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# E-waste Management in Germany

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**C**ollection group

One or more categories of e-waste collected in one container according to the (ElektroG 2005)

**C**ategory of electrical and electronic equipment (EEE)

Category of EEE according to Annex IA of the (WEEE Directive 2003)

**D**isposal

Any operation, which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. Annex I of (Waste Directive 2008) sets out a non-exhaustive list of disposal operations. (WEEE Directive 2008)

**D**istributor

Any person or legal entity that provides new electrical or electronic equipment on a commercial basis to the user. Any distributor who knowingly sells new electrical and electronic equipment from a non-registered producer is deemed a producer. (ElektroG 2005)

**E**nd-of-life full service provider (ESP)

An entity providing services related to the end of life of electrical and electronic equipment. This may comprise operative services such as logistics, storage, treatment, and disposal, as well as administrative services like producer registration at the clearing house, and reporting to the clearing house

**E**xtended producer responsibility (EPR)

Inclusion of further life cycle phases of a product beyond the manufacturing and the safety and reliability in use into the producer's responsibility; in the context of the WEEE Directive inclusion of the end-of-life of products into the producer's responsibility

**E**-waste

Electrical and electronic equipment in its end-of-life phase starting from the time when the last user disposes of or intends to dispose of electrical and electronic equipment

**E**-waste from private households

E-waste, which comes from private households and from commercial, industrial, institutional and other sources which, because of its nature and quantity, is similar to that from private households

**M**onopsony

Market with one buyer, but many sellers of a certain product or service, a form of incomplete competition

**P**roducer

Any person or legal entity, irrespective of the selling technique used, including distance communication, who (ElektroG 2005)

- manufactures and places electrical and electronic equipment under an own brand on the market for the first time in Germany
- resells under an own brand in Germany equipment produced by other suppliers. A reseller is not being regarded as the 'producer' if the brand of the producer appears on the equipment
- imports for the first time electrical and electronic equipment into Germany and places it on the market or exports it to another EU Member State and provides it directly to a user in that country

**R**ecovery

Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy. Annex II of (Waste Directive 2008) sets out a non-exhaustive list of recovery operations. (Waste Directive 2008)

**R**ecycling

Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations. (Waste Directive 2008)

**S**mall e-waste appliance

E-waste from small domestic electrical and electronic equipment, such as electrical shavers, mixers, toasters, coffee machines, mobile phones, radios

**T**reatment

Any activity after the e-waste has been handed over to a facility for preparation for re-use, depollution, disassembly, shredding and mechanical separation, recovery or preparation for disposal and any other operation carried out for the recovery and/or the disposal of the e-waste (WEEE Directive); collection, transport and storage are not part of the treatment

**T**ype of equipment

Equipment within a category of electrical and electronic equipment, which has comparable characteristics in terms of its uses or functions; examples for types of equipment in the 10 categories of EEE are listed in Annex IB of the (WEEE Directive), and Annex I of the (ElektroG 2005)

## List of Abbreviations

| | |
|---|---|
| B2B | business to business |
| B2C | business to consumer |
| CG | collection group |
| CTS | collective takeback scheme |
| EEE | electrical and electronic equipment |
| EoL | end of life |
| ESP | end-of-life full service provider |
| EPR | extended producer responsibility |
| EU | European Union |
| FCA | “Bundeskartellamt”, Federal Cartel Authority |
| FNA | “Bundesnetzagentur”, Federal Network Agency |
| GDR | German Democratic Republic |
| ICT | information and communication technology |
| IBTS | individual brand-selective takeback scheme |
| INTS | individual non-selective takeback scheme |
| PBB | Polybrominated biphenyls |
| PBDE | Polybrominated diphenyl ethers |
| PCB | polychlorinated biphenyls |
| PM | precious metal (gold, silver) |
| PoM | put on market |
| PuWaMA | public waste management authorities |
| PWB | printed wiring board |
| UBA | “Umweltbundesamt”, Federal Environment Agency |

# 1 Executive Summary

In 2008, around 10 million tonnes of electrical and electronic equipment (EEE) were put on the markets of the European Union member states. With some delay, the amounts of waste from these devices, the e-waste, has grown as well to the magnitude of around 10 million tonnes a year, and according to (Huisman 2007), the amount of EEE sold in the EU still grows with 2.5 % to 2.7 % every year. As a reaction, in order to environment-friendly collect and treat the e-waste, the (WEEE Directive 2003) was enacted in the EU in 2003. It extends the producers' responsibility towards the end of life of their products and sets minimum targets for collection, recovery and recycling of e-waste.

The EU member states transposed the WEEE Directive into their national legislations. The member states have certain freedoms in how they transpose and implement the provisions of the WEEE Directive so that each member state has individual e-waste legislation with the WEEE Directive as the common denominator.

This report describes the German e-waste management system in the European context. It explains the key players and their roles, shows the performance of the system, and discusses the positive and negative experiences obtained during the five years operation of the German e-waste management system.

Prior to the WEEE Directive, Germany collected and treated e-waste within the legislative and infrastructural framework for wastes. The public waste management authorities (PuWaMA) were responsible for the collection and treatment of e-waste, and consumers were charged for its treatment and disposal.

The (ElektroG 2005), the German transposition of the (WEEE Directive 2003), shifted responsibilities to the producers. Since 2006, consumers can bring e-waste free of charge to the municipal collection points. The PuWaMA are further on responsible for collection. Their responsibility ends with the handover of the collected e-waste to the producers who organize and finance the logistics, treatment and disposal of this waste.

Each producer putting EEE on the German market is responsible to take back the amounts of e-waste corresponding to his market share in the EEE put on the market (PoM). Producers establish takeback systems or otherwise organize the takeback of the e-waste. Different from most other EU member states, collective takeback systems are not common in Germany. Producers normally directly contract end-of-life service providers (ESPs) organizing the logistics, treatment and disposal of e-waste, for which each producer is responsible in accordance to his market share in PoM.

The German e-waste management system exceeds the minimum collection, recovery and recycling targets stipulated in the (WEEE Directive 2003). Nevertheless, Germany collects less than 50 % of e-waste arising, and treatment operators complain about the quality of collection because of damaged e-waste hindering proper treatment. The collection of e-waste needs better financing mechanisms to increase the rates and quality of collection. Higher collection rates could also help reducing the illegal transboundary shipments of e-waste to developing countries, which are a persisting problem in Germany like in all other developed countries.

The treatment operators are audited and certified annually by third party auditors in order to ensure they have adequate technology, knowhow and organization for a state-of-the-art treatment of e-waste. It is, however, difficult to prove whether treatment operators actually make use of their abilities in daily operation. Competition and cost pressure may compromise the treatment quality. Quality standards for the treatment of e-waste are therefore upcoming instruments to increase the transparency on the performance of treatment operators.

The treatment of e-waste requires excellent expertise and experience. The treatment must be adapted to the type of e-waste processed in order to achieve an economically and environmentally good result. Due to the high labor cost in Germany and in most other European countries, the treatment is highly mechanized. Nevertheless, environment-friendly treatment of e-waste requires a mix of manual labor and high-tech processing of e-waste balancing the legislative and the economical requirements.

# 2 Background on Waste Management in Germany

Electrical and electronic equipment (EEE) since the fifties of the last century more and more has influenced people's lives in particular in the developed countries. In the private and professional context, EEE until now progressively became an integral and indispensable part of everyday life. In 2008, around 10 million tonnes of EEE were put on the markets of the EU member states.[1]

Over the years, the amounts of waste from these devices, the e-waste, have grown as well to the same magnitude of around 10 million tonnes a year in the EU. According to (Huisman 2007), the amount of e-waste in the EU grows with around 2.5 to 2.7 % every year. E-waste is a highly variable mix of different types of equipment ranging from washing machines to computers and mobile phones. The construction and composition of EEE is highly complex. EEE contains toxic substances such as lead and cadmium as well as scarce and valuable resources like precious metals. [2] Avoiding pollution and saving the valuable resources requires specific treatment of the e-waste.

In the nineties of the last century, some member states and the European Commission started thinking about how to appropriately collect and treat the increasing amounts of e-waste. In 2003, this resulted in the enactment of the (WEEE Directive 2002), which the EU member states transposed into their national legislation. The WEEE Directive, however, allows the member states setting own priorities in this transposition process so that each EU member state has its own specific e-waste management system based on the WEEE Directive.

This report describes the German e-waste management system in the European context. It explains the key players and their roles, shows the performance of the system, and discusses the positive and negative experiences obtained during the five years operation of the German e-waste management system.

[1] Eurostat: http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/wastestreams/weee; last accessed 29 May 2011

[2] StEP-Initiative, What is e-waste?, http://www.step-initiative.org/initiative/what-is-e-waste.php; last accessed 25 June 2011

## 2.1 Political and Administrative Competences and Responsibilities for Waste Management in Germany

In Germany, the responsibilities and roles of the Federal and states Governments and other public authorities for the management of e-waste and other wastes is interlinked. Understanding the e-waste management in Germany hence requires some background on the political and administrative construction as well as on the competences and responsibilities in waste management.

Figure 1 provides an overview on the administrative and political structure in Germany.

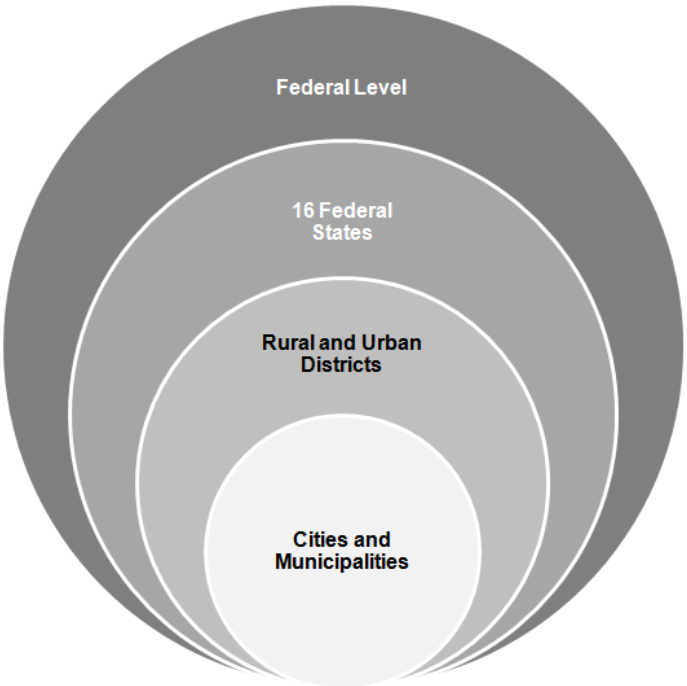


*Figure 1: Outline of Germany's administrative and political structure* [3]

Germany is a federal republic with the Federal Government in Berlin, the federal capital city. The federation consists of 16 "Bundesländer" (federal states), which have their own governments and parliaments. Below the federal level, the administrative

[3] Ernst Klett Verlag GmbH, Stuttgart: Online-Magazin Politik/Wirtschaft; http://www.klett.de/sixcms/list.php?page=miniinfothek&node=Deutschland+-+Politisches+System&miniinfothek=Online-Magazin%20Politik/Wirtschaft&article=Infoblatt+Administrativer+Aufbau+der+Bundesrepublik+Deutschland; last accessed 11 May 2011; in German language only

and political structure differs between the federal states. Rural and urban districts, as well as cities and municipalities, however, are common administrative units.[4]

### *Legislative Competences of the Federal Government and the Federal States*

Both the Federal Government and the federal state governments have legislative competences, which are specified in the "Grundgesetz" (Basic Constitutional Law), the constitution of the Federal Republic of Germany.[5]

In some areas, such as foreign affairs and defense, the Federal Government has the exclusive legislative competence. In other affairs such as education and culture, the sole legislative competence is with the federal states.[6] In a broad range of affairs, the Federal Government and the federal states share legislative competences [7]:

- The federal government may enact framework legislation, which each federal state then details and specifies with own legislation for its territory. This is the case for example for water management and for nature conservation. The resulting federal state legislation then differs between the 16 federal states.

- The concurrent legislation entitles the federal states to enact own legislation unless the Federal Government makes use of its legislative competence. The federal legislation then overrides the federal states' legislation. Since 1972, waste management falls into the field of the concurrent legislative competence.

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[4] Ernst Klett Verlag GmbH, Stuttgart: Online-Magazin Politik/Wirtschaft; http://www.klett.de/sixcms/list.php?page=miniinfothek&node=Deutschland+-+Politisches+System&miniinfothek=Online-Magazin%20Politik/Wirtschaft&article=Infoblatt+Administrativer+Aufbau+der+Bundesrepublik+Deutschland; last accessed 11 May 2011; in German language only

[5] Bundeszentrale für politische Bildung (BPB, Federal Center for Political Education): Infoblatt Gesetzgebungskompetenzen (Info Sheet Legislative Competences; http://www.bpb.de/files/QR63OR.pdf; last accessed 11 May 2011, in German language only

[6] Bundeszentrale für politische Bildung (BPB, Federal Center for Political Education): Infoblatt Gesetzgebungskompetenzen (Info Sheet Legislative Competences; http://www.bpb.de/files/QR63OR.pdf; last accessed 11 May 2011, in German language only

[7] Ernst Klett Verlag GmbH, Stuttgart: Online-Magazin Politik/Wirtschaft; http://www.klett.de/sixcms/list.php?page=miniinfothek&node=Deutschland+-+Politisches+System&miniinfothek=Online-Magazin%20Politik/Wirtschaft&article=Infoblatt+Administrativer+Aufbau+der+Bundesrepublik+Deutschland; last accessed 11 May 2011; in German language only

*Roles and Responsibilities for Waste Management in Germany*

In 1994, the Federal Government enacted the "Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal" (Substance Cycle Act 1994), which still nowadays, with some amendments, substantially and comprehensively regulates the waste management in Germany. (Wuttke 2011)

The federal states implement the regulations of the federal Substance Cycle Act (Wuttke 2011)

- appointing the competent authorities for the administrative implementation of the Substance Cycle Act within the federal state, and
- appointing the public waste management authorities for the operative implementation conducting the collection, transport, treatment and disposal of wastes on local level.

On this behalf, each federal state enacted legislation enforcing the federal level Substance Cycle Act. In all federal states, the rural and urban districts conduct the treatment and disposal of the wastes, whereas the local collection and the transport of wastes to the district recycling and disposal facilities in several federal states is the cities' and municipalities' competence. (Wuttke 2011)

The rural and urban districts and the cities and municipalities complement the federal state legislation with local regulations. These determine details such as the frequency and other modalities of collection, the installation of municipal waste collection points, how businesses and private households have to make their wastes available to the public waste management authorities (PuWaMA), and the fees they have to pay for the collection, treatment and disposal of their wastes. (Wuttke 2011)

As the ElektroG, the transposition of the WEEE Directive into German legislation, appoints the PuWaMA as the competent authorities for the collection of e-wastes in Germany, the implementation of the ElektroG uses the political and administrative structure in Germany, and the Substance Cycle Act's provisions apply to the collection and storage of e-waste as well unless the ElektroG stipulates otherwise.

## 2.2 Management of Wastes from Private Households

Waste management in Germany is mainly based on the (Substance Cycle Act 1994) and its enforcement regulations in the federal states. The public waste management authorities (PuWaMA) generally are responsible for the collection, transport, proper treatment and disposal of wastes. The Substance Cycle Act obliges private

households to make their wastes available to the PuWaMA. Private households are not allowed to contract third parties for the collection, treatment and disposal of wastes. This had actually happened for wastes, whose treatment or sales are economically profitable, such as waste paper and the newly introduced "Valuables Bins". The German Federal Administration Court recently stopped this practice.[8]

Generally, the (Substance Cycle Act 1994) allows PuWaMA to contract third parties for the collection, treatment and disposal of wastes. The responsibility, however, remains with the PuWaMA. Several private companies meanwhile are active in the collection and treatment of wastes throughout Germany.

### *Separation of Wastes in and at Private Households*

German households separate their wastes into several categories. Even though there may be differences between the districts and municipalities, common separation categories are

- packaging materials ("Gelbe Tonne", Yellow Bin, financed by producers using packaging materials for their products)
- glass (different containers for white, green and brown glass)
- organic waste
- paper and cardboard
- residual waste (household waste other than the above ones)

Some municipalities are about to introduce an additional container ("Wertstofftonne", Valuables Bin[9]), into which private households can drop of metals, woods, textiles, plastics that are not packaging materials, and small e-waste appliances such as toasters, mixers, shavers, mobile phones, after removal of the batteries. Further

[8] Federal Administrative Court decree BVerwG 7 C 16.08, http://www.bverwg.de/enid/0,ff33a4655f76696577092d0964657461696c093a09636f6e5f6964092d093132313738093a095f7472636964092d093133333232/Entscheidungen/Entscheidung_8n.html, and http://www.kostenlose-urteile.de/BVerwG-Kampf-ums-Altpapier-Entsorgung-grundsaetzlich-durch-oeffentlich-rechtlichen-Entsorgungstraeger.news8025.htm; last accessed 6 May 2011; both sources in German language only

[9] http://www.bmu.de/abfallwirtschaft/abfallpolitik/kreislaufwirtschaft/doc/47205.php; last accessed 16 May 2011, in German language only

approaches are to allow private households the disposal of small e-waste appliances and other valuable materials together with packaging materials in the Yellow Bins[10].

The residual waste containers generally are located on private premises at the households, while the other containers may sometimes be placed on public places close to the households instead.

### *Pickup of Wastes under Public Authority*

The PuWaMA pick up residual waste containers and other containers – besides those for the packaging materials - directly at the households and from the public places (collect system). Each household pays an annual fee for this service to the municipalities, at least for the residual waste container. The fees are different in the various municipalities, but they generally depend on the volume of the container. For the other containers, there may be payments as well depending on the PuWaMA.

Besides the collect systems, PuWaMA additionally run municipal collection points where consumers can hand in specific wastes like bulky objects, furniture, carpets, chemicals, and all kinds of e-waste (bring system).

Some municipalities offer household collections of such specific items from time to time. They announce the date, and private households can place their waste items on the street for pickup. Private households can also call up the municipal waste collection authorities to pick up items from their household. This service normally has to be paid for.

### *Wastes Collected and Treated under Producer Responsibility*

Packaging materials in the "Yellow Bins" are collected, treated and disposed of under the responsibility of Dual Systems. Manufacturers using packaging materials for products put on the German market pay a fee for the collection, treatment and disposal of the packaging materials to one of the Dual Systems[11]. Producers integrate these fees into the product price at the point of sale.

Batteries are not allowed in any of the described waste containers. Consumers shall hand them in free of charge to shops selling batteries, or at special collection points. Producers have established a collective takeback system for the takeback, treatment

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[10] Gelbe Tonne Plus, http://www.gelbe-tonne-plus.de/; last accessed 16 May 2011, in German language only

[11] List of officially acknowledged Dual Systems in Germany (https://www.ihk-ve-register.de/inhalt/duale_systeme/index.jsp); last accessed 9 May 2011

and disposal of these batteries (GRS Batterien[12]) to comply with the (Battery Act 2009), the transposition of the European (Battery Directive 2006) into German legislation.

Since March 2006, e-waste in Germany is managed under the shared responsibilities of the PuWaMA and the producers, while before e-waste management was the PuWaMA's sole responsibility.

## 2.3 Milestones of Waste and e-Waste Management in Germany

The history of e-waste management in Germany must be considered together with the general waste management, as until 2005 no e-waste specific legislation was in place. Until the reunification of the Federal Republic of Germany (West Germany) and the German Democratic Republic (GDR, East Germany), each of the German states had its own legislation for waste management. Starting with the reunification on 3 October 1990, the West-German legislation including the waste management was gradually transferred to the territory of the former GDR. The following sections will therefore focus on West Germany.

### 2.3.1 Waste Management before 1972

Waste management including e-waste has been the responsibility of the municipalities. There was not much awareness of the pollution and resource implications related to wastes. Still in the early seventies of the last century, wastes from private households and from businesses, including hazardous wastes, were dumped untreated on around 50,000 (Wuttke 2011) municipal landfills in West Germany. Many of these landfills were unsecured. (Wuttke 2011)

The use of small and big domestic electrical appliances such as washing machines and refrigerators in private households, even though started in the early fifties already, had taken off in the late sixties (Handrick 2004). Electronic devices beyond

[12] Stiftung Gemeinsames Rücknahmesystem Batterien (GRS Batterien), http://www.grs-batterien.de/; in German language only; last accessed 8 May 2011

TVs, radios and tape recorders, later stereo equipment and video players, were not common in the households. The volumes of e-waste hence must have been low in the fifties until the early seventies. Statistics on this could not be found.

Weekly collection of household wastes by districts or municipalities was not yet common everywhere in Germany. At least on the countryside, it sometimes was limited to collection of bulky objects a few times a year ("Sperrmüllabfuhr"), which were then disposed of untreated on landfill sites as well.

E-waste including accessories such as batteries was collected and disposed of untreated with other wastes on the landfills. The author still experienced on the countryside side in West Germany how at least until the early seventies households disposed of all kinds of wastes such as household wastes, construction wastes, and bulky objects. This included all kinds of e-waste like old fridges and freezers, washing machines, electrical ranges, TVs, and radios.

### 2.3.2 The 1972 and 1986 Waste Management Acts

In 1972 in West Germany, after an amendment of the constitution, waste management became subject to concurrent legislation. The Federal Government thus for the first time was in a position to enact waste legislation for the whole of West Germany. The Federal Government made use of this new competence with the adoption of the Waste Management Act in 1972. The main objective was to stop the uncontrolled waste dumping in the German municipalities and districts. The act hence was designed as a regulation for organizing and planning the disposal of wastes. (Wuttke 2011) Treatment and recycling of wastes were not specifically addressed.

The act clearly regulated the responsibilities for waste management, and in consequence, the number of landfills was reduced. In 1998, only 2.341 landfill sites were still in operation in the then reunited Germany. (Wuttke 2011)

In 1986, the Federal Act on Prevention and Disposal of Wastes was enacted, which for the first time stipulated basic principles for the prevention, treatment and recycling of wastes. E-waste still was not addressed in particular. (Wuttke 2011)

The 1986 act entitled the Federal Government to enact further regulations for prevention and recycling in order to reduce the amounts of wastes. The packaging ordinance as the regulative background for the German Dual Systems for packaging materials is an example for such measures. (Wuttke 2011)

## 2.3.3 Waste Management in East Germany until 1990

*Amounts of Waste and Recycling*

Compared to West-German households, the amounts of domestic waste generated in the GDR was low.[13] The GDR had established a system for collection and recycling, SERO, where consumers could hand in waste such as old paper, textiles, glass, bottles, metals and plastics.[14] The East-German Government strongly promoted the system. Persons handing in wastes were paid. On small scale, children generated a pocket-money level income, and small private businesses collected wastes on large scale level.


*Figure 2: Logo of the "VEB Kombinat Rohstofferfassung" SERO in the GDR* [15]

Compared to West Germany, the SERO system was more successful in collecting and recycling wastes. The background was that the East-German currency was not convertible on the world market. Raw materials hence had to be purchased in foreign convertible currencies and were hence scarce and expensive. After the reunification, under the new economic conditions, the SERO system became too expensive and was not continued.

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[13] Umweltbewegung in der DDR, http://umwelt-ddr.argus-potsdam.de/index.php?abfall, last accessed 22 June 2011, in German language only

[14] Umweltbewegung in der DDR, http://umwelt-ddr.argus-potsdam.de/index.php?abfall, last accessed 22 June 2011, in German language only

[15] Wikipedia, http://de.wikipedia.org/wiki/SERO, last accessed 22 June 2011, in German language only

*Disposal of Waste*

The disposal of wastes was the main problem of waste management in the GDR. The landfill sites had a low environmental and security standard until the end of the GDR in 1990. The disposal sites often were openly accessible, leachate water was not collected and cleaned. Groundwater contaminations were common. In 1985, 4,870 controlled landfills were counted in the GDR, of which only 920 complied with the low standards, and 7,437 unsecured landfills. The landfills were often located close to rivers or in areas from which drinking water was pumped. Imports and disposal of hazardous wastes, for example from West Germany, aggravated the problem. Even though the GDR did not have the capacities for adequate treatment and disposal, it imported around 5 million tonnes of wastes including hazardous wastes from West Germany. East Germany made "hard currency" money with these imports, and West Germany saved money with these exports. [16]

With the reunification, however, the East-German landfill problem befell the West Germany, and the reunified Germany invested billions of Euros, among others for the sanitation of the East-German landfills.

No information on e-waste specific waste management activities in the GDR could be found. Taking into account that in West Germany such measures started in the late eighties of the last century only after the discovery of the ozone hole, it must be assumed that the first e-waste-specific attempts on former East-German territory already were undertaken after the reunification.

### 2.3.4 The Discovery of the Ozone Hole and First E-waste Management Activities

In 1974, (Molina 1974) had published his research results about the ozone depletion effects of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). This important research had only gained wider publicity when the stratospheric ozone hole was discovered in 1985. [17]

The use of CFCs and HCFCs as cooling agents and as propellants in plastics was state of the art before their use was restricted in the Montreal Protocol signed in

[16] Umweltbewegung in der DDR, http://umwelt-ddr.argus-potsdam.de/index.php?abfall, last accessed 22 June 2011, in German language only

[17] See http://www.antarctica.ac.uk/press/press_releases/press_release.php?id=66; last accessed 8 May 2011

1987 [18]. Table 1 illustrates that almost every West German household was equipped with a refrigerator in 1988, and two thirds of the households had a freezer.

*Table 1: Electrical equipment in West German households in 1988 (Hampel 1991)*

| Type of Equipment | Prevalence in Private Households |
|---|---|
| **Refrigerator** | 98 % |
| **Vacuum Cleaner** | 98 % |
| **Electric Iron** | 96 % |
| **Washing Machine** | 91 % |
| **Electric Hand Mixer** | 86 % |
| **Coffeemaker** | 85 % |
| **Electric Cooker** | 77 % |
| **Freezer** | 66 % |
| **Dish Washer** | 29 % |
| **Tumble Dryer** | 18 % |

In the late eighties and early nineties, as first e-waste specific activities the German PuWaMA started collecting and treating cooling and freezing equipment to prevent stratospheric ozone depletion.

### 2.3.5 The 1994 Substance Cycle and Waste Management Act

In the early nineties, the Federal Government had to transpose the European Waste Framework Directive and the European Directive on Hazardous Waste into German waste legislation. On this opportunity, the waste management was further developed from linear substance flows towards substance cycles. The 1994 “Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal” (Substance Cycle Act 1994) targeted natural resource

[18] See http://www.epa.gov/Ozone/intpol/; last accessed 8 May 2011

conservation and environment-friendly treatment and disposal of wastes. (Wuttke 2011)

### *Corner Stones of the 1994 Substance Cycle Act*

Corner stones of this new legislation were the extended producer responsibility towards the end of life of products, and the partial reorganization of the responsibilities with more possibilities for privatization in the collection, treatment and disposal of wastes. The producer responsibility principle was intended motivating producers to adapt the design of their products to the requirements of a substance cycle economy. The producer responsibility was, however, not enacted automatically for all products with the enactment of the Substance Cycle Act, but required further specific regulation. (Wuttke 2011)

Still nowadays, the Substance Cycle Act including some amendments is the main base of waste management in Germany. E-waste was not yet addressed specifically in the Substance Cycle Act. Nevertheless, this regulation was the base for the collection, treatment and disposal of e-waste between 1994 and 2006, prior to the enactment and implementation of the European WEEE Directive in Germany.

### *E-Waste Management until March 2006*

Consumers could hand in e-waste at the municipal collection points. Some PuWaMA also collected e-waste from private consumers, either periodically or on demand. The municipalities then were responsible for the environment-friendly treatment and disposal according to the principles of the (Substance Cycle Act 1994). Depending on the municipalities, they handed over part or all the e-waste to private treatment operators, or conducted the treatment fully or partially themselves. Charity and other non-profit and mostly small profit organizations were also active in the field repairing and refurbishing used EEE such as washing machines, refrigerators, TVs, later also computers. They received such equipment from the PuWaMA, or sometimes collected it themselves attracting consumers to hand the equipment over to them. The used equipment was donated to schools (computers), and/or sold in second hand shops. Figure 3 illustrates the system.

Private consumers generally had to pay fees at the municipal collection point when handing in e-waste, at least for those types of equipment where the sales of the recycled materials could not cover the cost of treatment and disposal.

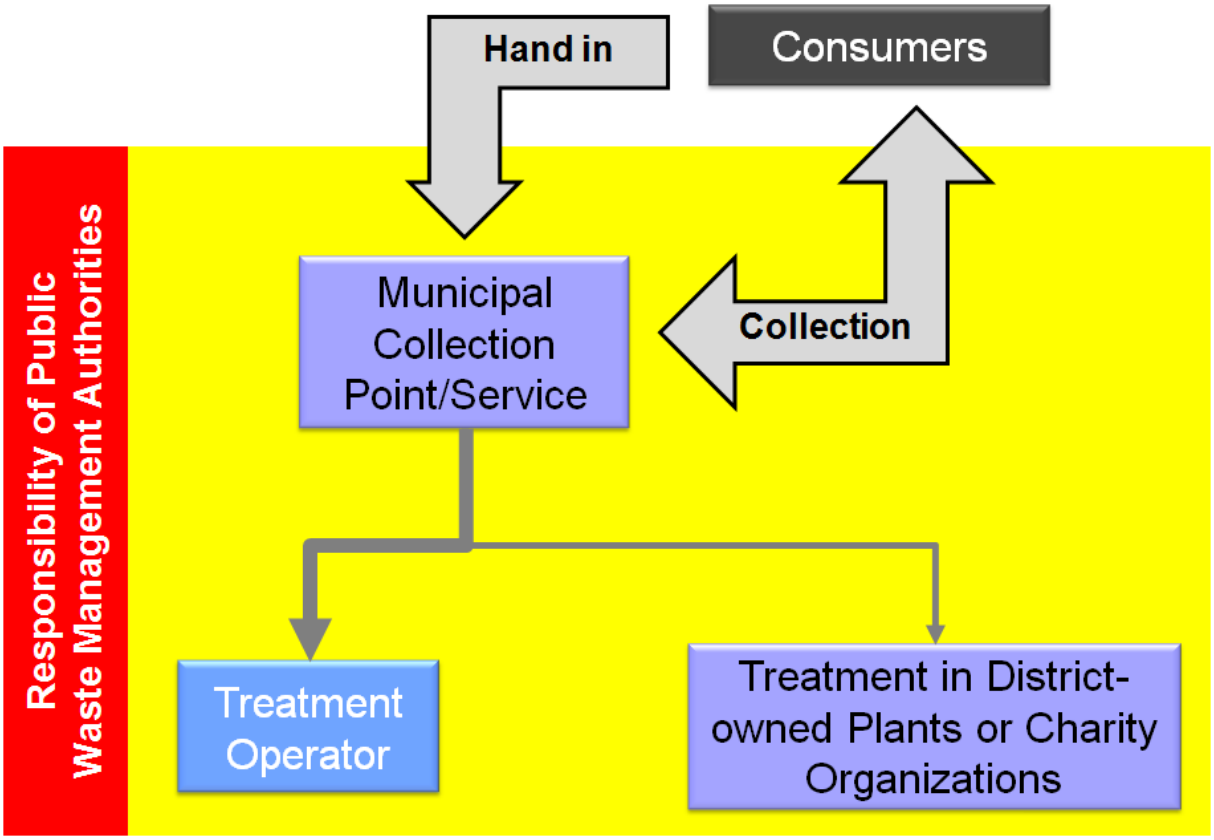


*Figure 3: E-waste management in Germany until 2006* [19]

Cooling and freezing equipment was exchanged old-for-new at the customer on delivery of a new refrigerator or freezer. This service was free of extra charge for the customer.

### 2.3.6 The European WEEE Directive and the German "ElektroG"

Reacting on the growing amounts of e-waste from electrical and electronic equipment (EEE), and the increasing integration of the European market, the European WEEE Directive was enacted in 2003. The WEEE Directive and its implementation into

[19] Gabriele Markmann-Werner, Ministry of Environment and Climate Protection of Lower Saxonia, Germany; modified

German national legislation, the “ElektroG” in 2005 marked an important further milestone for the management of e-waste in Germany.

## Responsibilities for E-Waste in the European WEEE Directive

The WEEE Directive’s scope covers 10 categories of electrical and electronic equipment (EEE) as defined in Annex IA of the (WEEE Directive 2003):

1. Large household appliances
2. Small household appliances
3. IT and telecommunications equipment
4. Consumer equipment
5. Lighting equipment
6. Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
7. Toys, leisure and sports equipment
8. Medical devices (with the exception of all implanted and infected products)
9. Monitoring and control instruments
10. Automatic dispensers

### *Responsibilities of Member States*

The member states of the European Union (EU) shall make sure that the e-waste from the above ten categories of EEE is collected and treated separately. As a minimum, each member state must achieve an annual collection rate of 4 kg per inhabitant from 2006 on. Some member states, in particular the new Eastern European members, had more time to match with this minimum rate. Moreover, member states must ensure that collection facilities are available and accessible for final users and distributors, where they can hand in e-waste from private households free of charge.

*Responsibilities of Distributors*

When supplying a new product, distributors shall ensure that end users can return waste from such products to the distributor at least free of charge on a one-to-one basis. This obligation applies as long as the waste equipment is of equivalent type and has fulfilled the same functions as the newly supplied equipment. Member States, however, may depart from this provision if returning the WEEE is not thereby made more difficult and remains free of charge for the final holder.

*Responsibilities of Producers*

The WEEE Directive is based on the core principle of producer responsibility. According to (WEEE Directive 2003) "[…] producer responsibility is one of the means of encouraging the design and production of electrical and electronic equipment which take into full account and facilitate their repair, possible upgrading, reuse, disassembly and recycling."

The core idea behind the producer responsibility approach is that producers will try to minimize the end-of-life (EoL) cost of their products, if they have to organize and finance collection and treatment of the waste from the EEE they put on the market. Producers can influence the EoL-cost of their products by Design for End-of-Life. The producer responsibility thus is assumed to make producers optimizing the product design for the EoL of their products. Figure 4 illustrates the principle.

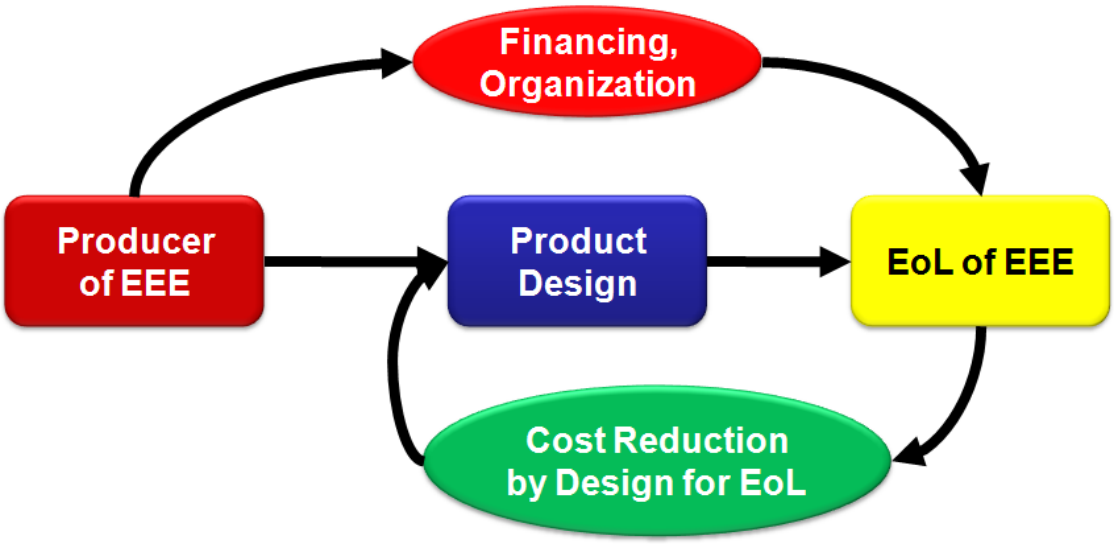


*Figure 4: Financial incentives driving Design for EoL in producer responsibility*

EoL end of life

A measure of design for EoL could be to make components and substances easily accessible that need to be removed from e-waste prior to further treatment according to Annex II of the (WEEE Directive 2003). Designing LCD flat panel displays that contain mercury backlights, for example, so that they can be removed more easily and quickly, would save expensive labor and thus reduce the EoL cost for this equipment. Such cost incentives would hence drive producers to continuously improve the design for EoL of their products, if the producers have to finance the EoL of their products.

Producer responsibility according to the (WEEE Directive 2003) comprises the following operational and financial aspects:

- Producers shall set up systems for the treatment of e-waste using best available treatment techniques.
- Producers shall at least finance the collection, treatment and environmentally sound disposal of e-waste from private households disposed of at collection facilities.
- Each producer shall finance the treatment of the waste from its own products put on the market after 13 August 2005.

Producers can choose to fulfill their above obligations either individually or by joining a collective scheme.

Additionally to the above obligations, producers have to comply with further requirements:

- Each producer must provide a guarantee when placing a product on the market to ensure that the collection, treatment and disposal of this product will be financed. The guarantee may take the form of the producer's participation in appropriate schemes for the financing of the management of WEEE, a recycling insurance or a blocked bank account.
- Producers must clearly mark the products they put on the market after 13 August 2005 with the symbol shown in Figure 5.

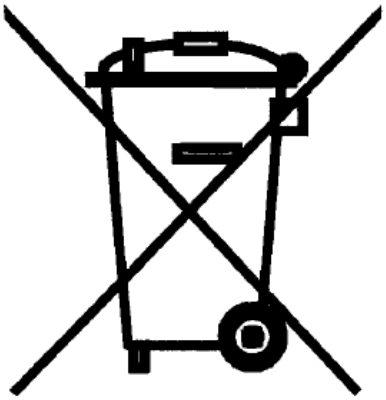

*Figure 5: Symbol for the marking of electrical and electronic equipment according to (WEEE Directive 2003)*

- Producers must achieve certain minimum targets for recovery and recycling of the e-waste collected separately. These targets vary depending on the category of EEE in Annex IA of the WEEE Directive. Figure 6 on page 31 details the requirements.

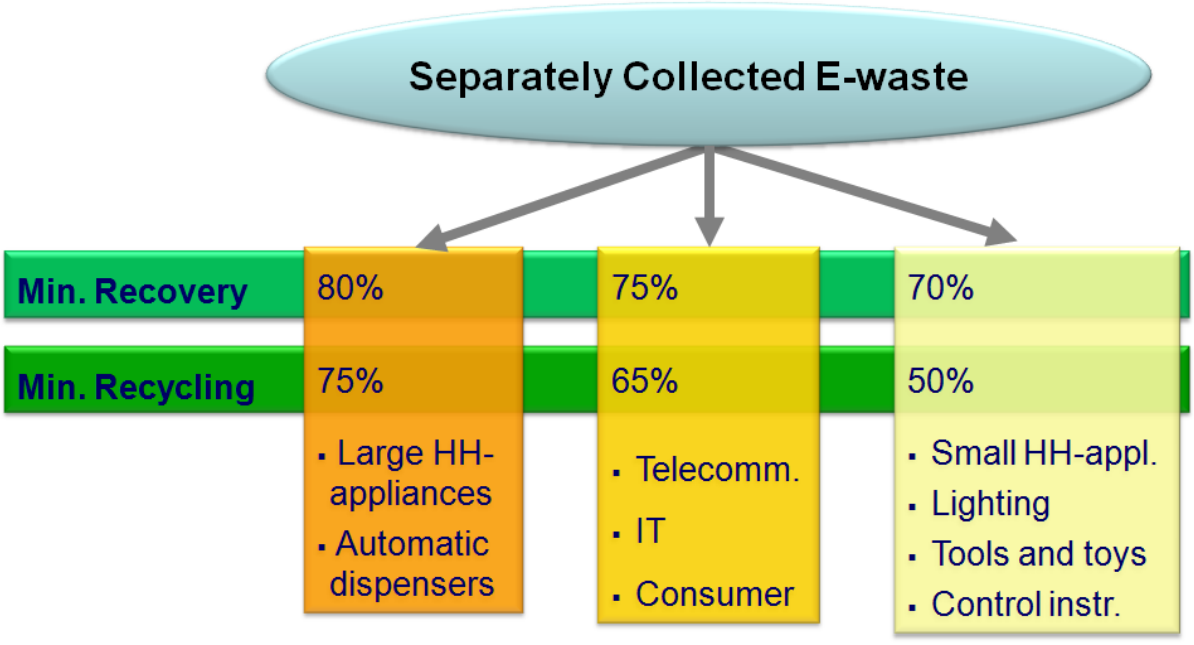


*Figure 6: Minimum recovery and recycling targets for separately collected e-waste*

Recovery and recycling are defined in the (Waste Directive 2008). Recovery means any operation the principal result of which is waste serving a useful purpose. Waste may replace other materials, which otherwise would have been used to fulfill a particular function, or it may be prepared to fulfill that function, in the plant or in the wider economy.

Recycling is any recovery operation reprocessing waste into products, materials or substances whether for the original or other purposes. Recycling does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations. (Waste Directive 2008)

Annex II of the (WEEE Directive 2003) stipulates the selective treatment of specific materials and components of e-waste. These provisions comprise

- the removal of certain substances, preparations and components from separately collected e-waste, and
- the specific treatment of certain e-waste components.

These specific operations shall be conducted without hindering the reuse of components or entire devices.

European directives like the WEEE Directive do not apply directly to the member states. The member states must transpose them into national legislation. The member states have certain freedoms how they implement the provisions of the WEEE Directive resulting in implementation differences between the EU member states.

## Transposition of the WEEE Directive into German Legislation – the ElektroG

The German e-waste management is based on the Act Governing the Sale, Return and Environmentally Sound Disposal of Electrical and Electronic Equipment (ElektroG 2005). The ElektroG is the transposition of both the European (WEEE Directive 2003) and of the European (RoHS Directive 2003) into German national legislation. The ElektroG entered into force on 13 August 2005. Some e-waste-related stipulations, such as the operation of the takeback systems, however, were delayed to 23 March 2006. The restriction of the hazardous substances entered into force on 1 July 2006, as foreseen in the (RoHS Directive 2003).

### *Priorities for the Implementation of the WEEE Directive in Germany*

The implementation of the (WEEE Directive 2003) into the German (ElektroG 2005) was influenced by the experiences made with another producer responsibility scheme. The “Duales System Deutschland” (DSD), the organization responsible for the collection, treatment and disposal of packaging materials, from the time of its introduction in 1990 until recently was a monopoly. Industry complained about high prices as a consequence.

This experience resulted in the following implementation priorities:

- Promotion of competition
  The e-waste management system shall avoid monopolies, and allow producers maximum freedom to decide how to comply with their extended producer responsibility (EPR).

- Prevention of freeriders
  The system shall ensure that all producers contribute to the treatment and financing of the e-waste in proportion to their market share in Germany.

- Prevention of cherry picking
  Each producer must collect from all over Germany thus avoiding that some producers focus on bigger cities, while other producers have to collect from rural areas with high logistics cost.

The stipulations of the ElektroG will be explained in chapter 3 describing the German e-waste management system.

### 2.3.7 Recast of the WEEE-Directive

The still ongoing recast of the WEEE Directive will mark the next milestone for e-waste management in Germany. The European (Commission 2008), the (European Parliament 2011) and the European (Council 2011) have submitted proposals for the revision of the WEEE Directive. No political agreement could be achieved yet between these institutions of the European Union and the member states. Based on the above-mentioned different proposals presented, the following important amendments may be expected:

- Open scope

  While the scope of the current (WEEE Directive 2005) is limited to the 10 categories in its Annex I, the new WEEE Directive will probably have an open scope covering all electrical and electronic equipment (EEE) with few exclusions only.

- Increased minimum collection target

  The current collection target of four kilograms per year and inhabitant in each member state will probably be amended. A certain percentage of the average amounts of EEE put on the market in each member state in the preceding years may have to be collected in each member state. Alternatively, the e-waste arising in each member state is proposed as a reference for the percentages of collection. The collection targets might also be differentiated

depending on the environmental relevance of the various types of equipment resulting in higher collection targets for environmentally more relevant types of e-waste.

- Increased minimum targets for reuse, recovery and recycling

  The minimum targets for recovery and recycling (see Figure on page 31) will probably be increased. Possibly, an additional minimum target for reuse of entire devices will be introduced.

- Financing of collection

  Consumers, distributors and producers together may have to finance a certain fee at the point of sale, which the PuWaMA or other parties responsible for collection may then use for the collection of e-waste, improving the collection infrastructure, and for awareness raising campaigns. Alternatively, member states may oblige producers to take over more financial responsibility for the e-waste collection directly from private households.

- Harmonization of registration and reporting

  The registration of producers in the member states may be simplified. Via interoperable registers, registration in one member state may be sufficient to be registered in all member states. Producers' reporting obligations to the member states may be harmonized in terms of reporting frequencies and formats.

- Prevention of Illegal Exports

  Exporting e-waste from EU member states to developing countries is illegal, but still ongoing. In the face of the severe environmental and health impacts of e-waste treatment in the developing countries, the European Commission, the Council and the Parliament all promote provisions to stop illegal exports of e-waste in their recast proposals for the WEEE Directive.[20] Testing certificates proving that the exported used electrical and electronic equipment is still functional and other accompanying documentation shall help to differentiate the illegal exports of waste from the legal shipments of used EEE for reuse.

The next important step in the political process is the European Parliament's plenary session voting on the recast WEEE Directive, probably on 30 November 2011.[21]

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[20] European Parliament Legislative Observatory, http://www.europarl.europa.eu/oeil/file.jsp?id=5723502; last accessed 15 May 2011

[21] European Parliament Legislative Observatory, http://www.europarl.europa.eu/oeil/file.jsp?id=5723502; last accessed 15 May 2011

# 3 E-waste Management in Germany According to the ElektroG

The following sections will explain the key players' responsibilities and the possibilities of compliance the ElektroG provides.

## 3.1 Key Players and their Roles

The key players in the operation of the German e-waste management system are:

- the public waste management authorities (PuWaMA, public),
- the producers of electrical and electronic equipment (private),
- the clearing house EAR (private with governmental authorization).

Further important players are the retailers and the consumers, even though the (ElektroG 2005) does not assign them specific responsibilities.

### 3.1.1 The Public Waste Management Authorities

*Collection of E-waste from Private Households*

According to the (ElektroG 2005), the public waste management authorities (PuWaMA) are responsible for the collection of e-waste. They must set up collection points in their districts to which final holders and distributors may return e-waste from private households in the vicinity (bring back system). The municipalities must not

levy any charges to the consumers for such e-waste returns to the collection points. The number of collection points depends on the population density and the local conditions. The PuWaMA may also collect WEEE directly from private households (collection system), but the ElektroG does not make this obligatory.

The PuWaMA may refuse to accept e-waste if it is contaminated in such a way as to pose a safety risk or a hazard to human health. The same applies to the delivery of more than 20 pieces of equipment in EEE categories 1 to 3. Such deliveries must be coordinated with the public waste management authorities. (ElektroG 2005)

Commercial collection by private collectors is not allowed. The PuWaMA, however, may delegate the collection to third parties, which may be private companies. The final accountability, however, remains with the PuWaMA. (Koch 2011) The involvement of private companies in the collection of e-waste thus is decided on the district and municipal level and may therefore differ from district to district.

### *Collection Groups*

The (ElektroG 2005) differentiates the EEE into the same 10 categories with the same types of equipment like the (WEEE Directive 2003). Like in the WEEE Directive, the listing of equipment types under each of the categories is not exclusive, but just gives examples of types of equipment.

The ElektroG requires the PuWaMA to collect and store the e-waste arising from these 10 categories of EEE in five collection groups as shown in Table 2.

*Table 2: E-waste collection groups in Germany (Espejo 2011, modified)*

| **Collection group** (ElektroG 2005) | **Corresponding category of EEE** (Annex I ElektroG 2005 and WEEE Directive 2003) | | **Example types of equipment** according to (Annex I ElektroG 2005, WEEE Directive 2003) |
|---|---|---|---|
| 1 | 1 | Large Household Appliances | Washing machines; clothes dryers; dish washing machines; cooking electric stoves; electric hot plates; microwaves; other large appliances used for cooking and other processing of food; electric heating appliances; electric radiators; other large appliances for heating rooms, beds, seating furniture; electric fans; air conditioner appliances; other fanning, exhaust ventilation and conditioning equipment |
| | 10 | Automatic Dispensers | Automatic dispensers for hot drinks, hot or cold bottles or cans, solid products or money; all appliances which deliver automatically all kind of products |
| 2 | 1 | Large Household Appliances | Large cooling appliances; refrigerators; freezers; other large appliances used for refrigeration, conservation and storage of food |
| 3 | 3 | Information and Telecommunication Equipment (ICT) | Centralized data processing: mainframes, minicomputers, printer units;<br>personal computing: personal computers (CPU, mouse, screen and keyboard included), laptop computers (CPU, mouse, screen and keyboard included), notebook computers, notepad computers, printers; copying equipment; electrical and electronic |

| | | | |
|---|---|---|---|
| | | | typewriters; pocket and desk calculators; other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means; user terminals and systems; facsimile; telex; telephones; pay telephones; cordless telephones; cellular telephones; answering systems; other products or equipment of transmitting sound, images or other information by telecommunications |
| | 4 | Consumer Electronics | Radio sets; television sets; video cameras; video recorders; hi-fi recorders; audio amplifiers; musical instruments; other products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image than by telecommunications |
| 4 | 5 | Lighting Equipment | Luminaries for fluorescent lamps with the exception of luminaries in households, straight fluorescent lamps, compact fluorescent lamps ("energy saving lamps"), high intensity discharge lamps, including pressure sodium lamps and metal halide lamps, low pressure sodium lamps, other lighting or equipment for the purpose of spreading or controlling light with the exception of filament bulbs |
| 5 | 2 | Small Household Appliances | Carpet sweepers; other appliances for cleaning; appliances used for sewing, knitting, weaving and other processing for textiles; irons and other appliances for ironing, mangling and other care of clothing; toasters, fryers, grinders, coffee machines and equipment for opening or sealing containers or packages; electric knives; appliances for hair-cutting, hair drying, tooth brushing, shaving, massage and other body care appliances; clocks, watches and equipment for the purpose of measuring, indicating or registering time; scales |
| | 6 | Electrical and Electronic Tools | Drills; saws; sewing machines; equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, bending or similar processing of wood, metal and other materials; tools for riveting, nailing or screwing or removing rivets, nails, screws or similar uses; tools for welding, soldering or similar use; equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means; tools for mowing or other gardening activities |
| | 7 | Toys, Sports and Leisure Equipment | Electric trains or car racing sets; hand-held video game consoles; video games; computers for biking, diving, running, rowing, etc.; sports equipment with electric or electronic components; coin slot machines |
| | 8 | Medical Products | Radiotherapy equipment; cardiology; dialysis; pulmonary ventilators; nuclear medicine; laboratory equipment for *in-vitro* diagnosis; analyzers; freezers; fertilization tests; other appliances for detecting, preventing, monitoring, treating, alleviating illness, injury or disability |
| | 9 | Monitoring and Control Instruments | Smoke detectors; heating regulators; thermostats; measuring, weighing or adjusting appliances for household or as laboratory equipment; other monitoring and control instruments used in industrial installations (e.g. in control panels) |

Each of the five collection groups is stored in a separate container at the municipal collection points consuming space. The limitation to five collection groups hence is a compromise allowing sufficient separation of e-waste with respect to efficient treatment on the one hand, and taking into account the practicability at the municipal collection points on the other hand.

*Handover of E-waste to the Producers*

The public waste management authorities hand over the e-waste in these five different containers to the producers of EEE free of charge. The producers have to provide the containers free of charge to the PuWaMA.

Each PuWaMA may choose, however, not to make the e-waste of a specific collection group available to the producers. The PuWaMA must provide three months' notice to the clearing house EAR and then enter into the producers' obligations including the recovery and recycling targets and the reporting obligations to the clearing house EAR.

## 3.1.2 Producers

The ElektroG adopted the provisions on the extended producer responsibility of the (WEEE Directive 2003). In Germany, like in most other EU member states, the producer responsibility starts with the handover of the e-waste to the producers at the municipal collection points, or with the takeover from distributors such as retailers.

### Producer Takeback According to the ElektroG

The ElektroG leaves the producers three principle possibilities to take back e-waste. Producers may set up individual brand-selective takeback schemes (IBTS), individual non-selective takeback schemes (INTS) or join a collective takeback scheme (CTS), as depicted in Figure 7.

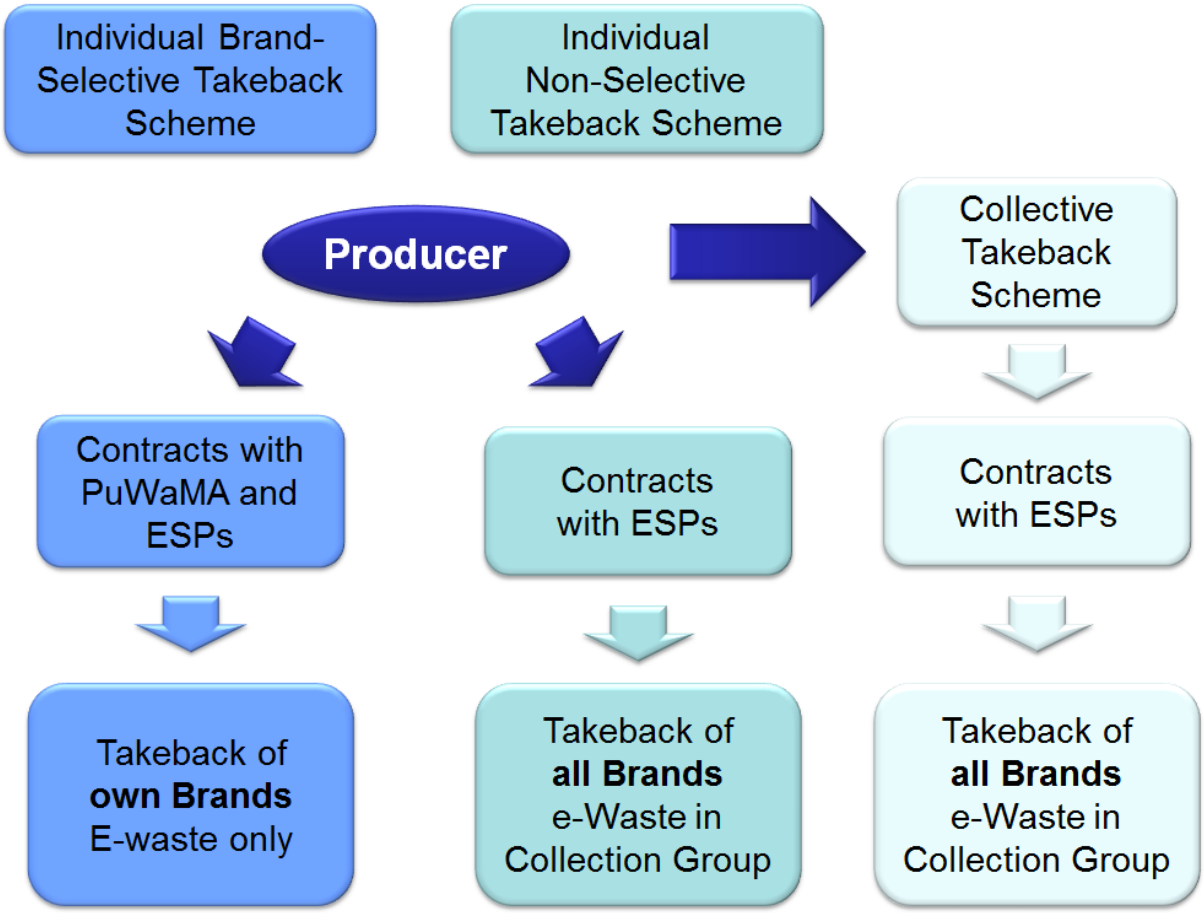


*Figure 7: Possibilities for producers to implement their extended producer responsibility in Germany*

ESP: EoL Service Provider

Producers normally will not operate the EoL of the e-waste themselves, but contract end-of-life service providers (ESPs) for the logistics, treatment and disposal of the e-waste. In IBTS and in INTS, the producers individually will make contracts with ESPs, while CTS will take over this task, if the producer joins such a system.

In individual brand-selective compliance schemes, producers will only take back e-waste of their own brands. On this behalf, they will need to make additional contracts with the PuWaMA and possibly with the distributors taking back e-waste from private consumers, as they must sort out the producers' brands from e-waste collected. In INTS and CTS, producers will have to take back all brands of e-waste in their collection group according to each producer's market share. The next section describes the different takeback schemes in more details.

## Takeback in the Different Producer Takeback Schemes

### *Individual Brand-Selective Takeback Schemes*

A producer can set up an individual brand-selective takeback scheme (IBTS), which then only assumes responsibility for e-waste of his own brands. As a result, producers setting up an IBTS receive back and have to take care of their own brands e-waste only. Figure 8 illustrates an IBTS for an example “Producer A” and his brands of EEE put on the German market.

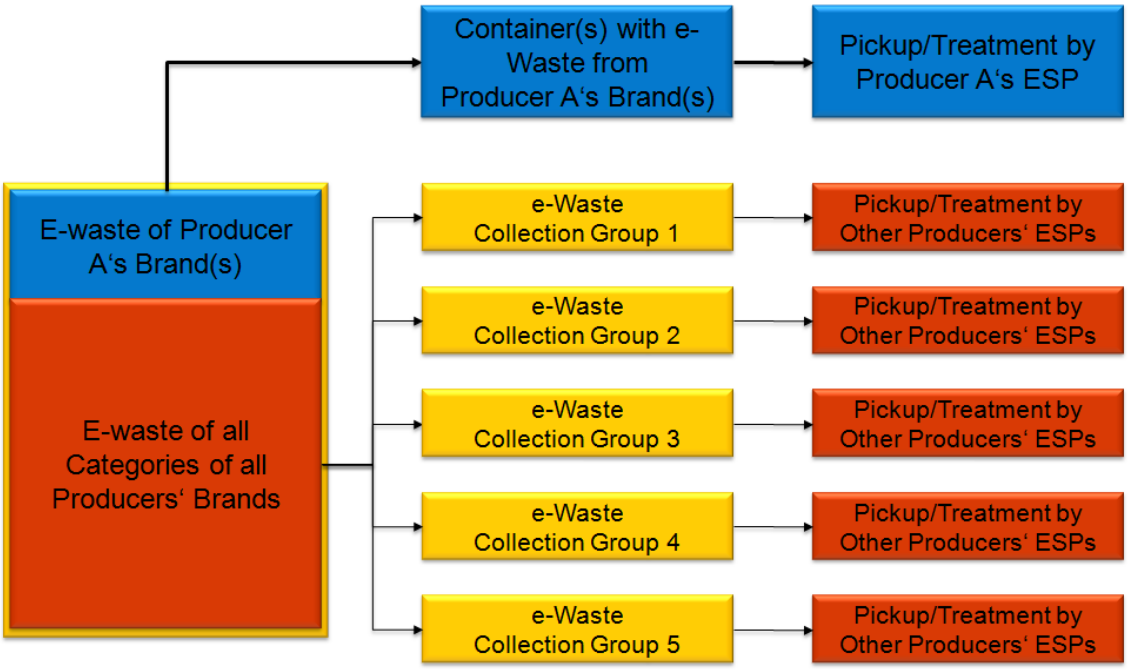


*Figure 8: Individual brand-selective takeback scheme*

An IBTS requires the PuWaMA to collect separately or sort out the e-waste of producer A’s brands. The e-waste must then be stored separately after collection to make it available to producer A’s ESPs. Alternatively, producer A may establish his own collection point, where the PuWaMA and consumers may bring producer A’s brands e-waste.

The producer will have to reimburse the PuWaMA for all additional efforts going beyond the PuWaMA’s obligations, which are stipulated in the ElektroG.

The producer will directly contract one or several end-of-life full service providers (ESPs). It is important to note, however, that the legal responsibility for the e-waste always remains with the producer.

The producers are responsible for the amounts of e-waste collected according to their market share in EEE put on the German market. The market share is calculated by the clearing house EAR. The EAR will periodically assess whether the amount of e-

waste the producer collected in his IBTS corresponds to the amounts of e-waste the producer has to collect and treat according to his market share. In case the producer has collected less than its share, it has to pick up and treat the missing share additionally.

Producers operating an IBTS take back e-waste of their own brands only, as long as they collect the amounts of e-waste at least in accordance to their market share.

### *Individual Non-selective Takeback Schemes*

For an individual non-selective takeback scheme (INTS), like for an IBTS, producers will directly contract ESPs to organize and conduct the EoL of their products. Contrary to an IBTS, however, the producer will not take back its own brand products only, but just the share of e-waste that falls under his responsibility within each collection group according to his market share.

Figure 9 below shows an example for such an INTS for a producer A putting products of EEE category 3 and 4 on the German market. These products are collected in the e-waste collection group 3.

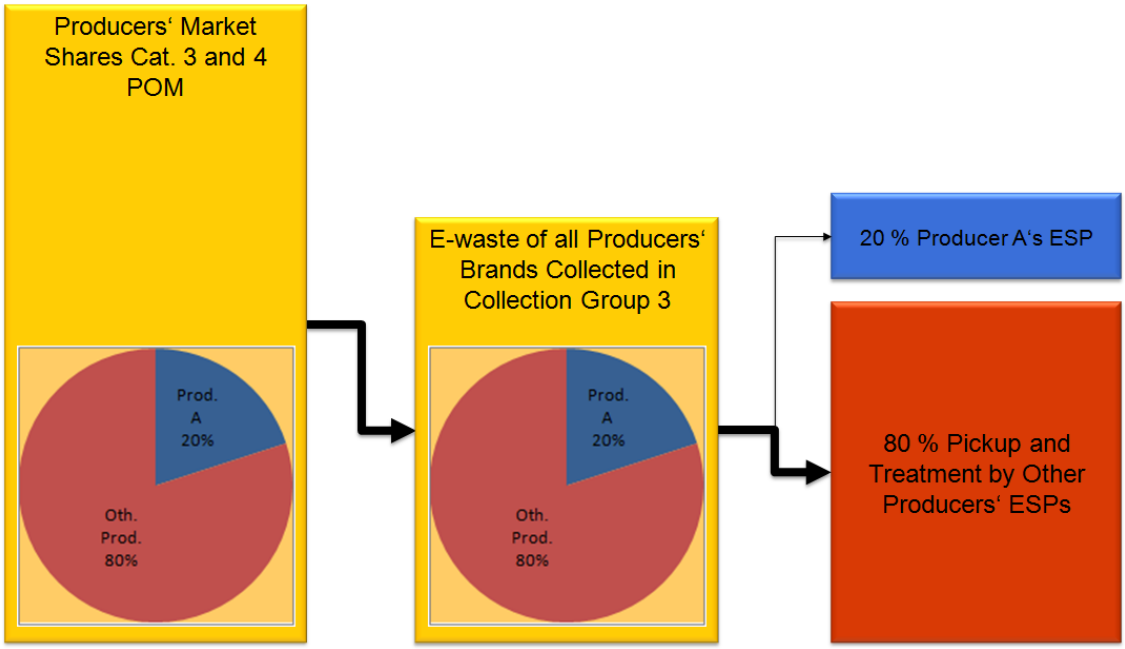


*Figure 9: Individual Non-selective Takeback Scheme*

POM put on the market

The amounts of e-waste collected in the official e-waste management system are lower than what is put on the market (POM). Each producer, however, must take care of this collected e-waste based on his market share in POM. If producer A's market

share in category 3 and 4 is 20 % in total, producer A must assume responsibility for 20 % of e-waste collected in collection group 3. The other 80 % of e-waste must be taken care of by the other producers' takeback schemes.

The PuWaMA collect and store the e-waste of category 3 in containers at their municipal collection points. The content of these containers is composed of all products of all producers' brands collected in collection group 3 besides those brands collected under individual brand-selective takeback schemes. Producers operating an INTS therefore take back containers with e-waste of all producers that produce EEE collected in the same collection group.

### *Collective Takeback Schemes*

Several producers may set up a collective takeback scheme (CTS) to jointly organize and finance the EoL of their EEE. Figure 10 shows an example CTS set up by two producers A and B manufacturing ICT and consumer equipment (EEE categories 3 and 4).

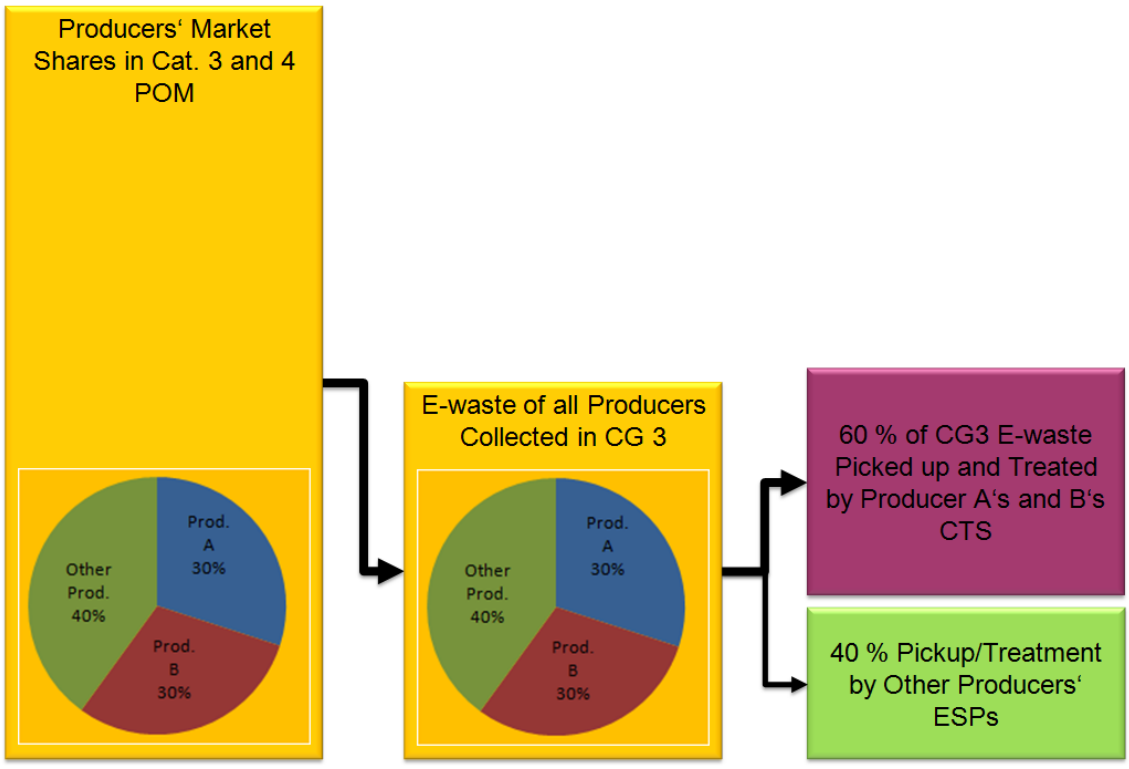


*Figure 10: Collective Takeback Scheme for e-waste of collection group 3*

CG collection group
POM put on the market

ICT and consumer equipment are collected in collection group 3. Producers A's and B's CTS is responsible for 60 % of all e-waste collected in this collection group all over Germany according to their added market shares in POM of 30% each.

Producers operating in CTS receive back containers with e-waste from all producers manufacturing EEE collected in the same collection group. In principle, CTS may decide to take back its own members e-waste only. Like in IBTS, the CTS would then have to remunerate the municipal collection points for sorting out its members' brands e-waste from the general e-waste stream and store it in separate containers, or establish its own collection points.

### *Specific Limitations for Collective Takeback Schemes in Germany*

Most EU member states have only one CTS in place taking back all kinds of e-waste, or several CTS each taking back e-waste from certain categories of EEE. In Germany, in order to maintain complete competition, the market shares of CTS are limited. The German "Bundeskartellamt" (Federal Cartel Authority, FCA) advised, for example, the producers of large white goods (category 1) not to set up a CTS covering more than 25 % of market share of EEE in collection group 1 (Heistermann 2011).

This 25 % limit, however, is not a general restriction for CTS in Germany, even though the FCA would not allow a single CTS covering an entire category of e-waste. The exact limit of a CTS' share in its collection group would depend on an in-depth case-by-case analysis of how a cooperation affects competition. (Bundeskartellamt 2005)

## Specific Stipulations for Historical E-waste and E-waste from Other Sources than Private Households

Historical e-waste is waste from EEE put on the market before 13 August 2005, the date when the ElektroG was enacted in Germany. Producers are responsible for the financing and treatment of this historical e-waste based on their market share like for the other e-waste collected separately. This obligation applies even if a producer had not put any EEE on the German market prior to 13 August 2005.

Besides e-waste from private households, producers are also responsible for e-waste from other than private households. This is e-waste from business-to-business (B2B) equipment. Such EEE is not or normally not used in private households. Examples are gas chromatographs, professional kitchen and laundry equipment, high end servers used in data centers, industrial tools, etc. For such B2B e-waste from EEE put on the market after 13 August 2005, the producer must offer a reasonable option for the return and disposal. The producer thus has the same obligations for this B2B e-waste like for e-waste from private households. The producer and the holder of EEE, however, may reach an agreement, which departs from these provisions.

For e-waste from EEE put on the market before 13 August 2005 – historical B2B e-waste - the holder is responsible.

### 3.1.3 Distributors and Consumers

Distributors such as retailers may take back e-waste voluntarily. Unlike in some other EU member states, they are not legally obliged to accept e-waste. Distributors offering this takeback service in Germany practice it as trade-in. Consumers may hand in their old equipment if they buy a new one of the same type.

The (ElektroG 2005) obliges consumers like any other owner of e-waste to place it in a collection separate from that for unsorted domestic waste. Disposal of e-waste into household waste containers thus is illegal, but difficult to control. Consumer awareness hence is a key to obtain access to e-waste. The PuWaMA shall therefore notify private households of their obligations and about

- options in their district for the return or collection of e-waste,
- their role in the reuse, recycling and other forms of recovery of e-waste,
- the possible impacts on the environment and human health from the disposal of harmful substances contained in electrical and electronic equipment, and
- the meaning of the symbol shown in Figure 11.

*Figure 11: Label to be put on EEE in Europe indicating the necessity of separate collection (WEEE Directive 2003, ElektroG 2005)*

Producers must label all EEE put on the market after 13 August 2005 with the above label to indicate to consumers that e-waste must not be disposed of in the domestic waste container.

The obligation for separate disposal of e-waste applies to the distributors as well. They are, however, not obligated to hand over the e-waste to the PuWaMA or to producer takeback schemes, but may use other possibilities like e-waste brokers. The same in principle applies to consumers, but only is of relevance for corporate consumers. Corporate consumers may hold large amounts of used EEE, which they want to sell as used equipment, where, however, it is not always clear whether it is actually e-waste or functioning second hand products.

### 3.1.4 The Clearing House

The functioning of the overall e-waste management system requires the coordination of the PuWaMA and the producers on the one hand, and of the individual producers' efforts on the other hand. The producers hence set up and finance the clearing house, the "Elektro-Altgeräteregister" (EAR), which is constituted as a foundation. It assumes coordinative and superordinated tasks such as producer registration, reporting and the calculation of the producers' market shares. These tasks will be described in detail in the chapter 3.2.1 on page 46.

In case of doubts, the EAR decides about which types of EEE are covered by the ElektroG. Annex I of the (ElektroG 2005) shows the 10 categories of EEE and lists specific types of EEE under each category. These types of EEE are in the scope of the ElektroG. The listing of types of EEE in Annex I, however, is not exclusive. If a specific type of EEE is not mentioned in Annex I, it cannot be concluded that the ElektroG does not cover such a type of EEE. In cases of doubt, the EAR decides, and the producers may challenge this decision in court in case they do not agree, which actually has already happened.

As the clearing house takes over sovereign powers, e.g. with the mandatory producer registration, it is authorized by the competent governmental authority, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), and supervised by the "Umweltbundesamt" (UBA, Federal Environment Agency). The EAR is constituted as foundation and as such does not make profits. It charges, however, the producers for the sovereign power acts according to the (Cost Ordinance).

The EAR's competences are strictly limited to the tasks required to the coordination of the system. It may not interfere with how the other key players comply with their obligations within the legally foreseen leeway.

## 3.2 Coordination and Interaction of the Key Players

### 3.2.1 Interaction of Producers and the Clearing House

Figure 12 shows the tasks of the producers and the clearing house EAR and their coordination and demarcation.

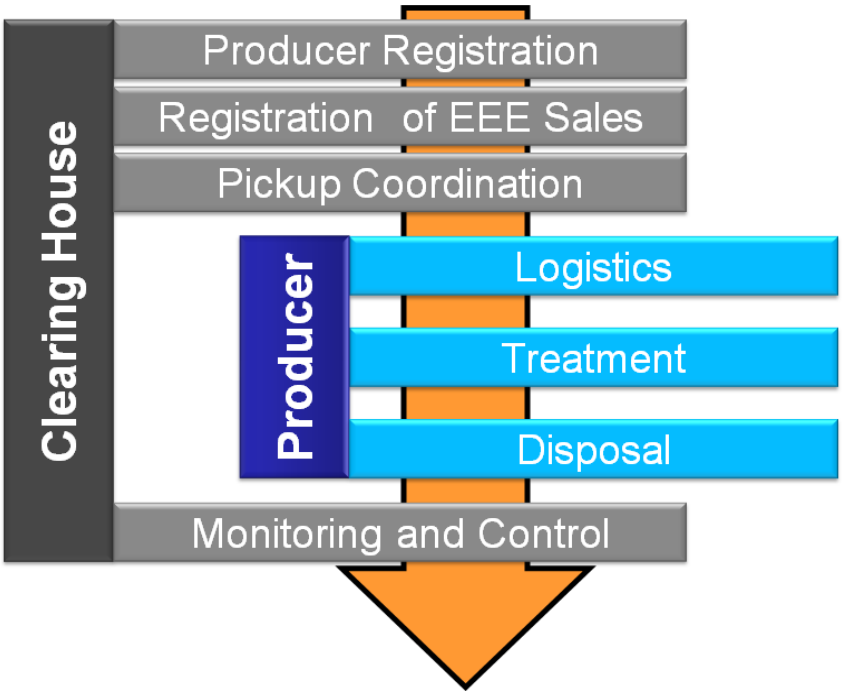


*Figure 12: Responsibilities of the clearing house EAR and the individual producers* [22]

The EAR registers the producers and their sales of EEE, and it allocates the containers of e-waste collected in Germany to the producers. It monitors and certifies that the producers comply with their extended producer responsibility within the legally foreseen leeway. The EAR is, however, strictly forbidden to tamper with how the producers organize their extended producer responsibility within the legally foreseen leeway. The EAR has to remain neutral. It must make contracts neither with any ESPs nor with producers.

[22] Source: Gebriele Markmann-Werner, Ministry of Environment and Climate Protection of Lower Saxonia, Germany; modified

Figure 13 illustrates the interaction between producers and the EAR in more detail.

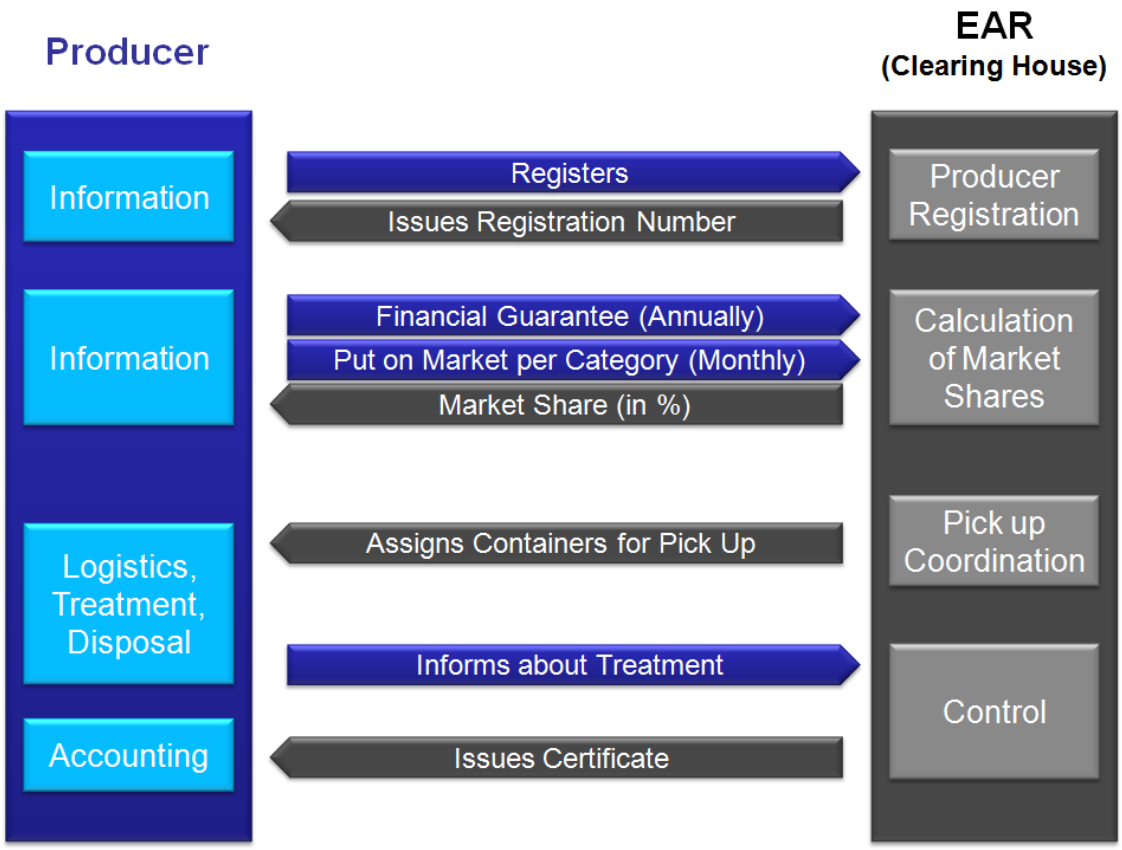


*Figure 13: Interaction of individual producers and the clearing house* [23]

The interactions are explained in more details in the following sections.

## Registration and Financial Guarantee

Before placing EEE on the German market, producers have to register with the EAR. Producers must register each of their brands. The EAR in return issues a registration number, which the producer has to use in all business transactions. Each registered producer will, however, only have one registration number, even if he registers several brands. The (ElektroG 2005) prohibits producers who fail to register or whose

[23] Source: Gabriele Markmann-Werner, Ministry of Environment and Climate Protection of Lower Saxonia, Germany; modified

registration is withdrawn to place EEE on the German market. The EAR publishes the registered producers in the EAR Producer Register. [24]

The first time with the registration, and then on an annual base, the producer has to provide an insolvency-proven guarantee for the EEE, which the producer intends to place on the German market in that year. In case a producer goes bankrupt, the financial guarantee shall prevent that other producers or the general public have to finance this producers' e-waste. The amounts of EEE the producers estimate to sell are adjusted at the end of the annual period with the amounts of EEE the producer actually has sold. (ElektroG 2005) The financial guarantee, however, does not need to cover EEE, for which the producer plausibly documents that it is not commonly used in private households. (ElektroG 2005) The guarantee may be provided in the form of an insurance policy, a frozen bank account or the producer's participation in an appropriate system to fund e-waste.

The PuWaMA enlist their municipal collection points at the EAR. This is, however, different from the producer registration and shall just enable the EAR to allocate the containers with e-waste at the municipal collection points to producers.

## Reporting of EEE Put on Market and Allocation of E-waste

On a monthly basis, each registered producer reports to the EAR the type and amounts of EEE it places on the German market. The amounts reported must be differentiated in EEE, for which the (ElektroG 2005) requires a financial guarantee – EEE for private households – and other EEE. As all producers report these amounts to the EAR, it can calculate the market share of each producer in the ten categories of EEE.

The (ElektroG 2005) offers two possibilities of how to assess this share:

- based on the market share a producer achieves in a category of EEE (see Table 2 on page 36) on the German market,
- based on the verified share of clearly identifiable e-waste, arrived at through sorting or application of scientifically recognized statistical methods, in the total quantity of WEEE according to equipment type. This option, however, is only eligible for e-waste put on the German market after 13 August 2005.

[24] EAR Producer Register Stiftung Elektroaltgeräte (EAR): List of producers registered at EAR; http://www.stiftung-ear.de/hersteller/verzeichnis_registrierter_hersteller (in German only); last accessed 20 February 2011

Each producer can freely decide how the EAR should calculate its share of e-waste for which it has to assume responsibility.

The calculation of each producer's market share was already shown in section "Takeback in the Different Producer Takeback Schemes" on page 40. Each producer is responsible for financing and treatment of the e-waste collected in accordance with his market share in the equipment put on the German market.

Regardless of whether a producer sells EEE locally, regionally or across Germany, he must pick up separately collected e-waste from all over Germany. Within each producer's market share, the EAR geographically allocates the containers to be picked up to the producers so that over time each producer has picked up containers from municipal collection points all over Germany, from the countryside as well as from big cities. The allocation is based on a scientifically approved method, which is published on the internet.[25]

## Monitoring and Controlling

Producers have comprehensive reporting obligations to the clearing house EAR to enable the EAR to monitor and control the producers' compliance. Each producer informs the EAR for each calendar year about:

1. the quantities per collection group of e-waste (see Table 2 on page 36) collected from public waste management authorities,
2. the types and quantities of e-waste collected in an individual or a collective takeback scheme,
3. the quantities per EEE category of e-waste the producer has
    - reused,
    - recycled,
    - recovered,
    - exported.

[25] Stiftung EAR: Calculation of market shares and container allocation; http://www.stiftung-ear.de/e1767/e1044/e2235/051123Berechnungsweise_ger.pdf; last accessed 13 March 2011; available in German language only

4. Each producer submits to the clearing house an annual report by 30 April each year. This report contains the data for the previous year for total quantities from primary treatment facilities about the mass of e-waste, its components, materials or substances when
    - entering the treatment facility (input),
    - leaving the treatment facility (output), and
    - entering the recovery or recycling facility (input).

Quantities are to be stated by weight or, if this is not possible, by number of units. If quantities cannot be reported, a well-founded estimate will suffice. The clearing house EAR may also request that an independent expert verifies the information provided.

The data are the base for calculating whether the producer has picked up and treated e-waste according to his market share, and whether he has achieved the minimum recovery and recycling targets. Finally, the EAR certifies that the producer has complied with his extended producer responsibilities according to the ElektroG.

### 3.2.2 Interaction of Public Waste Management Authorities, Clearing House and Producers

The PuWaMA and the producers share the responsibility for the e-waste. The PuWaMA collect the e-waste at municipal collection points in the five categories listed in Table 2 on page 36 and hand it over free of charge to the producers. The municipalities' responsibility for the e-waste ends with the handover of this e-waste to the producers or their authorized representatives, the EoL service providers.

When a collection volume of at least 30 m³ has been reached for collection groups 1, 2, 3 or 5, or at least three m³ for collection group 4 (for collection groups see Table 2 on page 36), the PuWaMA report to the clearing house EAR that containers are full and ready for pickup. (ElektroG 2005)

Figure 14 illustrates the interaction of PuWaMA, clearing house, producers and the ESPs.

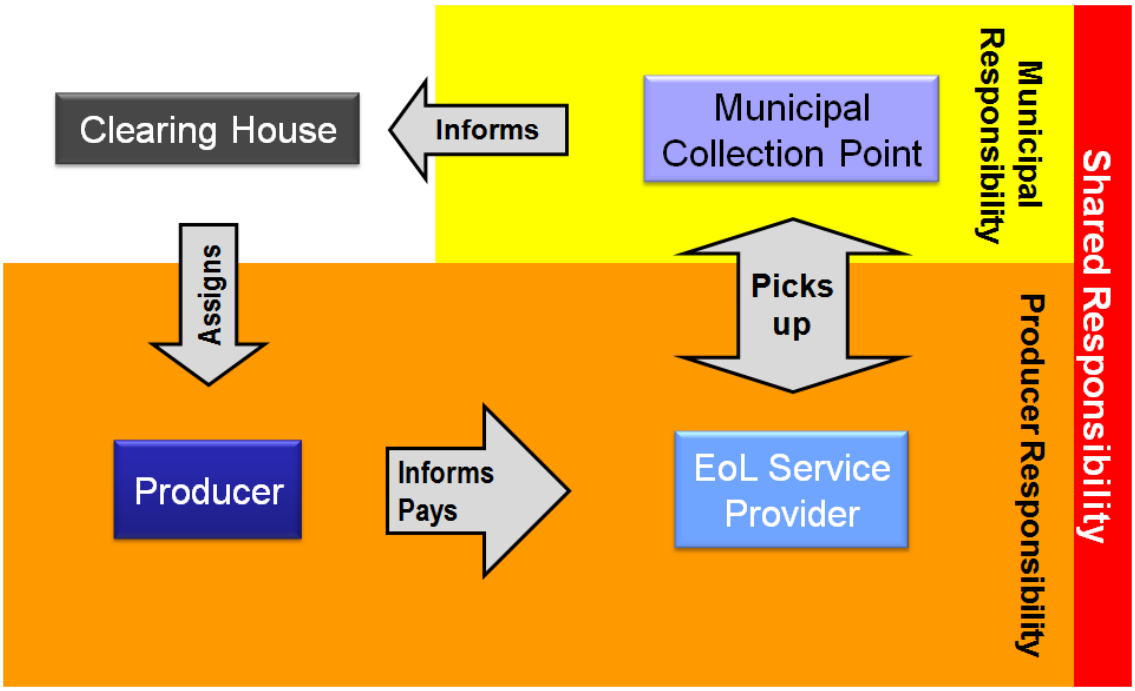


*Figure 14: Interplay of PuWaMA, clearing house, producers and EoL service providers* [26]

The EAR assigns the container to an individual producer of this collection group. The producer informs the ESP he has contracted. The ESP picks up the container at the municipal collection point and organizes or conducts the proper treatment and disposal of the e-waste and reports back to the producer that he has picked up and treated the container of e-waste. The producer hands on the information to the clearing house EAR in the frame of his reporting obligations.

[26] Source: Gabriele Markmann-Werner, Ministry of Environment and Climate Protection of Lower Saxonia, Germany; modified

# 4 The German E-waste Management System in Practice

The previous chapter explained the roles and the responsibilities of the key players for e-waste management, and the compliance possibilities the ElektroG offers. This chapter describes how the key players, in particular the producers, make use of their compliance possibilities, and the experiences collected in the years since the establishment of the e-waste management system in August 2006.

## 4.1 Collection and Treatment Performance

### 4.1.1 Amounts of E-Waste Put on the Market, Collected and Treated in Germany

Table 3 shows the amounts of EEE put on the German market in each of the years from 2006 to 2008, and the amounts of e-waste collected and treated. The data originate from the producers. They reflect the amounts collected and treated in the official e-waste management system. No data are available yet for the years 2009 and 2010.

*Table 3: EEE put on market in Germany, and collection and treatment of e-waste (BMU 2011)*

| | Put on Market | Collected | | | Treated | | |
|---|---|---|---|---|---|---|---|
| Year | Total (t) | B2C (t) | B2B (t) | Total (t) | In Germany (t) | In other EU (t) | Total (t) |
| 2006 | 1,836,912 | 709,785 | 44,113 | 753,900 | 722,865 | 19,055 | 741,920 |
| 2007 | 1,612,228 | 517,469 | 69,498 | 586,967 | 573,080 | 7,468 | 580,548 |
| 2008 | 1,883,545 | 642,287 | 51,488 | 693,775 | 678,346 | 6,640 | 684,986 |

In average, less than 10 % of e-waste collected is reported to be from other sources than private households, meaning B2B equipment. A small portion of e-waste accounting for around 1 % in average is reported to be treated in other EU member states. (BMU 2011) does not indicate the amounts of e-waste exported to countries outside the EU.

Figure 15 illustrates the amounts of EEE put on the market (PoM) in Germany, and the amounts of e-waste collected and treated from 2006 to 2008.

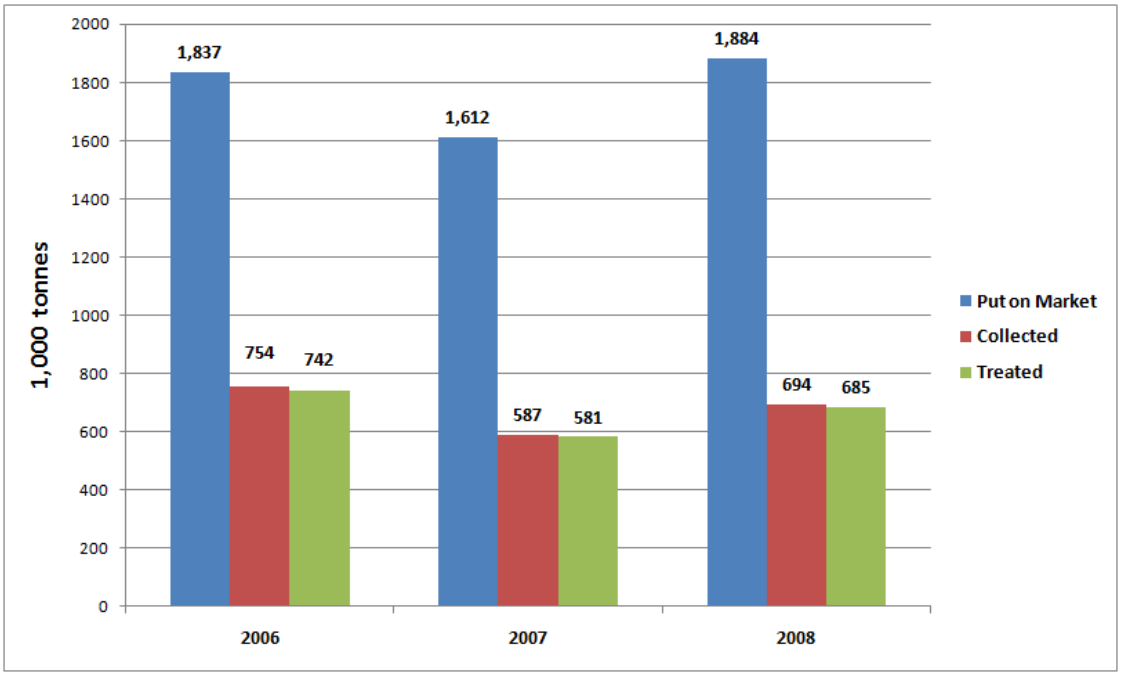


*Figure 15: EEE put on market, and e-waste reported as collected and treated in Germany (based on BMU 2011)*

At least 1.6 million tonnes of EEE in the categories 1 to 10 are put on the German market every year. Exact data for the amounts of e-waste arising are not available. The German market, however, has been saturated for almost all categories of EEE for years already. Despite of a general growth of EEE consumption of around 2.5 % to 2.7 % (Huisman 2007), it can be assumed that a high share of EEE put on the market is purchased to replace old EEE. For such saturated markets, PoM both in terms of total amounts as well as for the shares of the different categories can hence give a gross indication for e-waste arising.

Based on this assumption, only around 37 % to 41 % of e-waste arising in Germany is collected by the official e-waste management system. (Huisman 2007) forecast the annual amounts of e-waste arising in Germany from 2006 to 2008 with around 1.5 million tonnes per year, which would mean that around 40 % to 50 % of e-waste arising was collected and treated separately. Figure 15 indicates that almost all e-waste collected separately is treated in the official e-waste management system.

Little is known about the rest of around 750,000 tonnes to 1,000,000 tonnes, which does not appear in the official e-waste management system. Part of it is exported to developing countries. (Sander 2010) quantifies up to 216,000 tonnes of such e-waste exports every year (see section 4.4 on page 68). A certain share of it may be refurbished and reused, or may undergo treatment in Germany, but outside the official e-waste management system, such as possibly in plants processing used vehicles. No data are available about the quantities and the quality of such treatment. Private households also store used EEE, in particular smaller devices such as mobile phones. This effect could not be quantified either.

Figure 16 shows the share of the 10 categories of EEE in PoM and in the e-waste collected in each of the years from 2006 to 2008. In all three years, large household equipment, consumer electronics and ICT form the major amounts both in PoM and in collection, followed by small household equipment.

These four categories account for around 80 % of EEE in PoM. In collection, their share is at least 90 %. Generally, the share in PoM is in the same range like the share of collection for these four categories of EEE. The same applies to automatic dispensers, which is mostly large, bulky B2B equipment. An exemption is the share of big household appliances collected in 2006. According to Figure 15 on page 53, the highest amount of e-waste was collected in that year, even though consumers in Germany could only hand in e-waste free of charge since March 2006. Figure 16 reveals that the collection of big household appliances was around 50 % higher than in the following years, while PoM for big household appliances is similar to the next years. There is no clear explanation for this phenomenon.

The other categories of EEE account for around 20 % of PoM, and for around 10 % in collection. Unlike for the above categories, PoM and collection differ greatly. This effect is most striking for luminaries, where the collection is less than 10 % of PoM. Most of the equipment in EEE categories 5 to 9 is smaller equipment, or is equipment, such as toys, which consumers may not perceive as e-waste. Due to the small size, consumers dispose of such smaller equipment with household waste resulting in low collection rates for these categories of equipment, an effect which (Huisman 2007) had already described. Part of such equipment may also be stored in the households. Data on this are not available.

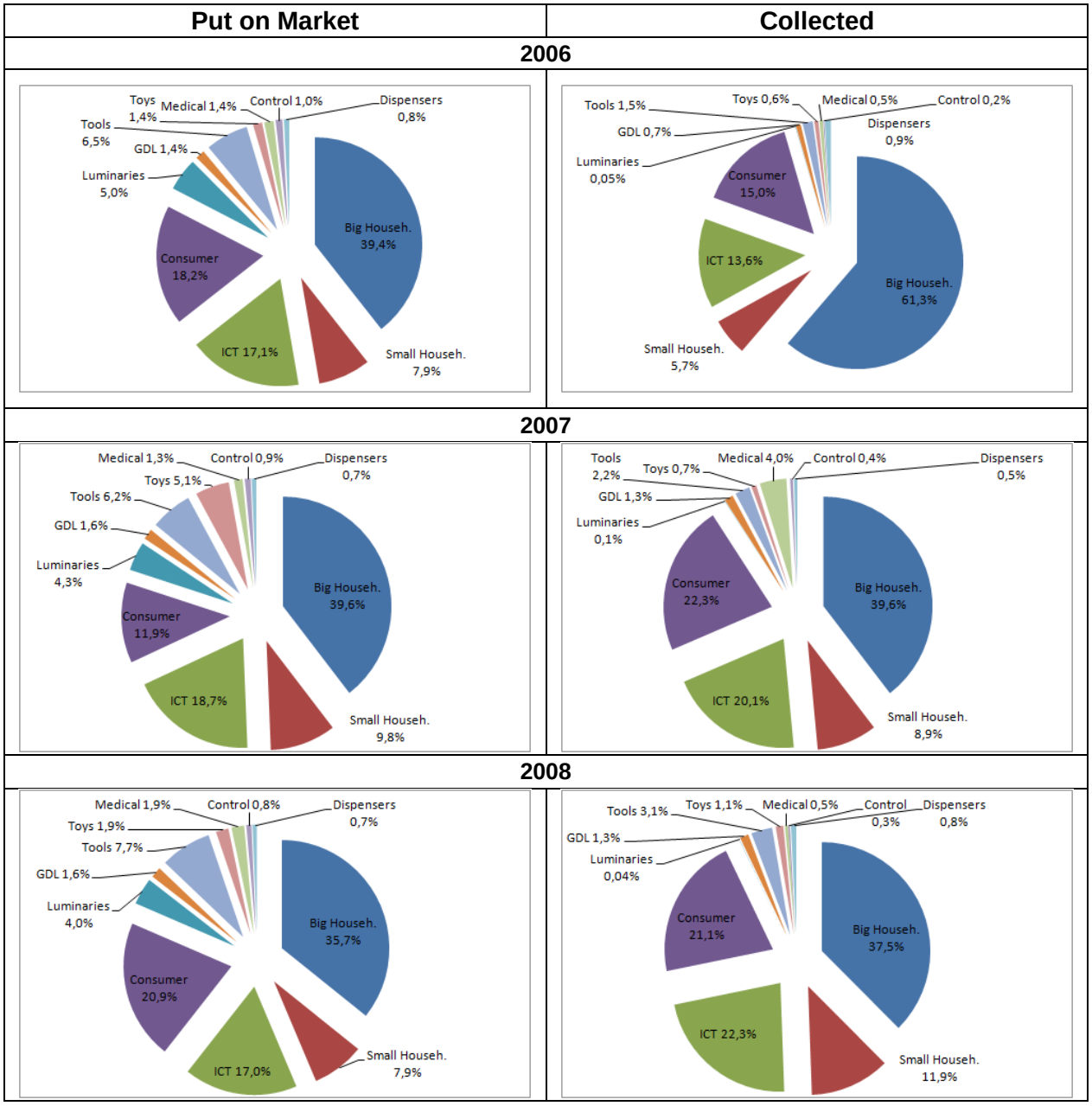


*Figure 16: Categories of EEE put on the German market and collected from 2006 to 2008*[27]

*ICT Information and Communication Technology*
*GDL Gas Discharge Lamps*

[27] Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit: Elektro-und Elektronikgeräte in Deutschland, http://www.bmu.de/files/pdfs/allgemein/application/pdf/daten_elektrogeraete_2007_2008_bf.pdf; last accessed 22 May 2011

As the data only cover three years, further conclusions on trends for PoM and collection are not yet possible.

### 4.1.2 Achievement of the Collection and Treatment Targets

Figure 17 depicts the amounts of EEE put on the market and collected per inhabitant and year. The figures comprise both B2B and B2C equipment.

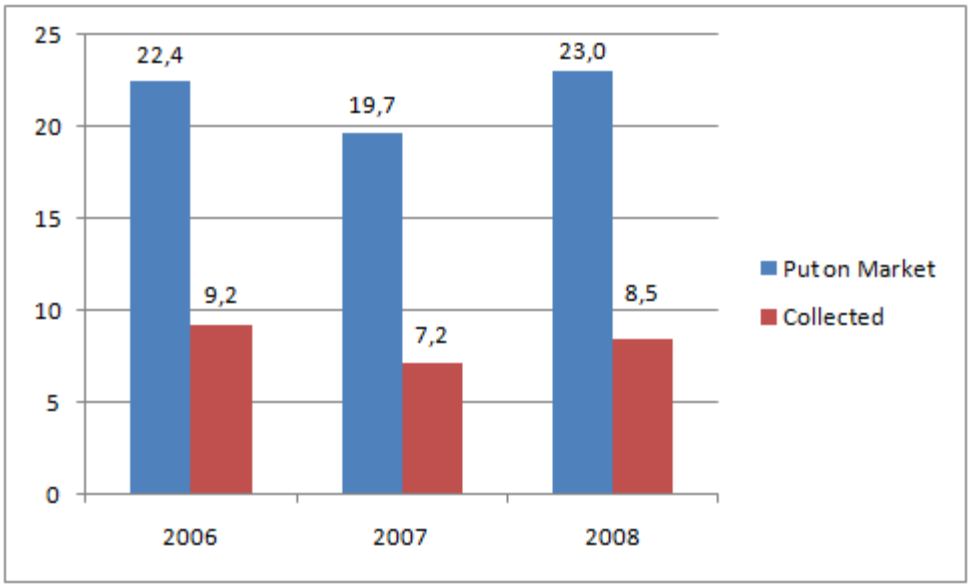


*Figure 17: EEE put on the German market and collected in kg per inhabitant and year* [28] [29]

The collection rate ranging between around 7 kg and 9 kg, there is still considerable potential for improvement considering PoM being well above 19 kg.

The WEEE Directive sets a minimum target of 4 kg per inhabitant and year for the collection of e-waste from private households. The ElektroG has adopted this

[28] Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit: Elektro-und Elektronikgeräte in Deutschland, http://www.bmu.de/files/pdfs/allgemein/application/pdf/daten_elektrogeraete_2007_2008_bf.pdf; last accessed 22 May 2011

[29] Statistisches Bundesamt Deutschland: http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/EN/Content/Statistics/Bevoelkerung/Aktuell,templateId=renderPrint.psml; last accessed 29 May 2011

minimum target. As the collection rates in Figure 17 above in PoM and collection comprises B2B equipment, Table 4 shows the rate for collection from private households only.

*Table 4: Collection rate for e-waste from private households*

| Year | 2006 | 2007 | 2008 |
|---|---|---|---|
| **Collection rate from private households in kg per inhabitant and year** | 8.7 | 6.3 | 7.8 |

Germany clearly exceeds the minimum collection rate of 4 kg per year and inhabitant. Figure 18 gives an overview on the 2008 collection rates in European countries.

Germany ranges in the middle field, but way behind the Scandinavian countries. Some EU member states do not achieve the minimum collection rate of four kilograms per inhabitant and year. It is, however, fair to state that in particular the new EU member states in Eastern Europe in the past had and generally still have lower amounts of EEE put on the market. The e-waste arising in these countries is thus lower, and collecting the minimum four kilograms of e-waste therefore a higher requirement compared to the Western EU member states. A collection target based on a percentage of EEE put on the market is discussed for the recast WEEE Directive, among other reasons in order to take into account these differences between the member states (see section 2.3.7 on page 33).

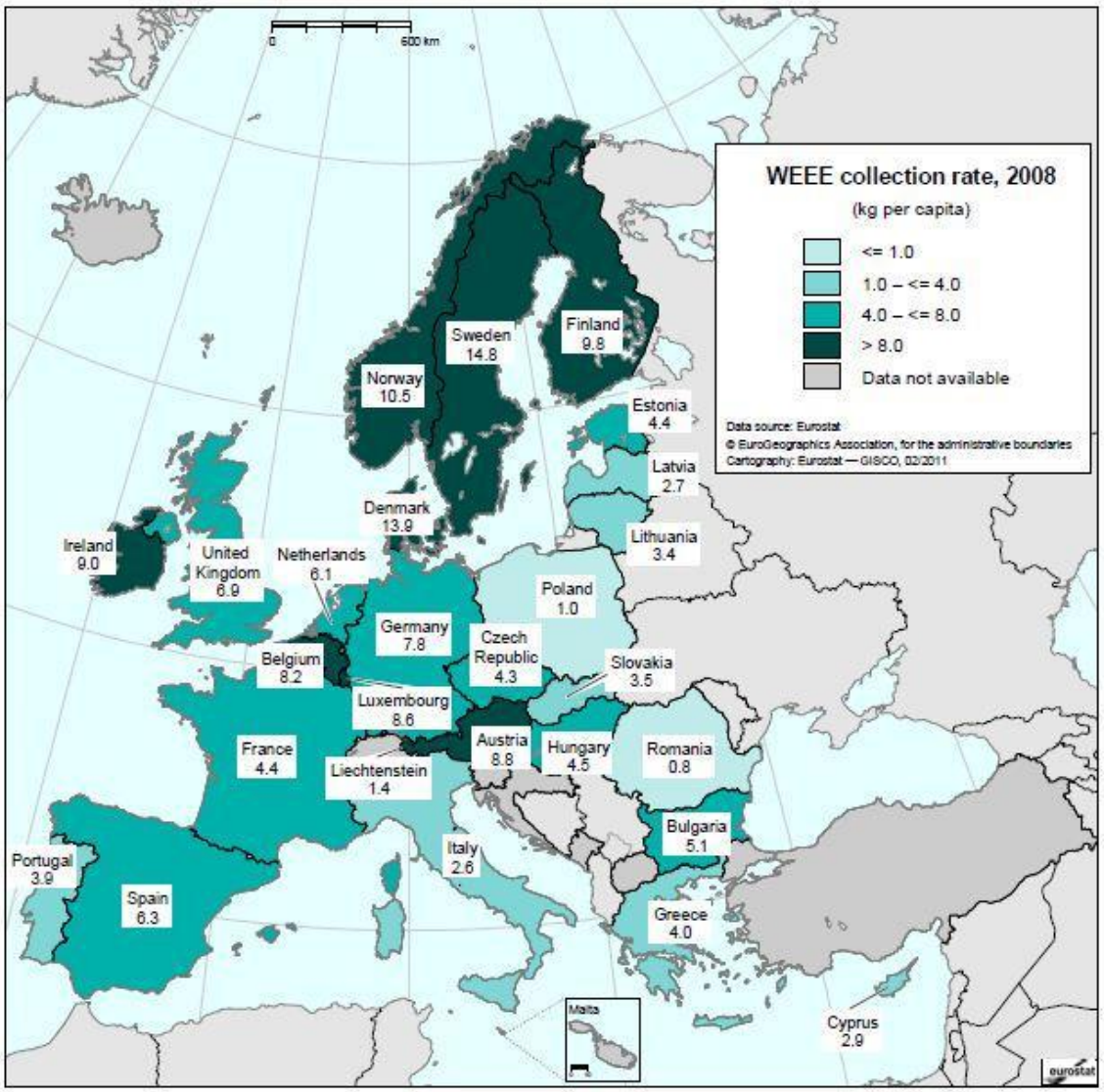


*Figure 18: Collection rates of e-waste from private households in Europe in 2008* [30]

Besides the minimum collection rate, the WEEE Directive stipulates minimum rates for recovery and recycling (see Figure 6 on page 31) of the separately collected e-waste. The ElektroG has adopted these minimum rates. Table 5 displays the recovery and recycling rates achieved in Germany for e-waste sent to treatment in 2008.

[30] Eurostat: http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/wastestreams/weee; last accessed 29 May 2011

*Table 5: Rates for recovery, recycling and reuse of e-waste in Germany in 2008 (BMU 2011)*

| Product Category | | Recovery Rate Achieved | Minimum Recovery Rate | Recycling Rate Achieved | Minimum Recycling Rate | Reuse of Entire Appliances (in % of B2B and B2C collected) |
|---|---|---|---|---|---|---|
| 1 | Big Household Appliances | 94 % | 80 % | 85 % | 75 % | 0.7 % |
| 2 | Small Household Appliances | 92 % | 75 % | 73 % | 65 % | 1 % |
| 3 | ICT | 95 % | 75 % | 82 % | 65 % | 3 % |
| 4 | Consumer Electronics | 94 % | 75 % | 80 % | 65 % | 0 % |
| 5 | Luminaries | 96 % | 70 % | 75 % | 50 % | 63 % |
| 5a | Gas Discharge Lamps | 99 % | 80 % | 99 % | 80 % | 0 % |
| 6 | Electrical and Electronic Tools | 94 % | 70 % | 76 % | 50 % | 1 % |
| 7 | Toys, Sports and Leisure Equipment | 93 % | 70 % | 77 % | 50 % | 2 % |
| 8 | Medical Devices | 95 % | 70 % | 81 % | 50 % | 15 % |
| 9 | Monitoring and Control Instruments | 95 % | 70 % | 79 % | 50 % | 4 % |
| 10 | Automatic Dispensers | 96 % | 80 % | 92 % | 75 % | 7 % |

For 2008, the producers in Germany exceeded the minimum recovery and recycling rates for the e-waste collected from private households. According to (BMU 2011), this applies as well for the years 2007 and 2006.

The (WEEE Directive 2003) does not allow counting the reuse of complete devices for the recovery and recycling rates, while the reuse of components is taken into account. In the reuse of complete devices, the rates for luminaries are particularly high. The reason behind could not be clarified, but (BMU 2011) discloses the same trend in the preceding years.

Summing up, Germany exceeds the minimum requirements for collection, recovery and recycling of e-waste. The more than 19 kg per year and inhabitant of EEE put on the German market reveals a large potential for collection rates beyond the current around eight kilogram per year and inhabitant.

### 4.1.3 Quality of Collection

The shared responsibility between the PuWaMA and the producers causes problems on the interface between the PuWaMA and the producers' takeback schemes and influences the quality of collection.

*Pickup Coordination*

In the initial implementation phase of the ElektroG, the pickup of the containers from the municipal collection points did not work very well. In January 2007, the PuWaMa complained that around five percent [31] of pickups from the municipal collection points were delayed. The long information chain from the PuWaMa via the clearing house and the producers to the producers' ESPs (see Figure 14 on page 51) took time to run in. In February 2008, the complaints had decreased to 0.2 % only.

*Damaged and Wrongly Sorted E-waste*

In the initial ElektroG implementation phase, treatment operators complained about containers containing e-waste of other collection groups, e.g. e-waste of collection group 5 in collection group 3 containers. Part of the e-waste was damaged already when it reached the treatment operators. Broken CRT TVs are difficult to treat. Of particular concern are damaged LCD displays and cooling and freezing equipment, as mercury, CFCs and HCFCs may be released into the environment. Figure 19 depicts the rear part of a flat panel display with broken backlights.

Treatment operators stated that with the implementation of the ElektroG, the rates of broken or otherwise damaged equipment increased. Improper handling at the municipal collection points was identified as one reason. E-waste such as old TVs were dropped off or thrown instead of stacking them carefully into the containers. While PuWaMA were responsible for the further treatment of e-waste prior to the implementation of the ElektroG, their accountability now ends with the handover of the containers to the producers. (Kramer 2011) PuWaMA are not paid for the collection and proper storage of the e-waste, and often feel that they do this work for the producers free of charge. The producers on their part have no contracts with the PuWaMA and thus no leverage to force improvements. In any case, the quality problems in collection hamper sound reuse and recycling of e-waste.

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[31] Presseinformation Nr. 19/2008, 3 Jahre ElektroG: http://www.umweltbundesamt.de/uba-info-presse/2008/pdf/pd08-019.pdf; last accessed 16 June 2011, in German language only

*Figure 19: Rear part of a flat panel display with broken backlights*[32]

Meanwhile, after more than five years of e-waste management according to the ElektroG, the situation seems to have improved due to intensive contacts and efforts of ESPs and treatment operators with the PuWaMA. (Kramer 2011, Werth 2011) The overall situation, however, seems to be inhomogeneous. Some ESPs consider the problems with the PuWaMA as a marginal remaining problem (Werth 2011), while others report persisting quality issues (Kramer 2011).

[32] Dr. Jaco Huisman, United Nations University

### 4.1.4 Quality of Treatment

#### Control and Certification of Treatment Operators

The (ElektroG 2005) demands an annual certification of facilities, in which primary treatment takes place. The certification shall ensure that the facility is technically suitable to achieve the recovery and recycling targets and that all the data needed to calculate and substantiate recovery rates are documented in a verifiable manner. The certification also validates the treatment operators' method to calculate the recovery and recycling rates.

The audits must be conducted by independent experts sufficing the requirements stipulated in the ElektroG. The maximum validity period of such certificates is 18 months. Facilities that are certified as "Entsorgungsfachbetrieb" (specialized waste management companies) according to (EfbV 1996) are deemed certified if the facility's compliance with the provisions of the ElektroG has been verified and documented in the certification. Such certification requires an annual audit as well.

Plants for the treatment of e-waste may cause emissions and noise. Establishing a waste treatment plant hence requires governmental approval according to German (Immission Control Act). This act sets strict limits for emissions, which are monitored and controlled by the competent authorities.

Treatment operators thus are monitored and controlled in Germany according to the (ElektroG 2005) and (EfbV 1996) as well as the (Immission Control Act) whether they possess the technical and organizational capability and the knowledge for a state-of-the-art environment-friendly treatment of e-waste.

Such controls and audits are valuable to assess operators' principal abilities to achieve certain treatment results. There is, however, no mean to control whether and how far operators' actually make use of their capabilities in day-to-day operations, when no auditor is on site. As in the end, the producers are responsible for the sound treatment of the e-waste, they should monitor their treatment operators as well. Unannounced controls could improve the situation. (Kramer 2011) states that some producers actually check their treatment operators regularly and carefully, while others forego any further monitoring.

There are suspects that some treatment operators may not or not sufficiently comply with the provisions of Annex II of the WEEE Directive such as the removal of components containing hazardous substances and the specific treatment requirements. It would be difficult to prove if a treatment operator shreds entire LCD displays, for example, instead of removing the mercury containing backlights before. Such incompliance would save cost for expensive manual disassembly of the LCD displays, and the small amounts of mercury would evaporate and be diluted in the waste stream.

Despite of all control and certification efforts, suspects remain that the strong competition and producers having little focus on quality may cause some treatment operators to not fully comply with the provisions of the WEEE Directive and the ElektroG. As such incompliance is difficult to prove, unfair competition may drive a downturn competition on quality.

#### Calculation of the Recovery and Recycling Rates

There is no commonly adopted and compulsory method for how to calculate the recovery and recycling rates, neither in Germany nor across the EU. The calculations may be based on flat rates. Most commonly used in Germany according to (Kramer 2011) is the document “Praxishilfe Erstbehandlung nach ElektroG“ (Practical Assistance to Initial Treatment Operators According to ElektroG“) from (Gallenkemper 2008). A hard disk drive, for example, which was treated at a pre-processor and then given into a recycling process, is accounted with 80 % recycling and 20 % of energy recovery resulting in 100 % recovery. This would be independent from the actual performance of the smelter. The data in (Gallenkemper 2008) are combined with actual recovery and recycling performance data. This procedure helps bridging data gaps and is a compromise between practicability and exactness in order to alleviate some of the bureaucratic burden on the treatment operators. In the end, each treatment operator may have his own calculation method. The calculation method is, however, part of the treatment operators’ certification.

## 4.2 Producer Takeback Schemes Operating in Germany

As pointed out in section 3.1.2 on page 38, producers in Germany may set up individual brand-selective (IBTS) or non-selective takeback schemes (INTS) as well as collective takeback schemes (CTS). In practice, producers in Germany prefer individual non-selective takeback systems.

### 4.2.1 Individual Non-selective Takeback Schemes

Individual non-selective takeback schemes are the normal case in Germany. Producers appreciate the freedom of individually choosing their ESPs and treatment

operators and the competition keeping prices low. As producers contract EoL service providers (ESPs) directly, they can define their own quality requirements and have maximum freedom of individually contracting those ESPs that suffice these requirements at best price. Producers can thus directly influence the EoL treatment. As they do the tendering and contracting of ESPs themselves, producers gain deep insight into the generation and composition of the total EoL cost, which maximizes cost control and minimizes the abuse of financial resources. (Bellenberg 2011)

Disadvantageously, each producer working with an INTS has to establish administrative capacity on its own to manage the e-waste he is responsible for. A large German producer of household appliances, for example, established a department with five employees for this task, while collective takeback schemes work a whole country with just five to 25 employees. The German system in this point puts at disadvantage small producers. For them the administrative burden is high compared to the company size, and with the small amounts of EEE they put on the market they cannot achieve economy of scale levels of e-waste enabling good prices for the EoL of this e-waste. (Bellenberg 2011) As collective takeback systems are not common in Germany, they cannot join such a system to reduce their cost.

Moreover, quality controls are complicated for producers working in an INTS. Most treatment operators process e-waste from several producers due to the comparatively small amounts of e-waste from single producers compared to a collective takeback scheme. Checking compliance with the minimum recovery and recycling rates for a single producer thus is a complex task. Producers in Germany do such checks together with other producers of the same e-waste collection group. To protect ESPs and treatment operators' competitive information, the producers contract third party auditors for such controls. (Bellenberg 2011)

INTS thus on the one hand enable producers keeping prices at competitive levels. Producers taking their extended producer responsibilities serious can influence the quality of treatment, and thoroughly monitor their ESPs. On the other hand, INTS are difficult to operate for small enterprises, and put producers in a position to increase cost pressure on ESPs compromising on quality.

As producers working with an INTS take back e-waste of all brands in their collection group, INTS do not set financial incentives for ecodesign.

### 4.2.2 Collective and Individual Brand-Selective Takeback Schemes

The Federal Cartel Authority (FCA) limits the market shares of collective takeback schemes (CTS) operating in Germany. (Bundeskartellamt 2005) The FCA ruling excludes CTS in Germany covering all e-waste of a collection group, or even the complete e-waste arising in Germany.

Currently, besides the many INTS, only one CTS is operating on the German market. It takes back luminaries such as LED and compact fluorescent lamps (energy saving lamps).[33] Nine producers of luminaries are running this CTS. This does not contradict the FCA's rule because there are more producers in the German market who are not members of this CTS. The FCA obviously does not consider this CTS as putting competition at stake. (Bundeskartellamt 2005)

In most other EU member states, large scale collective takeback schemes (CTS) are the normal case, with a single or few CTS only operating in the country. CTS are cost efficient in the sense that they reduce the administrative burden on the single producers, as explained in the previous section. CTS contract ESPs and treatment operators for their members. Compared to INTS, they administrate large amounts of e-waste. Thus, they achieve economy of scale enabling a strong position in negotiations with ESPs or treatment operators. Competition, however, is incomplete, as ESPs and treatment operators have just one or few potential business partners resulting in monopsonies. Producers in such countries do not have much choice either if they do not want to set up individual brand-selective takeback schemes.

For collective takeback schemes, controlling their contractors is less complicated than in the case of the INTS. CTS achieve high volumes of e-waste from various producers, for which compliance can then be declared collectively, not for each individual producer. (Bellenberg 2011) ESPs and treatment operators, however, prefer third party controls as well to maintain the confidentiality of their competitive information.

No individual brand-selective takeback scheme (IBTS) is known to operate in Germany or in any other EU member states. The producer would have to reimburse the PuWaMA for sorting out waste devices of his brands from the general e-waste stream and store it separately. Economy of scale is difficult to achieve resulting in higher cost for treatment. The practicability of IBTS is limited as well. With around 10,000 producers registered in Germany, the PuWaMa cannot provide enough space for the separate storage of containers for IBTS. Alternatively, producers may conduct the collection from private households and distributors, which, however, again would be a cost driver.

Like INTS, CTS do not set financial incentives for ecodesign, as such schemes take back all producers' e-waste in their collection group. IBTS would set such incentives. High cost and practical constraints, however, make IBTS unattractive for producers.

[33] lighcycle: http://www.lightcycle.de/; last accessed 30 May 2011

### 4.2.3 Cost of Logistics and Treatment

Figure 20 provides an overview on the end-of-life cost for the five collection groups of e-waste in Germany.

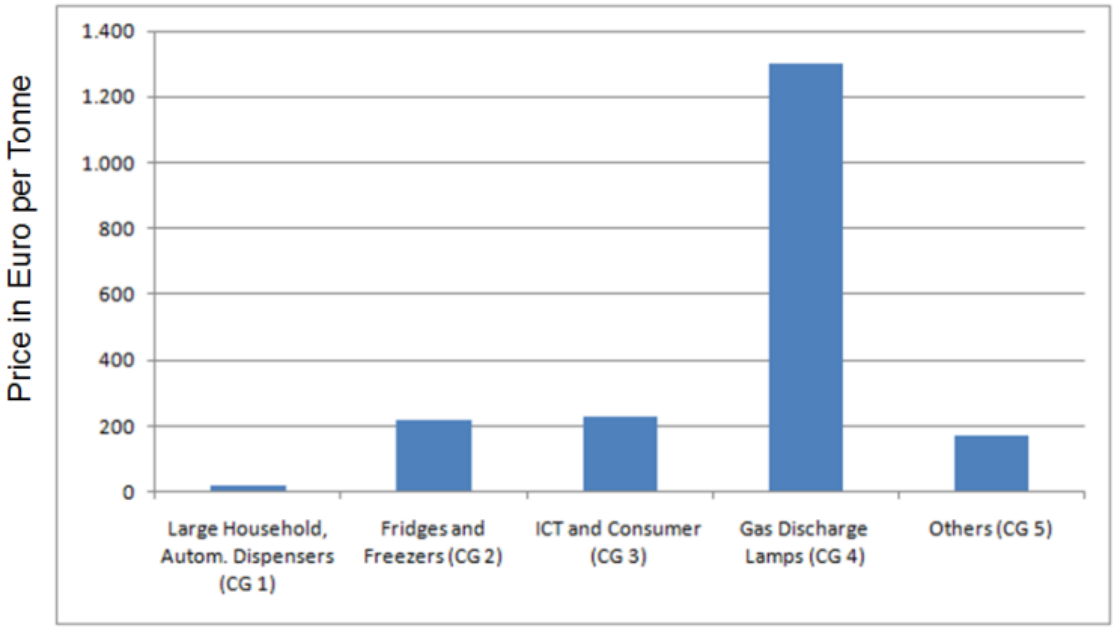


*Figure 20: End-of-life cost of e-waste in Germany (September 2010)*[34]

The prices comprise the logistics, storage and treatment of the e-waste starting from the pickup of the containers at the municipal collection points and hence do not include the PuWaMA's cost for the collection of the e-waste. The prices include the returns from sales of recycled materials and hence depend on the raw material prices. None of the collection groups could be treated with economic profit in September 2010. Prices of e-waste treatment in different EU member states were not available.

[34] Stiftung EAR, http://www.stiftung-ear.de/e47/e129/e1222/e1223/regeln1243/Garantiedaten_ger.pdf, last accessed 15 June 2011;

## 4.3 Achievement of the German Transposition Priorities

The transposition of the (WEEE Directive 2003) into the German ElektroG and its implementation targeted promoting competition, and preventing freeriders and cherry picking. These objectives could mostly be achieved.

*Promoting Competition*

With around 10,000 producers registered and demanding EoL services and a multitude of ESPs offering such services, the aspired complete competition on the German market could be achieved. Unlike in most other EU member states operating just one or few collective takeback systems, producers have freedom to individually organize the takeback of e-waste. Whether and how far this reduces the prices could not be investigated, as data on prices for the EoL of e-waste enabling reliable comparisons are not available for the different EU member states.

*Prevention of Freeriders*

Around 10,000 producers[35] putting EEE on the German market are registered at the clearing house EAR. The Federal Environment Agency (UBA) stringently pursues freeriders. These are producers that are not registered but nevertheless put EEE on the German market. Freeriders thus escape their financial and other obligations related to the EoL of their products. They may be fined with up to 50,000 Euro (ElektroG 2005). Their numbers have clearly decreased since the UBA tightened the controls after the initial implementation phase of the ElektroG. [36] The "Bundesnetzagentur" (Federal Network Agency, FNA) supports the UBA in this task. The FNA, among other tasks, monitors whether EEE put on the German market complies with certain technical product-specific requirements.[37] During these controls, the FNA additionally checks whether the producers of EEE are clearly identifiable and registered.

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[35] Presseinformation Nr. 19/2008, 3 Jahre ElektroG: http://www.umweltbundesamt.de/uba-info-presse/2008/pdf/pd08-019.pdf

[36] Presseinformation Nr. 19/2008, 3 Jahre ElektroG: http://www.umweltbundesamt.de/uba-info-presse/2008/pdf/pd08-019.pdf

[37] Marktaufsicht für elektrische/elektronische Produkte durch die Bundesnetzagentur; http://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/BNetzA/Sachgebiete/Telekommunikation/TechnischeRegulierung/InverkehrbringenGeraeteEMVGFTEG/HinweiseElektronischeProdukteInternetID15065pdf.pdf?__blob=publicationFile; last accessed 6 June 2011 (in German language only)

Besides the authorities, competitors can file a suit against freeriders for damages from unfair competition, which might result in higher fines than the 50,000 Euro foreseen in the ElektroG for non-registration.

*Prevention of Cherry Picking*

The clearing house EAR successfully prevents cherry picking, as each producer must pick up containers from all over Germany, on the country side with high logistics cost as well as in urban areas. The formula the EAR uses to allocate the containers to the individual producers is published [38] and the assignment mechanism hence transparent.

The ElektroG leaves the PuWaMA the option to take over the producers' responsibility for an entire collection group (see "Handover of E-waste to the Producers" on page 38). The PuWaMA make use of this possibility for collection groups yielding an overall economic benefit depending on the raw material prices. Producers hence consider this PuWaMA opting as cherry picking, the PuWaMA as an at least partial compensation for their expenses related to the collection of the e-waste. A more systematic financing of the collection, for example based on a fee paid at the point of sale, could compensate the PuWaMA without opting, prevent cherry picking and at the same time provide incentives for more and better collection. Details on this proposal are presented in section 4.5.1 on page 70.

## 4.4 Transboundary Shipments of E-Waste out of the EU

As was shown in the previous chapters, a big share of e-waste, probably around 50 % of the e-waste arising, never enter the official e-waste management system. There are no clear indications on the whereabouts of this equipment. Part of it is exported to countries outside the EU. (Espejo 2011) describes the informal sector in Germany consisting, among others, of informal collectors, informal collection points and exporters. Often, persons originating from the countries of imports but living in Germany organize the exports. (Espejo 2011) found that the equipment for export is mainly sourced from corporate consumers. Another source is collection from the streets. Private users put e-waste onto the street if the PuWaMA conduct household collections. The informal collectors wander through the streets prior to the formal

[38] Stiftung EAR: Calculation of market shares and container allocation; http://www.stiftung-ear.de/e1767/e1044/e2235/051123Berechnungsweise_ger.pdf; last accessed 13 March 2011; available in German language only

collectors and pick up the equipment. Informal collectors may also collect used EEE directly from private users, sometimes even offering money for it. (Espejo 2011) No clear evidence could be found that relevant amounts of e-waste leak out of the official sector into the informal sector. Neither the corporate consumers nor the receiving organizations, nor, of course, the informal collectors are obliged to inform the clearing house EAR about the amounts, which explains at least parts of the data gap. A big part of the e-waste arising in Germany thus never enters the formal, official e-waste management system.

(Sander 2010) indicates around 155,000 tonnes of e-waste exports out of Germany every year, ranging from 93,000 tonnes to 216,000 tonnes. The main types of exported equipment were monitors, TVs, cooling and freezing equipment, computers and small electronic devices such as toasters, mixers and shavers. The figures have, however, high uncertainties. The main destinations of these exports are developing countries like Nigeria, Ghana, China, India and Vietnam.

Transboundary movement of e-waste to developing countries and countries with economies in transition is a phenomenon that can be observed in all developed countries. The EU has implemented the Basel Convention in its legislation and hence bans exports of e-waste to developing countries. The driver behind the exports is the reuse value of such equipment in the receiving countries. In Germany, a mobile phone has a material value of around one Euro, and for CRT TVs, sound treatment costs more than the sales of the recycled materials can compensate. (Odeyingbo 2011) quantifies the price of untested mobile phones with five Euro at least in Nigeria, that of TV sets with around 17 to 35 Euros. The equipment is shipped in containers, or exported with used vehicles, which are loaded with used electrical and electronic equipment. (Odeyingbo 2011) calculated that importers into Nigeria can make profits of several thousand Euros per container. The situation is similar for other imports into other developing countries.

(Espejo 2011) states that the controls at the ports are minimum. Additionally, the exported equipment is labelled as EEE for reuse. While the export of e-waste is illegal according to the Basel Convention, transboundary shipments of used EEE for reuse are legal. Functional equipment is, however, difficult to differentiate from non-functional e-waste in the ports. Even if the containers get controlled and non-functional equipment is detected in a container, generally there is no prosecution of the exporters. The exporter has to take back the container on his cost, and then may try again later at the same or another port. (Espejo 2010)

While a big share of the exported equipment is actually reused, the serious environmental and health impacts in developing countries start with the recycling and dumping of e-waste when the equipment has no reuse value left. (Odeyingbo 2011, StEP-Initiative)

## 4.5 Measures and Incentives for Improvements

The current e-waste management system in Germany and in the other EU member states does not provide incentives for compliance and improvements. Higher collection rates and better quality collection increase the cost for the PuWaMA as well as for the producers, who must finance the transport and the treatment of the separately collected e-waste.

Nevertheless, the current e-waste management system requires improvements. Higher collection rates and better quality collection as well as more transparency in the treatment of e-waste are, among others, urgent tasks.

### 4.5.1 Increased and Better Quality Collection

#### Increase of Collection Rates

Currently only around 50 % of e-waste arising is collected separately and treated in the official e-waste management system. Treatment collected outside the official e-waste management system is not likely to undergo a state-of-the-art treatment. Additionally, most e-waste exported from Germany to developing countries never enters the official e-waste management system. Achieving higher collection rates hence is an important target, in particular important for e-waste, which may cause pollution or resource losses. Examples are

- cooling and freezing equipment, where emissions of CFCs and HCFCs contribute to global warming and depletion of the stratospheric ozone layer.
- all e-waste containing high amounts of precious metals, such as computers and mobile phones.

All proposals for the recast WEEE Directive listed in the (Legislative Observatory) target collection rates that for most EU member states would be higher than the current four kilograms per inhabitant and year, as described in section 2.3.7 on page 33. Measures to achieve these targets could be:

- Increase proximity of collection facilities to consumers
  Collect smaller e-waste, which consumers currently dispose of with household waste, together with other waste directly from private households provided the e-waste can be separated in a later stage for the further treatment. Approaches like the “Wertstofftonne” and “Gelbe Tonne Plus” (see section

"Separation of Wastes in and at Private Households" on page 19) collecting small e-waste together directly at the households may be viable approaches, even though there are concerns about this concept as well. [39] (Bünemann 2011)

- Make takeback of e-waste obligatory for retailers and shops selling EEE.
- Require collectors to conduct periodical household collections of e-waste, e.g. once a year. It must be taken into account, however, that such collections are a main source for used electronic and electrical equipment exported to developing countries. (Espejo 2011)
- Collectors, either PuWaMA or takeback schemes, could be required to offer a "one stop service" for retailers to lower the bar for them to give e-waste to the official system. The retailer just calls the collection service provider, who takes care of everything else.
- The PuWaMA in Germany should put more emphasis on awareness rising of consumers.

## Financial Incentives

The (European Parliament 2010) proposed levying a charge at the point of sale to improve collection. The levy shall be used for financing awareness raising campaigns for consumers to increase the amounts of e-waste collected. Additionally, the funds shall be used to remunerate the PuWaMA to incentivize higher quality collection. A remuneration model as shown in Figure 21 could provide even stronger incentives.

The reimbursement of collectors could follow a progressive tariff. The tariff paid per kilogram of e-waste collected increases with the total amount of e-waste collected and handed over to the foreseen downstream operator (tariff A in Figure 21).

The progression of the tariff could also take into account the environmental priorities. For e-waste containing hazardous materials or valuable resources, the progression could start from a higher level, and it could additionally be steeper triggering more collection efforts (tariff C in Figure 21).

The quality of the e-waste collection could be taken into consideration as well, in particular for environmentally sensitive products. Damaged e-waste, in particular of e-waste such as LCD flat panel displays, compact fluorescent lamps, fridges and

[39] Bundesverband Sekundärrohstoffe und Entsorgung e. V., http://www.bvse.de/11/4609/Kein_Elektronikschrott_in_die_Wertstofftonne; last accessed 16 June 2011, in German language only

cooling equipment containing HCFCs and CFCs, could result in a reduction of reimbursements (tariff B in Figure 21).

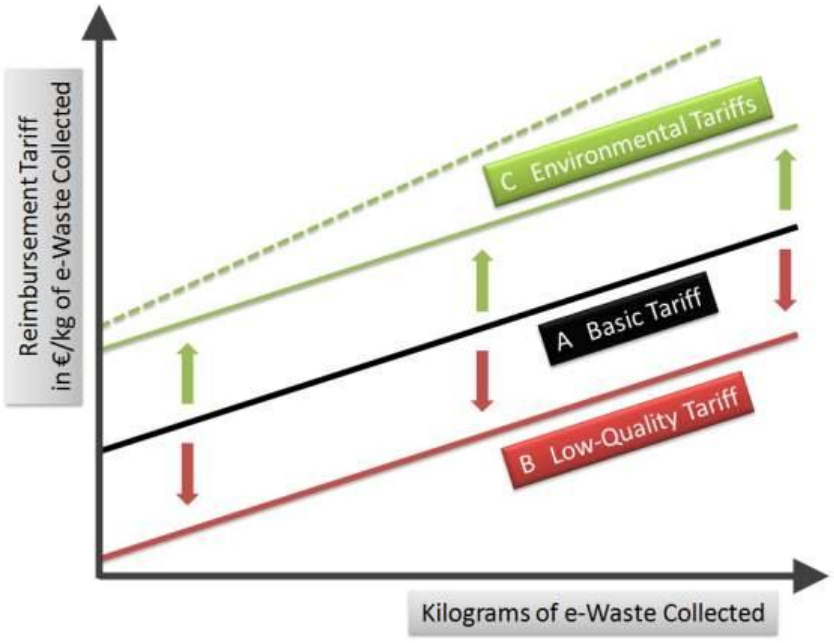


*Figure 21: Reimbursement model providing collection incentives*

After an evaluation of administrative costs and other drawbacks as well as of environmental and other benefits of such a reimbursement model, the above proposals may become part of standards for the collection of e-waste.

### 4.5.2 High Quality Treatment of E-waste

*Quality Standards*

Quality standards for the treatment of e-waste are considered as a mean to improve the treatment quality and to create market transparency on quality. Such standards aim at operationalizing legal requirements in order to make the operators' compliance checkable. Examples are mass balances of treatment plants. If the average content of mercury in e-waste going into a treatment plant is assessed over a certain period, it can be compared with the amounts of mercury the plant forwards to other operators for further treatment. This should enable at least a plausibility check. Quality standards are already available, such as (R2 2008) and (e-Stewards 2009). A further standard particularly for Europe, (WEEELABEX 2011), has just been published. As documentation of all activities is a key to compliance, the additional administrative burden on operators is a clear disadvantage.

Comprehensive improvements require, however, standardizing the entire end-of-life chain of EEE. Equipment, which is already broken when it arrives at pre-processing, can no longer be treated adequately. (Deubzer 2010) The (European Parliament 2011) has demanded the Commission to initiate the development of such standards for the EU.

### *Financial Incentives for Ecodesign*

The e-waste management system in Germany exceeds the minimum collection as well as the minimum recovery and recycling targets stipulated in the WEEE Directive and the ElektroG. The original idea to establish extended producer responsibility as an incentive for better ecodesign, however, could not be achieved, neither in Germany nor in the other EU member states. The producers' INTS and CTS operating in Germany collect e-waste from all brands (Figure 9 on page 41). Producers investing in ecodesign do not benefit more from these efforts than their competitors in the same collection group do. Producers still prefer INTS and CTS rather than bearing the higher cost of an IBTS, not to mention that with around 10,000 producers registered in Germany, IBTS cannot be implemented for all producers due to space constraints in the infrastructure.

The (European Parliament 2010) demands EEE to be tested on appropriate design for EoL, and well-designed EEE to receive a price reduction at end-of-life. This shall apply even if the producer is organized in a CTS. This approach would interfere with price setting in the producer takeback schemes. It is not clear whether the proposal will be adopted in the recast WEEE Directive. It would need a thorough assessment whether it is practical and effective to set incentives for ecodesign under the implementation conditions in the different EU member states.

### *Harmonized Calculation of Recovery and Recycling Rates*

As described in the section "Calculation of the Recovery and Recycling Rates" on page 63, the calculation of the recovery and recycling rates in Germany, and in between the EU member states is not harmonized. These treatment performance rates hence do not necessarily reflect the actual performance. The WEEE Directive obliges all EU member states to report their treatment performance data to the Commission. The data are published in one document[40], even though they are based on different calculation methods. There is hence urgent need to harmonize the calculation of the recovery and recycling rates across the EU. Comparable treatment performances could stimulate competition for better treatment in between treatment operators and in between member states.

[40] Eurostat: WEEE – Key statistics and data: http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/wastestreams/weee; last accessed 24 June 2011

# 5 Technical, Economical and Ecological Principles of E-waste Treatment

The basic objectives of e-waste treatment are the prevention of pollution and the recycling of resources.

## 5.1 Basic Objectives of E-waste Treatment

### 5.1.1 Pollution Prevention

E-waste may contain hazardous substances. The treatment of e-waste targets preventing these substances from being released into the environment.

Some of the substances can be recycled along with the other materials from e-waste. They remain within the technosphere for further use where they can be controlled and are not released into the environment. Examples for such hazardous substances are heavy metals like lead and cadmium. Other substances in e-waste, such as HCFCs and CFCs in older cooling and freezing equipment and PCB contained in certain capacitors, cannot be recycled. They must be removed from the e-waste material flow and be incinerated in order to prevent pollution.

Hazardous components, preparations and substances can be removed

- in an initial treatment step, prior to further processing like shredding and mechanical separation (initial removal), for instance by disassembly of the e-waste device and manual removal,

  or

- during or after subsequent processes (process-integrated removal).

The removal prior to any further treatment is indispensable if at least one of the following conditions applies:

1. Hazardous substances or components cannot be controlled in subsequent treatment processes and therefore may be released into the environment during the treatment processes or from the resulting fractions or materials.

2. These substances or components otherwise disturb treatment processes of e-waste, fractions or materials thereof in operations of the initial or downstream operators thus seriously compromising the quality of the recycled materials.

3. These substances or components otherwise end up in incineration or on landfill sites, which are not equipped to accept them.

4. These substances or components otherwise end up in incineration or on landfill sites, even though recycling would be the environmentally better option.

The initial removal of such substances and components from e-waste is dispensable if

1. they can be controlled, isolated and removed safely and to a sufficient degree during or after the recovery and recycling operations,

   and

2. if these removed hazardous substances subsequently can be treated, incinerated or disposed of in a way that allows treatment preventing pollution to a degree comparable to the prior separation of these substances from e-waste.

Annex II of the (WEEE Directive 2003) stipulates requirements for the removal of certain hazardous components and substances from e-waste.

### 5.1.2 Recycling

The principle objective of all recycling activities is generating materials from waste products in a quality, which is as close as possible to the status of primary materials. Such secondary materials can be reused at a high reapplication level replacing valuable primary raw materials and hence have a higher ecological value compared to downcycled secondary materials. As products generally consist of more than one substance or material, the separation of the materials and substances in products into

different fractions, from which they can be recycled, is a key step in all recycling activities. For e-waste, this separation is a particularly difficult task due to its complex composition.[41]

## 5.2 Treatment of E-waste

The following sections will give an overview on the treatment of e-waste in Germany. Useful additional technical information can be found in (VDI 2343).

### 5.2.1 Overview on the Treatment

Figure 22 gives an overview on e-waste treatment in Europe comprising preprocessing and material recycling.

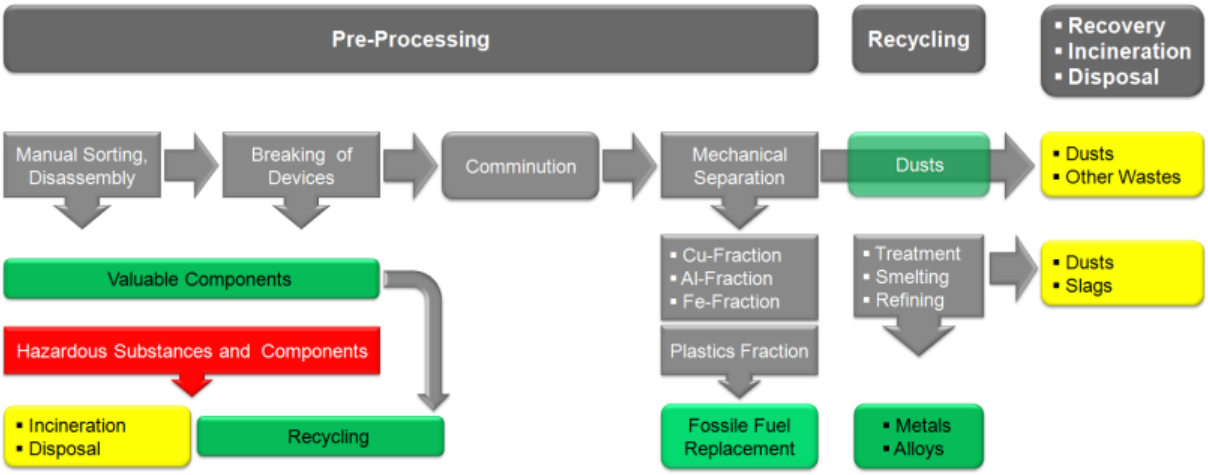


*Figure 22: Overview on e-waste treatment*

[41] StEP-Initiative: What is e-waste, http://www.step-initiative.org/initiative/what-is-e-waste.php; last accessed 20 June 2011

The outline shows the principles, which treatment operators will adapt and modify depending on the types of e-waste they treat, their process technology and their knowhow. Figure 25 on page 82 shows an example of such a pre-treatment process.

### Removal of Hazardous Components and Substances

Depending on the composition of the collected e-waste, preprocessing may start with the manual sorting of the e-waste. Collection group 3, for example, comprises devices of ICT and consumer electronics resulting in an inhomogeneous mix of e-waste. For some of these devices, Annex II of the (WEEE Directive 2003) stipulates specific treatment and the removal of hazardous substances. Examples in collection group 3 are CRT TVs and flat panel displays containing backlights with mercury, and batteries. Such devices must be sorted out from collection group 3 e-waste prior to further treatment steps. Otherwise the hazardous substances cannot be controlled and may be released into the environment. Substances and components removed from e-waste are forwarded to specific treatment, where they may be

- recycled, e.g. mercury and batteries
- incinerated, like the capacitors containing PCB,
- disposed of on special landfills, like phosphorous layers removed from CRT TVs.

Next to hazardous components, bulky and strong parts may disturb the shredding and mechanical separation process, or even damage the process equipment. Examples are compressors from air conditions and from cooling and freezing equipment. The cooling liquids are removed, and the compressors treated separately.

### Separate Treatment of Valuable Parts

E-waste devices such as computers and mobile phones may contain printed wiring boards and other components, which are rich in precious metals. Figure 23 shows an example composition for a high grade printed wiring board in comparison to a low grade one. Equipment with such high grade printed wiring boards may be sorted out and disassembled. The printed wiring boards are then sent to separate treatment to improve the recycling result (see chapter 5.2.3 on page 81).

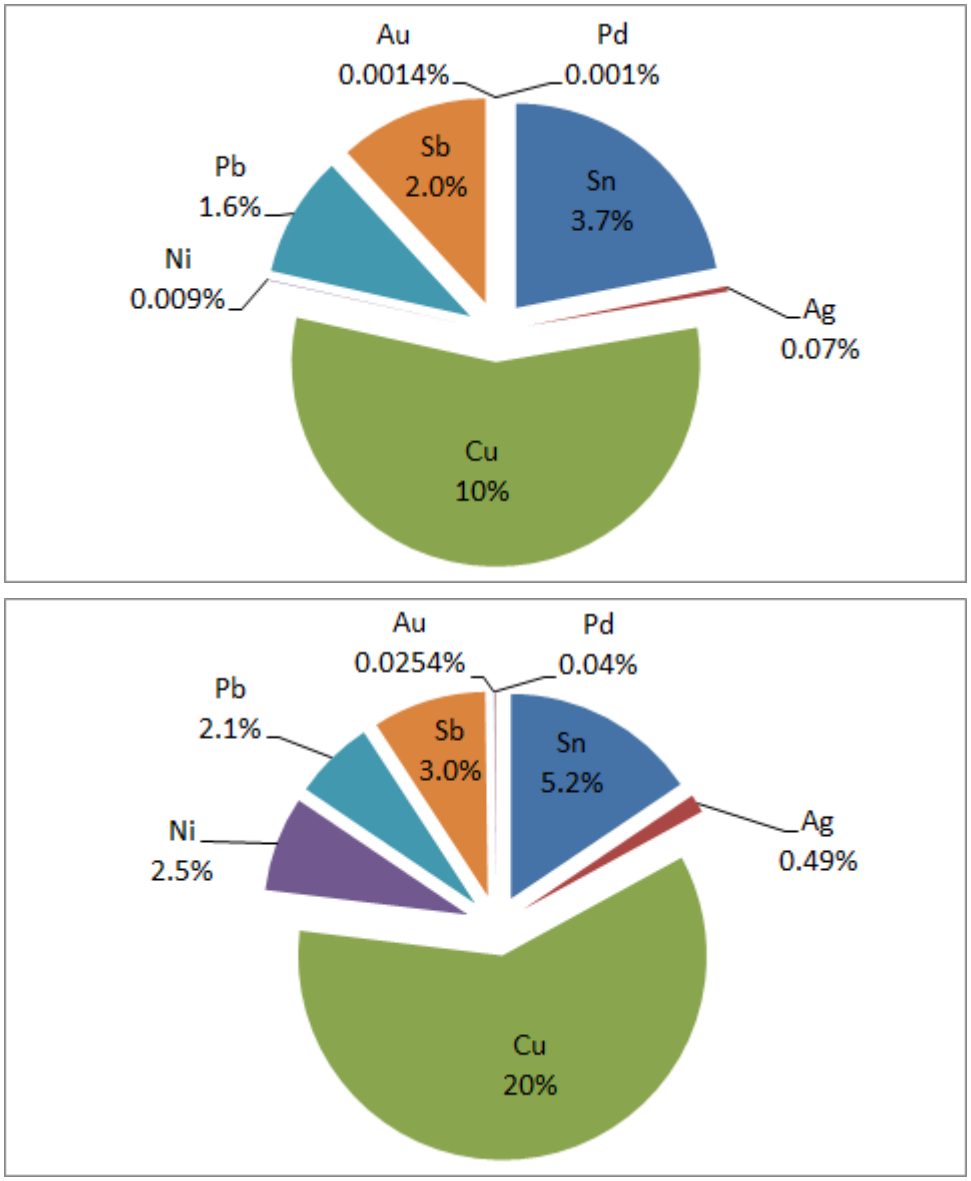


*Figure 23: Example of shares of different metals in a low grade (top) and a high grade printed wiring board; percentages missing to 100 %: epoxy resin, glass fibres, plastics and other metals (Deubzer 2007)*

Big parts consisting of homogeneous materials like plastic casings of TVs may be removed as well. The removal prevents downcycling. These removed parts can be processed back to materials whose quality is close to or the same as primary materials.

The removal of such parts may either be done manually directly from the e-waste, or after a mechanical process that opens up the e-waste devices without breaking the different components. Batteries, PWBs and big homogeneous material parts are then easier to access.

### Comminution and Mechanical Separation

The comminution of the e-waste is the introductory step for the subsequent mechanical separation. Shredding is the most common comminution process. The mechanical separation generates four fractions:

- aluminum fraction
- copper fraction
- iron fraction
- plastics fraction

The three metal fractions are treated further to prepare the recycling of the metals in smelters, or go directly into the smelters. The most important fraction is the copper fraction.

Pre-processing as well as in the recycling processes generate dusts mainly from the flue gas filters. The dusts contain metals. Glass from products like washing machines, scanners, copiers and small displays is pulverized during the comminution process. Most of it ends up in the filters together with other dusts, or in the metal fractions. (Kramer 2011) Depending on the metal prices and on the composition of the filter dusts, the metals may be recycled from the dusts. Alternatively, the dusts are disposed of on landfills.

## 5.2.2 Treatment of the Fractions from Pre-processing

### Copper Fraction

The copper fraction is the target fraction for all metals besides iron and aluminum. Copper smelters can recycle a wide range of different metals to a high percentage and in good quality. Figure 24 shows the recycling performance of copper smelters. The data go back to averages of five different European copper smelters including the treatment of filter dusts and other fractions in other smelters, like for example in tin smelters.

Figure 24 shows that copper and the precious metals (PMs) gold, silver, platinum and palladium can be recycled very well from such copper fractions with recycling rates of more than 95 %. For the other metals, the recycling rates decline.

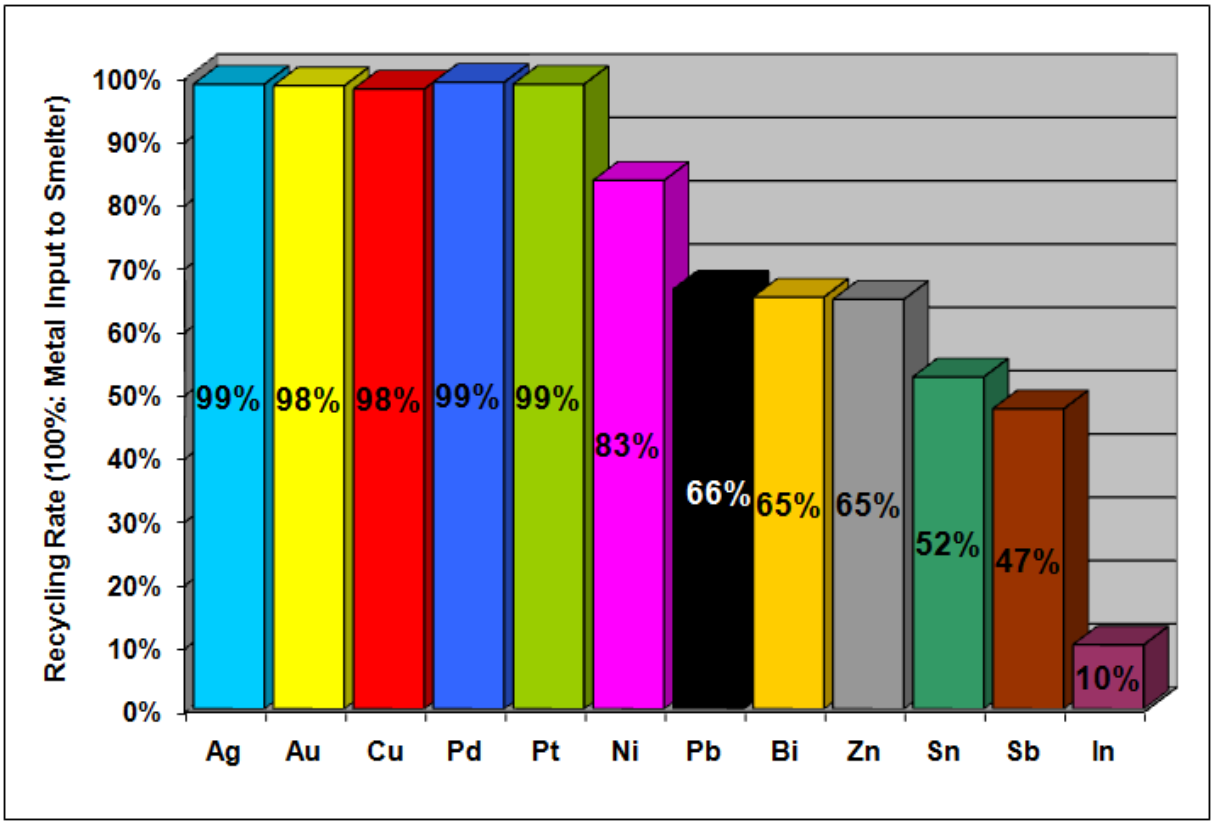


*Figure 24: Recycling rate of metals from e-waste copper fractions (Deubzer 2007)*

Copper and PMs can be recycled to metals with the same purity and quality like primary metals. Nickel is recycled as sulfuric acid, which may be used e.g. in electroplating. Most of the other metals leave the copper smelter as alloys, like for example tin-lead alloys, or as salts, from which the metals can be recycled in further treatment steps at other plants.

The copper fraction contains certain amounts of plastics, iron and aluminum. These metals cannot be recycled in copper smelters, but become slag. The plastics burn up in the smelting processes.

Slag from copper and other smelters are used in road construction, or for backfilling of mines.

### Other Fractions

The plastics fraction contains a mix of different plastics, which in Germany is incinerated for example in cement kilns, where it replaces fossil fuels. The plants must be equipped with a state-of-the-art flue gas cleaning technology, as otherwise dioxins and furans may be generated and emitted into the environment. The plastics fraction contains a certain share of copper, which catalyzes the synthesis of dioxins and furans from such plastics, in particular from those containing brominated flame retardants like the PBDEs and PBBs banned in the (RoHS Directive 2003). Such flame retardants were legally used in EEE put on the market before July 2006. (Wäger 2010) Alternatively, advanced sorting technologies may be used to differentiate the plastics and to improve their recyclability.[42]

The iron fraction and the aluminum fraction may undergo further preparatory treatments before they are finally recycled. Different from the copper fraction, contaminations with other metals such as lead, tin and copper cannot be removed easily and the quality of the recycled materials may be lower than that of primary metals.

Copper, PMs and the other metals in Figure 24 normally are not recycled from the iron, aluminum and plastics fractions.

## 5.2.3 Performance of Pre-processing

Comminution is the preparatory step for the mechanical separation. The e-waste devices are destroyed and disassembled into small pieces. Mechanical separation is a combination of several processes, which separate the materials making use of their Figure 25 shows an example for such a process.

Specific metals can only be recycled from certain fractions. The crucial performance of the shredding and mechanical separation process hence is to direct each of the metals into the fraction, from which it can be recycled, and to separate the plastics from these metals into the plastics fraction. A high share of plastics in the metal fractions may cause thermal problems in the smelters.

[42] Markowski, Jens, BTU Cottbus, Germany: Rückgewinnung von Kunststoffen aus Elektronikschrott, https://www-docs.tu-cottbus.de/aufbereitungstechnik/public/Poster/PosterKunststoffrecycling.pdf; last accessed 25 June 2011, in German language only

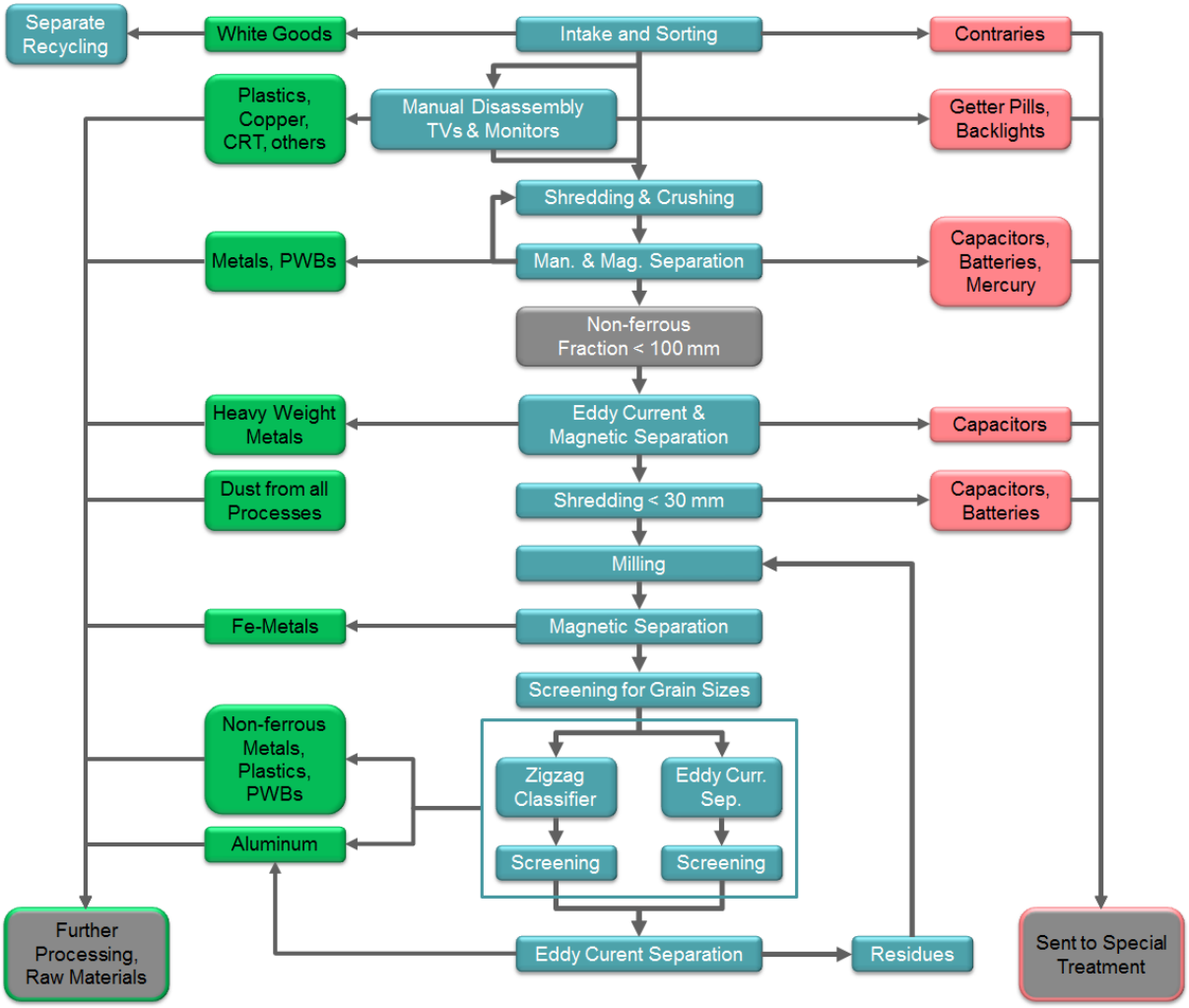


*Figure 25: Example of pre-processing with shredding and mechanical separation (EMPA, Switzerland; modified)*

(Chancerel 2009) assessed the performance of a state-of-the-art e-waste preprocessing plant in Germany for gold, silver, palladium and copper. The plant processed e-waste of collection group 3. Only 26 % of gold and palladium contained in the processed e-waste was found in the copper fraction, and as little as 12 % of silver. The rest was distributed over the other fractions and dusts, from which they are not likely to be recycled. For copper and iron, the effectiveness of the process was much higher. The process succeeded in directing 60 % of the copper to the copper fraction, and around 96 % of iron to the iron fraction. This process and how it is used yields good results for iron and acceptable ones for copper, but obviously is not adequate to treat PM-rich components.

(Shöps 2010) assessed two commercially applied treatments of PCs at a German and an Austrian pre-processor. PM-rich components such as the motherboards, plug-in cards and connectors were removed mechanically or manually prior to the

comminution process (Figure 22 on page 76) and treated directly in the copper smelter. The results in Table 6 illustrate that this treatment greatly improves the recycling performance for the PMs.

*Table 6: Recycling rates for gold, silver and palladium with removal and direct treatment of PM-rich components in copper smelters (Schöps 2010)*

| | Gold | Silver | Palladium |
|---|---|---|---|
| Recycling Rate in % of total content in treated e-waste | 70-80 | 49-75 | 41-66 |

The studies of (Chancerel 2009) and (Schöps 2010) illustrate that pre-processing requires knowledge to adapt the treatment to the treated e-waste. It is not sufficient to install a shredding and mechanical separation process and simply treat all kinds of e-waste with it in the same way. Good pre-processing requires a balanced application of manual labor and state-of-the art mechanical processing for each type of e-waste.

## 5.2.4 Economical and Ecological Implications of Recycling

### Basic Economical Considerations

In a competitive environment, operators will try to minimize their cost and operate their treatment at an overall economic optimum. Beyond the legally stipulated treatments such as the removal of hazardous components, the following considerations are economical cornerstones for deciding about the appropriate treatment:

- Labor cost is high in Germany. Depending on qualification and activity, workers in a pre-processing plant may cost 12 – 22 Euro per hour (Kramer 2011). The entire treatment therefore is highly mechanized and treatment operators reduce manual work as far as possible.

- A mechanical separation process can never achieve a 100 % separation of metals and plastics into their target fractions. Each separation process hence has a separation performance below 100 %. The exact performance is

different for each output material, and additionally depends on the type of process as well as on the composition of the input.

- The direct treatment of PM-rich components in copper smelters avoids the losses of PMs and thus increases the revenues. The components must, however, be separated from the e-waste stream. This requires additional processing and in particular manual labor causing additional cost.

- Iron and aluminum cannot be recycled in copper smelters. The revenues from iron and aluminum decrease, if components are treated directly in copper smelters.

The direct treatment of components in copper smelters hence is economically viable only if the revenues from the avoided PM losses at least compensate the additional labor cost and the losses of revenues from those metals, which cannot be recycled in copper smelters.

The same economical considerations apply to any kind of separation of components and parts such as bigger iron and aluminum parts. The higher revenues from the sales of the removed components must at least compensate the additional cost for the separation to make this operation economically viable.

In all other cases, treatment operators will choose mechanical processing of the entire devices, unless legal compliance requires the removal of substances and components, or if specific components in the e-waste disturb the comminution and mechanical separation. As (Chancerel 2009) showed for iron and copper, a state-of-the-art comminution and mechanical separation process produces good results for e-waste with low contents of PMs.

## Ecological Considerations

The economically driven decisions on the way of treatment affect the ecological balance of the treatment as well. PMs are scarce metals, and they have huge ecological backpacks. Mining and refining of PMs require moving huge volumes of materials and consume immense amounts of energy compared to mass metals like iron and lead, but also in comparison to copper and aluminum.

Separating parts of homogeneous materials like aluminum, iron and copper parts from e-waste prior to comminution avoids material losses and the dilution of the materials in the generated fractions. The higher material purity facilitates reapplying the recycled materials at a higher level similar to that of primary materials.

## Low Labor Cost as Enabling Factor

(Schöps 2010) showed that, compared to the results displayed in Table 6 on page 83, a deeper manual dismantling of PM-rich components may further increase the recycling yield for PMs. Beyond manually dismantling motherboards, plug-in cards and connectors from PCs, additionally hard discs, disc drives and power supply units were dismantled, and the printed circuit boards removed from these devices. The results for the recycling of PMs increased to

- 99 % for palladium,
- 97 % for gold,
- 92 % for silver.

Feng[43] confirms these results for deep manual dismantling in the StEP Best of Two Worlds project.[44]

With labor cost between 12 – 22 Euro per hour, deeper manual dismantling of e-waste is economically not feasible in Germany. Lower labor cost in developing countries and countries with market economies in transition may enable better treatment. Manual labor can replace and complement mechanical treatment. In the end, the effectiveness of each single process in the entire treatment is important for the total overall effectiveness of recycling, and the process with the worst performance decides on the overall recycling rate. In combination with modern technologies for additional mechanical separation, in particular for complex materials with high share of plastics, and with highly effective smelting and refining plants as shown in Figure 24 on page 80, manual disassembly of e-waste may enable economically and ecologically highly effective and efficient treatment of e-waste.

[43] Wang, Feng, et al., United Nations University: StEP Best of two Worlds, not published

[44] StEP Initiative: Best of Two Worlds, http://www.step-initiative.org/projects/project.php?id=72; last accessed 19 June 2011

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