Personal Communication to IPTS, 15 October 1998

[94] Electrolux proposes a direct producer responsibility. According to this proposal each manufacturer should be responsible for (financing) the occurring recycling cost of his own produced products (products sold after the entry into force of the directive). It shall be possible for manufacturers to co-operate at different levels, however the responsibility requirement must remain individual. Furthermore, Electrolux proposes that manufacturers shall take responsibility for all products (**new products and historical waste**) after a transitional period. The transitional period should be determined from country to country, depending on the existing systems.

offers several disadvantages, mainly because of its complexity. From one point of view, levies on new products to finance the old will only result in burdening present consumption with costs arising from past consumption without providing a direct link between the levy and the recycling properties of the new products[95]. In our view this issue needs to be better understood and therefore we see the need for further study.

The **"Last Owner Pays"** principle appears to be a flexible solution. While it does not create in absolute terms economic disadvantages to the consumer, their key drawback is the higher risk for uncontrolled dumping of WEEE. In this respect, the solution to the problem would be to introduce efficient provisions for **a total ban on incineration, landfill and shredding of WEEE that has not been pre-treated by a certified company.** Such a proposal is presently being elaborated in Sweden.

Regarding the management of waste from products put on the market before entry into force (historical waste) of the proposed Directive, a transition period of five years is granted. While the concerns of most sectors of the electronics industry will be met by this transition period, producers of products with longer lifetimes might need further assistance to address the problem of historical waste. In this context, Member States would remain free to allow producers to cover these costs through a visible, fixed fee on the price of new products.

Whatever financial model will be chosen, it is most important that the consumer should be able to "see" at the time of purchase information indicating the take-back scheme that is responsible for the WEEE management and the associated recycling fees. This will raise **consumer awareness** about the cost and the associated infrastructure for the WEEE management. In addition, such an indication is needed, as it is also the case with packaging, to ensure that all producer and retailers are associated in take-back schemes and that the number of free riders is minimised.

There is wide agreement that the applied legislative, organisational and financing models must promote driving forces towards better ecology and economy. By keeping ecology standards as high as possible, **better economy can be achieved through competition concerning the efficiency of take-back schemes** and through the development of new product designs that lower recycling cost (e.g. designed for dismantling, and use no hazardous components). In conclusion, environmental legislation shall be limited to setting the frame for the operation of these schemes by describing their obligations to take-back WEEE and the practices according to which WEEE shall be treated. In this way it is conceivable, that **market forces guided by a "best practices" approach will lead the developments towards better ecology and economy**.

[95] Electrolux, American Electronics Association

6.3 "Best Practice" based approaches[96]

Stimulating competition towards more efficient take-back schemes may be seen as the key issue for achieving high environmental protection and financial benefits. This can be achieved if implementation of collection, recovery and recycling activities are supported by **systematic action plans** and the private initiative is properly coordinated by public involvement.

To stimulate competition in a systematic way, waste management regulation needs to open the door for a mechanism which recognises the need for an "*adaptation to scientific and technical progress*", providing a legal basis for the introduction of the concept of evolutive "best practices". This is coherent with the approach taken by the IPPC (Integrated Pollution Prevention and Control) framework directive. This **concept of periodical updating of the legislation** opens an ideal frame for the establishment of a procedure for the systematic assessment of the novel available techniques, their performance and environmental impact. Such a rigorous procedure can help avoid the setting of rigid and arbitrary targets.

To provide transparency and a basis for stimulating competition, **a detailed technical evaluation procedure must be developed** to set the ground for building the political consensus in each case where alternative waste management and recycling options are debated**.** This technical procedure would present the technical performance and economic data of the alternative options in a standard format, under the form of a "reference technical note" for each alternative option. Agreed "criteria" would then be needed for the integrated assessment of environmental impacts, the screening of the **"best" practices** and the identification of "appropriate" targets[97].

Clearly, **a neutral European body, free of vested interests, without "lead country" attitude and having the necessary technical skills is needed to continue this effort**. This body could develop a consensus building methodology preserving the integration with other policies. Industrial, employment, R&D and environmental policies must be linked to this enterprise. The waste management targets that can be elaborated by such an institutional approach hold the promise to provide a permanent state-of-the-art referencing system flexible enough to allow its adaptation to technical progress and to local circumstances across the EU.

Uniform application of these targets for the managing WEEE across the EU can ensure that comparable performances are achieved in all Member States and that costs are distributed equally.

[96] L. Bontoux, F. Leone, M. Nicolai and D. Papameletiou**:** "Impediments and Prospects of the European Recycling Industry"; EUR 17271 EN, Final report to the Environment Committee of the European Parliament, IPTS, Seville, 1996

[97] The "best practice" approach proposed by IPTS is supported by many actors, including the following: EUROBIT; CECED; DANFOSS; IPC, USA; AMERICAN ELECTRONICS ASSOCIATION, LUCENT TECHNOLOGIES,

7. Conclusions and recommendations

The ultimate scope of any WEEE regulatory framework is to maximise prevention, to ensure avoidance of uncontrolled disposal and to minimise environmental impacts across the entire waste management chain, which includes several steps such as **“collection”**, **“reuse”, “treatment”, “recycling or energy recovery” and “disposal”.**

It appears that the uncontrolled disposal of WEEE, which is today a common practice, cannot be regulated alone by conventional landfill legislation, especially because it does not provide an adequate frame for attributing responsibilities to the polluters. At least in Europe, there is wide agreement that such a frame should be introduced by a WEEE-specific regulation.

Barriers to the straightforward establishment of solutions arise due to fact that there is presently no large-scale experience with WEEE management techniques and schemes. In particular, compared to waste packaging materials, which are managed rather centrally by a relatively small number of economic operators, in the case of WEEE there is a risk that a multitude of WEEE management schemes will emerge in the EU. Such WEEE management schemes can be established and operated by single producers, groups of producers, retailers, municipalities and specialised waste management industries. In combination with emerging non-harmonised national regulations, this prospect is associated with a **high probability for significant variations in the operational efficiencies of the different schemes. This could cause distortions in the Internal Market**. Therefore, EU-wide co-operation between the actors concerned is desirable to ensure that equally high ecological and economical operation of WEEE management schemes can be achieved throughout Europe. To this end, there is a clear need for well-founded and acceptable “rules of the game” to achieve **harmonised conditions for the management of WEEE in the EU**.

An important issue, is the evaluation of a realistic implementation timing, in particular regarding the treatment of "difficult" WEEE categories such as small electronic appliances. In this respect, there is a real need to evaluate the preparedness of the EU to operate efficient take-back systems for all the different WEEE categories. This should be carried out in a systematic and transparent way in order to contribute to the establishment of consensus at EU level about a feasible implementation timing and about the appropriate levels for the prevention, collection, treatment, reuse, recycling, recovery and disposal of WEEE.

In general, it appears that implementation of a purely collection based WEEE management strategy is by far not sufficient to prevent environmental problems. The focus must equally be placed into the minimisation of the quantities of hazardous materials in products and into the minimisation of the release of these materials into the environment during treatment or disposal of WEEE.

Regarding the phase-out of substances, it is advisable that implementation deadlines are proposed only in cases when these are transparently supported by widely acceptable ecological and techno-economic evaluation of the effects the substitute materials will have. In the case of the proposal for the phase out of lead solders such evaluations are missing and should therefore be carried out.

The regulatory approach of choice should include as a first priority the provision of a common **guidance to the producers, to the operators of take-back schemes and to the controlling Authorities on the acceptable processing practices and the achievable performances**. Performance targets should be technically, economically and ecologically meaningful and most

particularly demonstrated at an industrial scale. On this basis, the legislator can develop the so-called **"best practices"**, which can be used as benchmarks for the production of EEE with preventive measures and for the certification of collection, recycling, recovery and disposal activities.

The description of "best practice" guidelines needs to be carried with transparency by following an appropriately designed expert consultation procedure.

According to our analysis the existing pilot municipal schemes in the EU were designed without a central co-ordination to meet different objectives. Therefore, we estimate it will now be difficult to establish a consensus on a preferred European-wide solution. In this light, it is suggested that **further pilot experiences** and systematic evaluation work need to be carried out to understand how and which optimum levels of **reuse, recycling, energy recovery and disposal** can be achieved.

There are several financing models, which have been in use to raise funding for the management of packaging waste. Theoretically these models could also be applied to cover WEEE management costs. However, it is also clear that differences in the product characteristics between packaging and EEE, in particular concerning life-time, make **it necessary to develop and operate new concepts**, in particular for the **"historical waste".**

Consumer awareness is a key issue for the success of WEEE management. Whatever financial model will be chosen, it is most important that the consumer should be able to "see" at the time of purchase information indicating the take-back scheme that is responsible for the WEEE management and the associated recycling fees. This will raise consumer awareness about the cost and the associated infrastructure for the WEEE management.

In conclusion, there is wide agreement that the applied legislative, organisational and financing models must promote driving forces towards better ecology and economy. While keeping ecology standards as high as possible, it seems feasible to achieve **better economy through competition concerning the efficiency of take-back schemes** and through the development of new product designs that lower recycling cost (e.g. designed for dismantling, and use no hazardous components).

Information Sources

Proposal for a Directive on Waste Electrical and Electronic Equipment and for a Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment, European Commission, COM (2000) 347, 13th. 06. 2000

ENEA: Priority Waste Stream, Waste from Electrical and Electronic Equipment, Information Document, third draft, Rome, June 1995

AEA Technology: Recovery of WEEE: Economics & Environmental Impacts. Final Report. A Report produced for European Commission, Environment DG, June 1997

Georg Welslau and Hans Hermann Kraus: “Electronic Waste” Directorate B, Division for the Environment, Energy and Research, STOA, European Parliament, 05. 05. 1998, PE 167.543

R. Gabriel und S. Salhofer: Bregenz Pilot Project - Waste From Electric and Electronic Equipment. , Universität für Bodenkultur Abteilung Abfallwirtschaft, Institut für Wasservorsorge, Gewässerökologie und Abfallwirtschaft. Summary Document prepared for the Bundesministerium für Umwelt, Sektion III-Abfallwirtschaft, Wien, April 1996

R. Gabriel und S. Salhofer: Pilotproject Flachau zur Sammlung und Behandlung von Elektrogeräten. Universität für Bodenkultur Abteilung Abfallwirtschaft, Institut für Wasservorsorge, Gewässerökologie und Abfallwirtschaft, Endbericht, erstellt im Auftrag der Salzburger Landesregierung, Abteilung 16-Umweltschutz, Wien, Februar 1998

FIEE: Produits Electriques et Electroniques non portables en fin de vie en region Rhone-Alpes, Rapport Final, Paris, Janvier 1997

Ploos van Amstel Miieu Consulting B.V.: Back to the beginning: National pilot project, for collecting, recycling and repairing electrical and electronic equipment in the district of Eindhoven, Apparetour, Eindhoven, September 1997

ICER (Industry Council for Electronic Equipment Recycling): Report on the UK Industry for Recycling End of Life Electrical and Electronic Equipment, First Draft, London, April 1998

Comparison of Systems for Collection/Recycling/Disposal of End-of-Life Electrical and Electronic Equipment (EEEE), Economic Impact. A study by FEEI (Austrian Electrical and Electronic Industries Association) produced at the Institute of Industrial Research (Economic University of Vienna), July 1996

Erfassung von Elektro-Haushalt-Kleingeräten aus Haushalten mit verschiedenen Erfassungssystemen, INFA, Endbericht im Auftrag des Zentralverbandes Elektrotechnik-und Elektronikindustrie e.V (ZVEI), August 1995

Kommission der Niedersächsischen Landesregierung zur Vermeidung und Verwertung von Abfällen, Niedersächsisches Umweltministerium, Abschlußbericht des Arbeitskreises 13 “Elektronikschrott”, Hannover, März 1998

End-of-life management of cellular phones - an industry perspective and response. Report of the ECTEL Cellular Phones Takeback Working Group, November 1997

P. Hedemalm, P. Carlsson and V. Palm: Waste from electrical and electronic products. A survey of the contents of materials and hazardous substances in electric and electronic products. Tema Nord 1995:554, Nordic Council of Ministers, Copenhagen 1995

Swedish Environmental Protection Agency: Electronic and Electrical Equipment. The Basis for Producer Responsibility, Report 4406, Solna, 1 March 1995

US EPA: Cleaner Technologies Substitutes Assessment. A Methodology and Resource Guide, EPA 744-R-95-002, December 1996

US EPA: Printing Wiring Board Technologies Substitutes Assessment: Making Holes Conductive, Volume 1 DRAFT, EPA 744-R-97-002a, June 1997

US EPA: Implementing Cleaner Technologies in the Printing Wiring Board Industry: Making Holes Conductive, EPA 744-R-97-00, February 1997