

# **Waste from electrical and electronic equipment (WEEE)**

**- quantities, dangerous substances and treatment methods**

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# Executive summary

Waste from electrical and electronic equipment (WEEE) is one of the priority waste streams of EU policy due to its complex and often hazardous composition and the steadily increasing quantities to be disposed of in the forthcoming years. Several difficulties are encountered for the successful management of WEEE, such as the absence of reliable statistical data of generated WEEE quantities, the inadequate separate collection and treatment of such waste as well as the limited application of recycling/recovery schemes, so that a considerable effort has to be undertaken in order to finally assess the extent of the environmental problem caused and to suggest effective reduction measures.

This report presents in summarised form the scope and main findings of a project (1997-2000) aimed at the development of models and tools for the projection of WEEE amounts, dangerous substances contained in WEEE and the resulting emissions from waste treatment.

## Objective

The objectives of the project were:

- To develop a methodology for estimating potential quantities of WEEE and emissions of dangerous substances from WEEE management.
- To estimate potential quantities for selected appliances of WEEE for 1990-99 and generate projections for 2000-2010.
- To estimate emissions of dangerous substances from waste management of selected appliances of WEEE.
- To give recommendations on reduction of amounts of WEEE and emissions of dangerous substances.

## Methodology

A computerised four-phase model has been developed by the European Topic Centre on Waste as the basis for the necessary analysis to show the emerging trends of WEEE in quantitative (waste quantities) and qualitative (dangerous substances emitted) form. This model forms the framework for the assessment of waste quantities and future trends as well as for the determination of dangerous substances emitted during treatment and disposal.

WEEE quantities are analysed in four phases: phase I (production/sales of electric/electronic equipment (EEE)), phase II (consumption (use) of EEE) and phase III (collection of WEEE), while in phase IV (treatment/disposal of WEEE) the composition of WEEE and emissions of dangerous substances are considered.

Six EEE appliances were selected as 'case studies' for the preparation and testing of the model: refrigerators, personal computers, TV sets, photocopiers, fluorescent tubes and small household appliances. The six types of appliances present different distinguishing features, so that the appliances represent products in already saturated and fast growing markets.

## Conclusions

This report gives a first insight into the complex nature of WEEE generation and management by giving indications of many important issues to be analysed and assessed, in order to achieve an acceptable level of WEEE management in the next years, when the legislative and regulatory level of the forthcoming WEEE directive will form the context and framework to be followed by decision-makers and waste management authorities. The key conclusions of this project are summarised below:

- Data needed to carry out the calculations is rather poor. The absence of reliable data implies that the estimated potentials of future WEEE generation are of limited value and should be used only with great caution.

- A large recycling potential exists, which, if thoroughly explored, can significantly contribute to a reduction in the amounts of dangerous substances emitted as well as the recovery of considerable quantities of valuable materials. This is in line with the proposal for the WEEE directive where targets have been established for recovery and component, material and substance reuse and recycling. The recycling quota (ratio of kg recycled material per average weight of appliance) shows that the EU minimum rate of component, material and substance reuse and recycling in the proposed WEEE directive has been achieved by using the so-called 'state of the art' recycling schemes for all selected appliances except for PCs.
- With respect to the projections, the most interesting factors are trends and tendencies of how each appliance as well as the total potential may develop in the future, as it is considered to be too unreliable to forecast the actual quantities.
- The emission fraction (ratio of kg emitted dangerous substance per 1000 t input of appliance) is calculated for the selected appliances and shows that the lead emissions from recycling of PCs and TVs are the highest in comparison with the other appliances. Main contributors to these emissions are the copper and lead recycling plants. Given the fact that TVs and PCs account for approximately 55 % of the overall WEEE-potential of these appliances, lead emissions from the treatment of TVs and PCs must be considered to be potentially significant.
- To reduce the amount of WEEE and the emissions from the treatment of such waste, focus may be waste management oriented, product oriented and consumer-oriented.

Waste management oriented measures:

- Separate collection of WEEE is the first and very important step to enable appropriate treatment.
- Dismantling and separation at pre-treatment facilities, where removal of parts containing dangerous substances takes place.
- Improvement of recycling technologies.

Product oriented measures:

- The trend towards increased recyclability of products has led to the concept of design for recyclability (DFR) and disassembly (DFD). The product design determines to a large extent how easily a product can be recycled.
- Substitution of dangerous substances, especially brominated flame retardants, Cd, Hg, Pb and PCB must be further supported.

Consumer-oriented measures:

- A new approach to saving raw materials and resources is product leasing or selling service - the so-called eco-efficient services.

# Introduction

This report contains consolidated information about waste from electrical and electronic equipment (WEEE) which is one of the priority waste streams to be managed in Europe in the forthcoming years. The report's objective is to give a first insight into the characteristics of this complex waste stream by providing data and information on quantities arising as well as the emissions of dangerous substances from WEEE treatment and disposal.

After the introductory chapters concerning environmental relevance and legal framework for WEEE at European level, a review of the existing situation concerning data coverage and availability as well as data evaluation and estimation of potential waste quantities has been made. The second part of the report (chapter 6) consists of an analysis of WEEE composition and of the treatment methods applicable for their elimination whereas the final chapter gives a summary of options for the reduction of waste amounts and emissions from WEEE.

During the period 1997-2000, the European Topic Centre on Waste (ETC/W), as part of its work for the European Environment Agency, has included in its activities the analysis and assessment of data concerning WEEE in a step-by-step basis. A four-phase model has been adopted and developed as the basis for this analysis, aiming to show the emerging trends of WEEE in quantitative (waste quantities) and qualitative (dangerous substances emitted) form. The main elements of this model are presented in this report.

# 1. Environmental relevance

The waste from electrical and electronic equipment (WEEE) is one of the priority waste streams of EU policy, since it will probably become one of the major challenges for waste management in the future.

Even if some parts of the electrical and electronic equipment (EEE) market show signs of saturation - e.g. TV sets, refrigerators, washing machines etc. - other parts of the market show clear signs of dynamic growth - e.g. IT-equipment, telecommunication equipment and electronic toys.

The environmental implications as well as the complexity of the subject will be briefly analysed below.

## **Increasing quantities**

It is expected that WEEE quantities will be growing rapidly in the coming years. The amount of WEEE generated in the EU is estimated at 6.5-7.5 million tonnes per year in the late 1990s<sup>1</sup>. In the European Union the waste stream of electrical and electronic equipment constitutes 4 % of municipal waste, increasing by 16-28 % every five years – three times as fast as the growth of average municipal waste<sup>2,3</sup>. Furthermore, it is one of the largest known sources of heavy metals and organic pollutants in municipal waste. However, a detailed calculation of WEEE amounts is almost impossible.

Because of the complex aspects related to product, production and consumption of EEE a detailed calculation of WEEE amounts is almost impossible. In some markets, for example in the market for mobile phones, the present annual increase of mobile phone users of 40-100 % has been predicted to last until 2002. After this the market will be saturated, with proposed annual growth of less than 3 % (EITO, 2000).

There is no reliable data on which of the two main sources, industry or households, produces most WEEE. Information is equally scarce on the quantity of old equipment, which is currently stored by waste producers and which will only appear when economically sound collection and treatment systems are available.

## **Complex waste stream**

WEEE is one of the most complex waste streams requiring management. This is due to the fact that EEE covers a wide variety of products ranging from mechanical devices such as hair dryers to highly integrated systems such as computers and mobile phones.

Technological innovation accelerates changes in product composition, e.g. the replacement of CRT monitors by LCD displays, or the replacement of old products with new products, e.g. the replacement of record players by CD-players. In addition, electronic appliances are increasingly included as integral parts of other product groups, for instance, electronic systems in vehicles and machinery.

### **1.1. Potential for negative environmental impact**

The potential for negative environmental impact resulting from the treatment of these wastes is high due to the presence of hazardous substances within the waste

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<sup>1</sup> AEA Technology - National Environmental Technology Centre; *Recovery of WEEE: economics and environmental impacts. Final report*; A report produced for the European Commission DG XI; June 1997.

<sup>2</sup> Press release of the European Commission, 13 June 2000, Commission tackles growing problem of electrical and electronic waste.

<sup>3</sup> The amount of WEEE in Germany represents about 4 % of municipal solid waste arisings and it is expected to grow by 5 to 10 % annually over the next 10 years, Environmental Protection Agency Germany; Information Paper *Electrical Scrap*; Berlin; May 1998.

stream, e.g. capacitors containing PCB, bromine-containing substances in printed circuit boards, plastics stabilised with heavy metals, fireproofing in casings and semiconductors.

The risks, however, are difficult to quantify because the waste stream is made up of so many different complex appliances. Most of the WEEE is treated as municipal waste and disposed of in landfills or municipal solid waste (MSW) incineration plants, causing the release of dangerous substances into the environment. In addition, even more hazardous substances might be produced in thermal treatment plants without adequate control.

## **1.2. Inadequate collection and treatment**

Even in regions or municipalities with separate collection schemes for WEEE, not more than 60 % of end-of-life appliances from households can be collected and thereby put into a recycling system: small appliances (e.g. electrical tools, tubes) are often mixed with household waste (Jentoft, 1999).

## **1.3. Lack of information**

Since the official waste statistics normally do not include separate estimates of WEEE from households, offices and industry there is a lack of information on where WEEE presently ends up and the environmental fate of the waste streams. The extensive uncontrolled and unrecorded transboundary movements of these end-of-life goods or their components make tracking of WEEE and its final disposal routes difficult.

The way to obtain some indication of WEEE quantities is from economic statistics and market research institutes: the pieces of equipment, the quantity, the specific production area (country), imported/exported, availability on the market and sale to the consumer. In addition, secondary data, for instance how well equipped are households, the life span of equipment, and consumer attitude, is required in order to establish the amount of WEEE.

## **1.4. Treatment, re-use and recycling**

Electrical and electronic end-of-life products contain significant quantities of valuable substances such as base metals, precious metals, high quality plastic and other components which should be recovered.

Various technical and organisational measures to reduce the amount of WEEE already exist. Methods for sorting, dismantling and treating WEEE aimed at re-using end-of-life goods, recycling components of WEEE, and recovering valuable material contained in WEEE have been developed but not yet fully implemented. It will require more time and effort to build up the necessary infrastructure for take-back systems and to implement adequate re-use or recycling measures. This effort could be more effective, if internationally recognised technical standards for separate collection, treatment and disposal of WEEE existed.

## **1.5. Integrated product policy and extended producer responsibility**

The major producers of EEE are working on the 'greening' of product standards, e.g. Green TV, and also developing take-back systems for certain types of end-of-life EEE. These product-related efforts have already led to encouraging results, for instance the EcoPC requires less material (6 kg instead of 16 kg), fewer component parts (29 instead of 87), and less energy (70 W instead of 200 W).

EEE producers are subject to a proliferation of international environmental policies and standards which go beyond the traditional concerns about wastes and emissions from manufacturing processes to impact on corporate management practices, product design and marketability and post-consumer product disposal.

Despite the fact that a systematic approach to environmentally friendly life cycle management presents opportunities for producers to lower product costs, there is still a vast potential for improvement. Whilst many producers are taking their first steps in the right direction, many are also opposing proposed regulations concerning extended product responsibility at EU or national level. The success of integrated product policy measures and the introduction of extended product responsibility could be given considerable support world-wide by adopting standards on reparability and extending product lifetime.

## 2. Legal framework at EU level

To meet the challenge associated with WEEE, the European Commission and the European Parliament are setting out clear measures in the proposed Directive on Waste Electrical and Electronic Equipment and its amendments (2002/C 110 E/01)<sup>4</sup> that aims to:

- prevent waste from EEE;
- reuse, recycle and recover such wastes to reduce the disposal of waste; and
- improve the environmental performance of all operations involved in the life cycle of electrical and electronic equipment (EEE).

The objectives are to be achieved by means of a wide range of measures, such as:

- **Producer responsibility:** producers should take the responsibility for certain phases of the waste management of their products;
- **Collection of WEEE from private households:** separate collection has to be ensured through appropriate systems, so that private and professional users can return their electrical and electronic equipment free of charge;
- **Treatment of WEEE:** Member States shall ensure that producers set up systems to provide for the treatment of WEEE; Member States may set up minimum quality standards for the treatment of collected WEEE; and treatment plants must obtain a permit from the competent authorities;
- **Information:** to achieve better collection rates and to facilitate recovery of WEEE, users of EEE should be informed about their role in the system.

The proposal for the Directive provides definitions for EEE, divided into 10 categories (table 2.1).

**Table 2.1: The 10 categories of WEEE included in the proposal for the directive**

No	Category	No	Category
1	Large household appliances	6	Electrical and electronic tools
2	Small household appliances	7	Toys, leisure and sports equipment
3	IT & telecommunications equipment	8	Medical devices
4	Consumer equipment	9	Monitoring and control instruments
5	Lighting equipment	10	Automatic dispensers

The proposed Directive imposes Member States to take the necessary measures to ensure that a minimum rate of separate collection of four kilograms on average per inhabitant per year of WEEE from private households is reached. This target must be achieved within 36 months of the entry into force of the Directive. Member States are to provide to the Commission information on an annual basis on the quantities and categories of electrical and electronic equipment put on the market, collected and reused, recycled and recovered within the Member States. On the basis of this information a new and compulsory collection target of WEEE is to be formulated.

The proposal for the Directive imposes Member States to ensure that producers meet specific targets as regards recovery as well as component, material and substance reuse and recycling. The targets are not equal for all categories of WEEE (table 2.2).

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<sup>4</sup> Common position (EC) No 20/2002, adopted by the Council on 4 December 2001 with a view to adopting Directive 2002/.../EC of the European Parliament and of the Council of ...on waste from electrical and electronic equipment, (2002/C 110 E/01).

**Table 2.2: Targets on recovery, reuse and recycling in the proposal**

	<b>Minimum recovery rate</b>	<b>Minimum rate of component, material and substance reuse and recycling</b>
Large household appliances, by an average weight per appliance	80 %	75 %
IT and telecommunications equipment and consumer equipment, by weight of the appliances	75 %	65 %
Small household appliances; lighting equipment; electrical and electronic tools; toys, leisure and sports equipment; monitoring and control instruments; and automatic dispensers, by an average weight per appliance	70 %	50 %
Gas discharge lamps, by weight of the lamps	-	80 %
Year to achieve targets	46 months of the entry into force of the directive	

Source: Common position (EC) No 20/2002, adopted by the Council on 4 December 2001 with a view to adopting Directive 2002/.../EC of the European Parliament and of the Council of ...on waste from electrical and electronic equipment, (2002/C 110 E/01).

Furthermore, five years after the entry into force of the Directive the European Parliament and the Council shall establish targets for recovery and reuse/recycling, including for the reuse of whole appliances as appropriate, and for medical devices, for the years thereafter.

## 3. Scope of work and objectives

### 3.1. Scope of work

One of the aims of the project was to provide WEEE data and information to waste management authorities, EEE producers and other stakeholders in the different EU Member States. This will assist them in getting a fair idea of quantities to be collected and treated, as well as the distribution of WEEE on categories and sources of generation. This may be helpful in the future planning of transposition measures, collection infrastructure and treatment capacity.

Another aim of the project was to give a first insight into the characteristics of this complex waste stream by providing data and information on substances contained in WEEE, and emissions of dangerous substances from their treatment and disposal.

### 3.2. Objectives

The objectives of the project were:

- To develop a methodology for estimating potential quantities of WEEE and for emission of dangerous substances from waste management of WEEE.
- To estimate potential quantities for selected appliances of WEEE for 1990-99 and generate projections for 2000-2010.
- To estimate emissions of dangerous substances from waste management of selected appliances of WEEE.
- To give recommendations on reduction of amounts of WEEE and emissions of dangerous substances.

The initial step in the project focused on collection of data and information available for the Topic Centre partner countries at that time: Austria, Denmark, Germany, Ireland and Spain. Under this step, six types of appliances were selected: refrigerators and freezers, personal computers, TV sets, photocopiers, fluorescent tubes and small household appliances. Later in the project, data collection was extended to cover some more of the EEA member countries (depending on data availability).

The six types of appliance are presented in table 3.1. The table shows for each type of appliance which category under Annex IB to the WEEE Directive it corresponds to. Furthermore, the reasons for selection of the specific appliance are outlined, and the main dangerous substances included in the appliance are stated. It appears that the six types of appliances present different distinguishing features, so that the appliances represent products on already saturated and fast growing markets, and they all represent contents of various dangerous substances. Finally, the selected appliances cover together a broad selection of EEE.

**Table 3.1: Selected appliances**

Selected appliances	Corresponding category in proposal for the WEEE directive	Reasons for selecting the appliance	Main dangerous substances included in the appliances
Refrigerators and freezers	Cat. 1: Large household appliances	<ul style="list-style-type: none"> <li>• example of a well-defined WEEE</li> <li>• example of a saturated market and 'steady-state model'</li> <li>• regulations for collection and treatment in some countries implemented</li> </ul>	CFCs, Hg
Personal computers	Cat. 3: IT & telecommunication equipment	<ul style="list-style-type: none"> <li>• rapidly growing market and the treatment of used PCs is an increasing problem</li> <li>• example of 'dynamic-state model'</li> </ul>	Pb, PbO, Hg, Cd, PCB, PVC, flame retardants
TV sets	Cat. 4: Consumer equipment	<ul style="list-style-type: none"> <li>• same remarks as for refrigerators</li> </ul>	Pb, PbO, Cd, PCB, PVC, flame retardants
Photocopiers	Cat. 3: IT & telecommunication equipment	<ul style="list-style-type: none"> <li>• example of up to 85 % take-back and re-use of parts and components</li> </ul>	Se
Fluorescent tubes	Cat. 5: Lighting equipment	<ul style="list-style-type: none"> <li>• widespread, common appliance</li> <li>• different collection and treatment schemes</li> </ul>	Hg
Small appliances	Cat. 2, 4, 6, 7: Small household appliances, consumer equipment, electrical and electronic tools, toys	<ul style="list-style-type: none"> <li>• most of these appliances are disposed of with household waste</li> <li>• take-back systems are not yet available</li> </ul>	Hg, Cd

## 4. Systematic network

### 4.1. General aspects of material flow schemes

The analysis, presentation, and interpretation of both material flow and energy flow within a specified system, such as production site, region, or country, is one of the most important tasks in the field of general environmental management, and it is becoming increasingly important in waste management.

The difficulty to set-up material flow balances often lies within the complexity of the system and in the lack of reliable data and information. Therefore, the modelling of material flow schemes requires a simplified system and method of calculation, based on data representing the 'real' situation as well as assumptions.

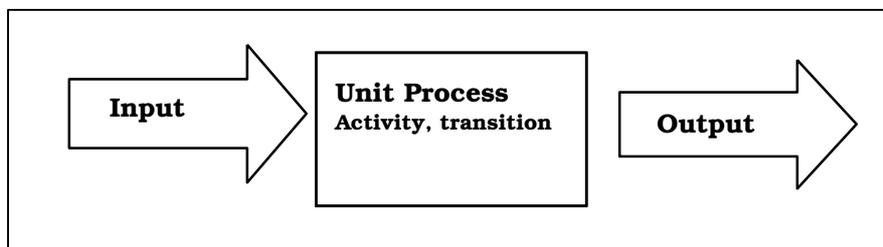
Material and energy flow models are normally based on accounting methods, for instance input/output balances or inventories for the activities or processes being examined, and networks to connect the activities or processes being examined, thus indicating the flow of material or energy.

This enables the user to put data and information in a systematic mathematical context, to reflect and assess data and information relevant to decision-making and to make projections about future prospects, even if the conditions within the system might change.

The model developed by ETC/W for WEEE is based on the 'unit process approach': a unit process represents processes or activities. It is the smallest portion of the system for which data is collected. There are two different kinds of unit process: The first type receives material and energy stocks, without any alteration: no losses and no conversions. Therefore, input is equal to output; e.g. use and collection of EEE. In the second type, a conversion of materials and/or energy takes place, thus creating new materials (products, waste, etc.); e.g. treatment of WEEE in an incineration plant or disassembly plant.

Arrows indicating the flow of material or energy link the unit processes. The material flow model considers all unit processes and flows within a defined boundary. The boundary is the interface between the system being examined and the external environment or other systems (Fig. 4.1).

**Figure 4.1: The unit process approach (simplified)**

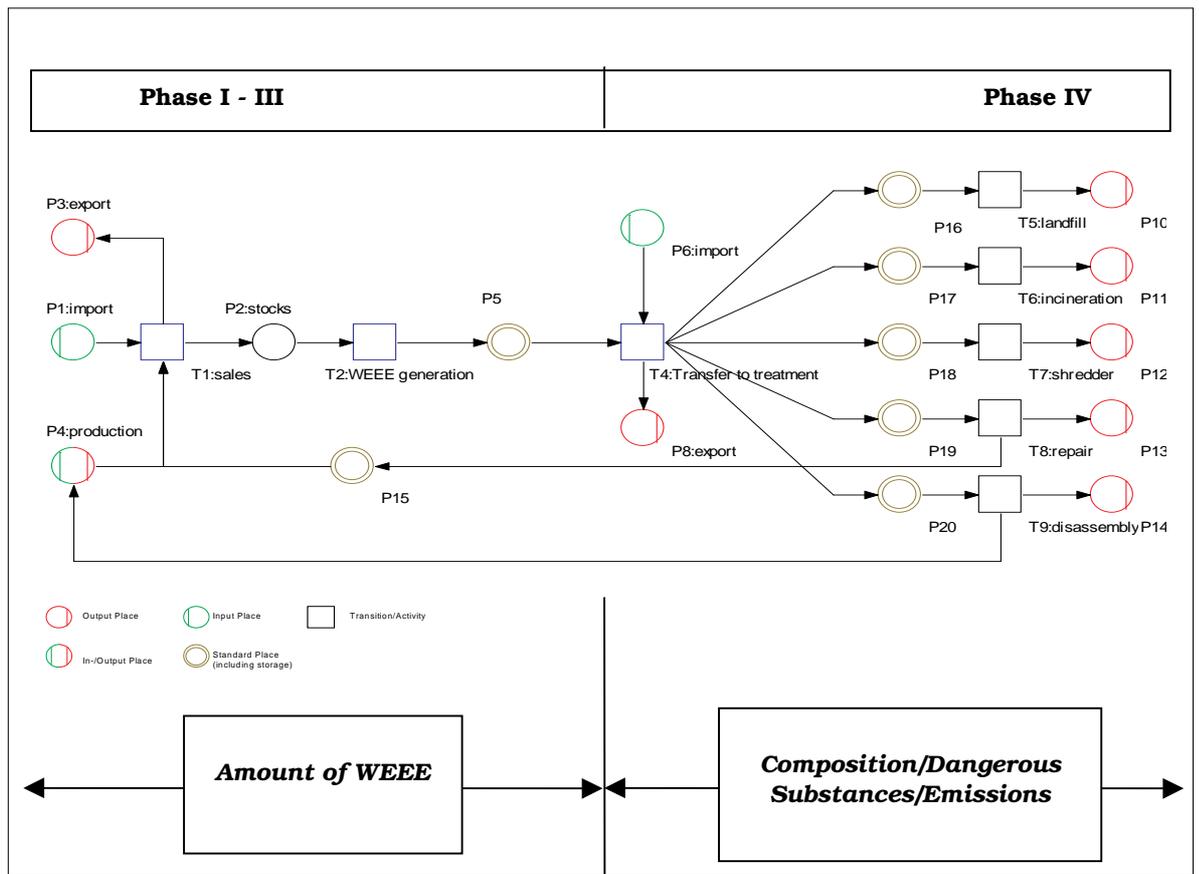


**The 'Four-Phase-Model' — from EEE to WEEE**

The material flow model covers four phases of EEE as well as end-of-life EEE (WEEE):

- Phase I: Production and sales of EEE, including import, export, and input of equipment for re-use from repair of WEEE.
- Phase II: Consumption of EEE, use of EEE in households, offices and industry.
- Phase III: Collection of end-of-life EEE (WEEE), including transfer to treatment/disposal sites, import/export.
- Phase IV: Treatment/disposal alternatives for WEEE, landfill, incineration, shredder, repair and disassembly, material as well as energy recovery, including the emitted material or substances.

**Figure 4.2: From EEE to WEEE - The 'Four-Phase-Model'**



The model has to be designed with clear mathematical rules and features. Therefore, unit processes as well as flow of different material streams in the phases I to IV have to be clearly defined (see Table 4.1)

**Table 4.1: The four phases**

<b>Phase I — Production / Sales</b>	
<p>Relevant for the design of the model in phase I is the mass or number of pieces of equipment sold to consumers within a specified time period (t). It is assumed that no losses occur and no conversion of material takes place. Therefore Input = Output.</p>	<p>Input/Output for Sales:</p> <p>Input (t)            = Production (t) + Import (t)            + re-use of collected WEEE (t)            - Treatment/Disposal of non-saleable EEE (t)</p> <p>Output (t)            = Consumption (t) + Export (t)</p>
<b>Phase II — Consumption</b>	
<p>Relevant for the design of the model in phase II is the mass/number of pieces of equipment bought and used by the consumers. After a certain time span (average life time t) the end-of-life goods are passed on for collection. It is assumed that in the consumption period no losses occur and no conversion of material takes place. The model will not consider the servicing of the equipment, the replacement of parts etc. Therefore Input = Output.</p>	<p>Input/Output for Consumption:</p> <p>Input (t)            = Output Sales (t) - Export (t)</p> <p>Output (t)            = WEEE generated (t)</p>
<b>Phase III — Collection</b>	
<p>Relevant for the design of the model in phase III is the mass or number of goods collected after the consumption period. It is assumed that in the collection period no losses occur and no conversion of material takes place. In addition the import of WEEE has to be considered.</p> <p>The transport itself and its need for energy are not considered. Therefore Input = Output.</p>	<p>Input/Output for Collection:</p> <p>Input (t)            = WEEE generated after consumption (t)            + import of end-of-life EEE (t)</p> <p>Output (t)            = end-of-life goods transferred to disposal/treatment/re-use [possibilities 1 .... n (t)]            + export (t)</p>

**Phase IV - Treatment / Disposal**

Relevant for the design of the model in phase IV is the mass or number of WEEE collected and transferred to the different treatment/disposal activities. Within these activities a conversion or transition of the WEEE takes place, thus creating new materials (fractions, components, dangerous substances).

In phase IV the model has to be designed for each specific type of treatment/disposal, taking into account the material input and the conversion of the material. Output depends on conversion/transition of the material and will lead to specific transfer factors.

Note: Depending on situation treatment/disposal may comprise one, two or even more successive steps with different technologies used. The calculation formula will be developed together with the development of the model specifically for each of the relevant treatment/disposal alternatives.

## 5. Data coverage

### 5.1. Data sources

#### **Statistics**

Production, import and export data regarding sales of electric and electronic products were mainly obtained from Eurostat and secondly from national statistic offices.

#### **Reports/scientific publications**

- Reports produced for the European Commission DG Environment
- Reports produced for national and international institutions e.g. - Nordic Council of Ministers, Copenhagen
- Italian National Agency for New Technology, Energy and Environment, Rome
- Federal Environment Agency, Berlin
- Other reports from universities and institutes

#### **Publications from market research institutions**

- Euromonitor
- Young and Rubicam
- EITO (The European Information Technology Observatory 1993–2000)
- Gartner Group
- AC Nielsen
- International Data Corporation

#### **Interviews/contacts**

With representatives from ETC/W partner countries, Eurostat, NGOs, public authorities, manufacturers, and manufacturers' associations.

#### **Others**

- Articles in professional journals
- Internet

### 5.2. Evaluation of data

#### **5.2.1. Statistical data**

In this technical report, official statistical data has an important position. To ensure comparability of data from different countries, Eurostat was used as the primary data source. The published population data from Eurostat as well as the data relating to economic development and employment is of fundamental importance for the calculations. The production data for the products under investigation was often found to contain inconsistencies, which made the calculation of WEEE difficult.

#### **Unusual features, characteristics found in European statistics**

##### *Data from different sources*

Sales data was calculated from production data, import and export statistics. Difficulties arose because the classification method used for production data differs from that used for import and export data. As a result, direct comparison of the two sets of data is problematic. Also, classification numbers for some products (PCs and TV sets) had changed over the years.

### *Confidential data*

In countries such as Ireland or Austria, where the manufacture of certain items is small, most of the data on production is not published due to confidentiality laws. In these cases it becomes impossible to calculate sales unless production information can be obtained from industry sources.

### *Potential inaccuracies in data*

It was found that production, import and export statistics had a high potential for error, e.g. trade statistics are normally taken from commercial documents presented to customs whenever goods cross a national border. Only when certain threshold levels of monetary value and/or net weight of a shipment are exceeded is the data passed to the statistic offices. Difficulties arise due to different methods of valuation, for example, external trade valuation.

Industry sources also identified that the classification of items was confusing and may result in incorrect data supplied.

### *Eurostat data not matching country data*

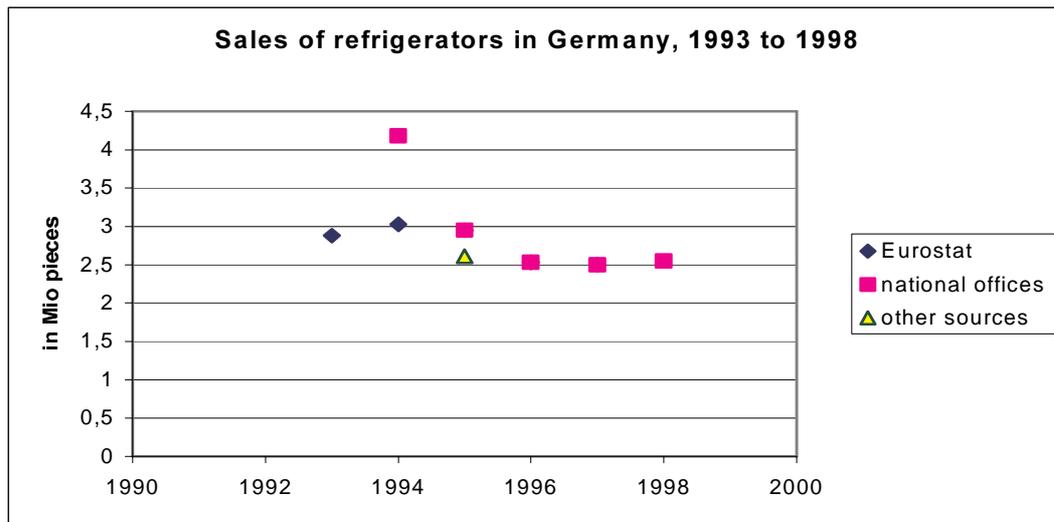
It was found that the national data compiled and published by Eurostat did not always match that published by the statistics office of the respective Member State. Differences of up to 30 % (Figure 5.1) may be revealed.

### *Change in the method of collecting export data in 1993*

Data on all external trade of EU Member States was collected by means of the so-called 'Single Administrative Document' until the end of 1992. With the creation of the single market in January 1993, the Single Administrative Document was, therefore, abolished for the purpose of trade between Member States and was replaced by a new system called 'Intrastat'. Under this system, a large number of enterprises make either a simplified declaration or no declaration at all, depending on the value of their total transactions for one year (Eurostat, 1997).

At national level, the systems have also changed. For example, in Germany, the systematic register of goods used in production statistics was restructured in 1995. There was also a change in the method in ascertaining waste data in 1994, which means that the most recent data available is for 1993. In accordance with the new legislation, data on waste was first collected again for 1996, but has not yet been made public.

**Figure 5.1 Example: Sales data for refrigerators from different data sources**



### **5.2.2. Market analysis**

It has been found that data collected by market research companies as part of a market analysis reflects more accurately the situation and trends of the EEE market, especially for the dynamic personal computer market. A considerable advantage of using data made available by market research institutes is their knowledge of the area of activity and the expertise in compiling and assessing the results. This was also confirmed in the more extensive studies carried out on Ireland.

### **5.2.3. Empirical data**

The statistical data has also been compared with empirical data gained from pilot projects for collection of WEEE. Pilot projects for collection of WEEE have been carried out in a number of municipalities in various countries. Many types of collection systems have been established during these pilot projects, some of which have become the standard for the collection of WEEE. In some schemes the WEEE was collected directly from the households, but, more often, WEEE had to be delivered to central collection sites. The following table summarises the results of some projects in different countries.

**Table 5.1: Quantities of WEEE collected in various regions in Europe**

Region and source	Total WEEE	Small items	Large items	TV sets	Fridges	Fridges and freezers	Other (e.g. laundries)	Fluorescent tube lights
(Data in kg/head of population per year)								
Austria								
A1		0.21	0.79	0.22				
A2		0.37	1.01	0.27				
A3		0.92	1.81	1.08	0.92			
A4		0.68		0.69	0.68			
A5		0.08		0.16	0.08			
A6	3.5	0.60		0.51	0.08			
Germany								
D1		0.67	1.94	1.75				
D2		1.4	2.9					
D3		0.57	0.73	0.25	0.47			
D4	5.0	0.65		0.48		1.14	1.55	
D5		1.22						
D6	1.03—1.8							
D7	2.3	0.6	0.8	0.3		0.6		
D8	4	0.6	1.6	0.56		1.18		
D9					1.05			0.02
The Netherlands								
N1				0.43				
France								
F1	5.2			0.7				
F2	2.3			0.3				

**Region and source:**

- A1 Average of collection projects in different districts, 1997. (Großversuch Steiermark, 1998)  
A2 Collection project Weiz, 1995. (Großversuch Steiermark, 1998)  
A3 Collection project Bregenz, 1996. (IPA, 1997)  
A4 Collection project Bürmoos, 1996. (IPA, 1997)  
A5 Collection project LAUV, 1996. (IPA, 1997)  
A6 Collection project in the district of Flachgau, 1998. (Lohse, 1998)  
D1 Collection project Freiberg, 1996. (IPA, 1997)  
D2 Collection project Rostock, 1996. (IPA, 1997)  
D3 Collection project Berlin, 1996. (IPA, 1997)  
D4 Various urban and rural regions in Germany. (INFA, 1997)  
D5 Household waste investigation by ARGUS, 1996. (Seddigh, 1996)  
D6 Household waste investigation in the city of Dortmund, 1995. (INFA, 1997)  
D7 Collection project Hannover, 1995. (Lohse, 1998)  
D8 Collection project Bremen, 1995. (Lohse, 1998)  
D9 Waste audit 1998 from Baden-Württemberg. The waste audit shows the quantity of waste which the public service waste department had to deal with  
N1 Collection project in the district of Eindhoven, the Netherlands, 1997. (Lohse, 1998)  
F1 Collection project in the region Rhône-Alpes. (Lohse, 1998)  
F2 Collection project in the region Envie-Terra. (Lohse, 1998)

The results show clear differences. One reason for the difference can be the export of second-hand appliances, in particular, goods such as TV sets are collected from waste left for collection or from scrap yards and transported, primarily to Eastern Europe.

**5.3. Selection of relevant data sources**

With considerable effort, the data collected from the various sources described above was assessed for suitability in the calculation of WEEE according to:

- reliability;
- availability, amount and range of data, completeness;
- relevance in terms of the chosen method of calculation.

The assessment regarding completeness and relevance of the data was product specific due to the fact that the circumstances concerning typical consumer goods such as refrigerators differ considerably from those of products primarily in commercial use, e.g. photocopiers. Incomplete data was supplemented with product specific assumptions.

**5.3.1. Refrigerators**

For refrigerators, comparatively good data exists because they are a widespread consumer good. It is possible to calculate the sales data for 1993 to 1997 from the

statistics available from Eurostat. All the market research data is for 1991 to 1996 and covers all EEA countries with the exception of Iceland, Liechtenstein and Norway. For Austria, Ireland, Germany and Spain, Eurostat data was of good quality and was therefore used for the calculations. For the other countries, data from Euromonitor was used. With this relatively standardised database, a good comparability of information for the different countries was possible.

Concerning the market penetration of refrigerators, the European Marketing Pocket Book was used as an all-round source of information.

### **5.3.2. Television sets**

As for refrigerators, there is good market information on television sets for most European countries. It is possible to calculate the sales for 1993 to 1997 from the data available from Eurostat. All the market research data is for 1991 to 1996 and covers every European country with the exception of Iceland and Liechtenstein.

Data from Euromonitor could be used confidently with the exception of data for Spain where the sales data suggested a fall of 50 % between 1991 and 1996 which did not agree with the other facts. Eurostat data for 1993 to 1996 was used.

Regarding market penetration of television sets, the European Marketing Pocket Book proved to be a comprehensive source of information.

### **5.3.3. Personal computers (PC)**

The market for personal computers in every European country has been characterised by rapid growth over the last few years. For the majority of European countries, the analysis of statistical data showed substantial fluctuations which often made it impossible to see a trend. The annual fluctuations often amounted to more than 100 % contradicting the generally accepted development of this market. As a result, the official statistics were not used in the calculation of waste potential from PCs.

The European PC market is regularly observed and analysed by several market research institutes. However, the resulting processed data is only partly available. The data available from different sources was studied with regard to suitability for waste calculations.

For Ireland, Gartner Group provides sales data for PCs for 1996 to 1999, drawing a distinction between PC sales to private consumers and industry.

Euromonitor provides data for most European countries for 1991 to 1996. This data relates only to the sale of PCs to private consumers and not to industry.

A fully comprehensive and easily available source of information is the European Information Technology Observatory's annual publications (EITO, 2000). The EITO publications include PC sales in Europe from 1993 to 1999 as well as forecasts for 2000 and 2001.

### **5.3.4. Photocopiers**

In Europe the market for photocopiers is saturated, so that for recent years steady sales data can be expected. Data for this is relatively incomplete and includes some uncertainties, which makes the calculation of waste potentially difficult.

The published statistics from Eurostat differ widely so that they can only be partly used in the calculations. Among the other sources of data, the EITO publications contain relevant information, including sales of photocopiers in almost every European country from 1991 to 1999 as well as forecasts for 2000 and 2001.

Since photocopiers are almost exclusively for commercial or industrial use, market penetration in private households is irrelevant in this case. There is no comprehensive data available on the current numbers of photocopiers in industry. A further uncertainty when calculating the waste potential involves the return and

reconditioning of used copiers, carried out to differing extents by individual manufacturers (Mahr, Xerox). Reconditioned appliances reduce the waste potential because, after their first use, they are immediately fed back into circulation and subsequently sold as new appliances.

#### **5.3.5. Fluorescent tube lights**

There is very little reliable data available on fluorescent tube lights for some countries. If sales data is calculated from official statistics, very different values for individual countries are obtained when they are compared with the corresponding population statistics: a comparison of data from Ireland and Denmark shows that specific sales data for Denmark from 1993 to 1997 is 3.4 to 6.7 times higher than for Ireland. As fluorescent tube lights are a widely used product in private households as well as in commerce and industry and both countries show a similar level of industrialisation, it can be assumed that the actual specific sales are of a similar magnitude. According to one trade organisation in Germany (ZVEI, Lichttechnische Industrie, 1999) the market share is 40 % private household and 60 % commercial use.

#### **5.3.6. Small appliances**

Small electrical appliances found in households include power tools, household appliances, entertainment electronic devices and toys. In view of the large number of different products, a quantitative inclusion of production statistics covering the whole spectrum is not possible. Statistics are not available from market research institutes either. However, a comparatively good database exists for toasters as well as for mobile phones and these have therefore been included as examples in the calculation of WEEE.

##### **Toasters**

Statistics exist for most European countries thus allowing the calculation of sales data. Of all market research institutes, Euromonitor provides the only comprehensive source of information for most European countries for 1991 to 1996.

The comparison of the sales data for different countries as well as market research results which have been established, make the reliability of the emerging statistical data doubtful. For Germany, for example, sales obtained from statistical data lie between 61 % and 121 % above the values from Euromonitor for 1993 to 1996. Regarding market penetration of toasters, data is only available for Germany (Hausgeräte-Fachverbände im ZVEI, 1999) which shows a steady market penetration of about 87 % between 1990 and 1999. There is no information for the other European countries on market penetration. As a result, a steady market penetration has been assumed for all European countries.

#### **5.3.7. Mobile telephones**

The European market for mobile telephones has shown an extraordinary rate of growth over the last few years. Because of this, the availability of possible up-to-date data for this sector is of particular interest. However, the analysis of available statistical data only enables the calculation of sales up to 1997.

Comprehensive data on the distribution of mobile phones as well as the development of the turnover in Euro in recent years up to 1999 for most European countries is available from EITO. In addition, forecasts for 2000 and 2001 are given. Because of the standardised system, the EITO publications are taken as a major source of data in the calculation of mobile phones. Data from market research institutes (Young & Rubicam, 2000) is used to fill in missing data.

### **5.4. Potential quantities of WEEE**

Due to lack of data the results of the potential quantities of WEEE presented here cover only five of the six types of appliances that were chosen (refrigerators, personal computers, TV sets, photocopiers and small household appliances). For the same

reason the projections cover only four types of appliances (refrigerators, personal computers, TV sets and photocopiers). Thus, the calculations presented here do not cover total potential quantities of WEEE. They have been made on the basis of the findings of the pilot studies and on existing data.

According to the proposal for the WEEE directive<sup>5</sup>, various estimates of the quantity of WEEE indicate that the collection target of 4 kg per inhabitant constitutes only 25 % of the overall annual generation of this waste.

In this section the potential quantities for the appliances are added up in totals, but the quantities for each appliance are presented in Annex II.

#### 5.4.1. Potential of WEEE 1990-99

In table 5.2 the total waste potential of WEEE for the five types of appliances (refrigerators, PCs, TV sets, photocopiers and toasters) are shown for 17 countries and EU15. No data is available for Liechtenstein.

**Table 5.2: Total waste potential for five appliances (tonnes)**

	Austria	Denmark	Germany	Ireland	Spain	Greece	France	Italy	Luxembourg
1990	3 568		40 026	3 170	13 452	2 040	30 620	19 720	8
1991	26 358		335 100	10 729	141 754	21 108	215 909	195 673	887
1992	28 495		351 596	10 343	138 734	21 017	221 401	195 013	885
1993	29 279		346 516	11 022	137 537	20 818	221 943	166 402	798
1994	28 411		373 909	12 099	142 435	20 623	233 303	178 241	835
1995	27 950		381 392	13 207	144 298	20 286	222 251	185 345	831
1996	26 530		302 504	12 145	133 481	18 696	201 920	177 273	819
1997	31 818		436 077	12 934	150 779	18 879	221 552	173 406	760
1998	17 829		267 054	15 644	174 362	23 451	180 917	218 332	879
1999	23 593		295 645	22 777	163 113	18 432	232 892	190 518	745

	Netherlands	Belgium	Portugal	Finland	Sweden	UK	EU15	Iceland	Norway
1990	13 961	5 210	2 446	3 801	8 059	34 981	185 343	170	2 100
1991	65 734	31 330	23 617	15 510	36 331	181 604	1 326 698	168	11 567
1992	57 865	31 697	26 114	12 978	33 913	178 962	1 333 237	171	12 253
1993	56 415	30 538	24 934	13 705	32 140	186 562	1 302 820	161	13 210
1994	61 657	31 063	25 038	14 407	35 841	189 507	1 376 704	156	15 970
1995	53 246	29 277	26 329	14 953	30 143	165 370	1 342 447	160	13 690
1996	39 796	24 775	23 276	14 577	18 298	132 956	1 152 831	161	11 049
1997	33 378	24 529	23 113	13 355	25 422	122 722	1 311 511	156	10 567
1998	13 321	25 260	27 149	17 025	29 845	231 628	1 268 488	153	11 992
1999	23 130	26 141	24 297	16 204	33 577	146 683	1 246 463	154	11 040

In general, the data for 1990 is particularly poor and include toasters only, which explains the low values. Furthermore, data for photocopiers only covers the period 1994-99.

For Iceland the data includes toasters only. For Luxembourg there is no data for personal computers and photocopiers. For the Netherlands, the figure for 1998 does not include refrigerators and TV sets.

For 1991-99 it seems as if the potential is declining for several countries. This is especially evident for the Netherlands where the potential seems to have been reduced by 65 % from 66 000 tonnes in 1991 to only 23 000 tonnes in 1999.

The potential for EU15 seems to decline by 8 % from 1.3 million tonnes in 1991 to 1.2 million tonnes in 1999.

Table 5.3 shows the waste potential for the five types of appliances stated in kg per inhabitant.

<sup>5</sup> Proposal for a Directive of the European Parliament and of the Commission on waste from electrical and electronic equipment, COM(2000)347 final, Brussels, 13.6.2002.

**Table 5.3: Total waste potential for five appliances (kg per inhabitant)**

	Austria	Denmark	Germany	Ireland	Spain	Greece	France	Italy	Luxembourg
1990	0.46	0.83	0.51	0.90	0.35	0.20	0.54	0.35	0.02
1991	3.39	4.87	4.20	3.05	3.65	2.07	3.80	3.45	2.31
1992	3.62	4.69	4.38	2.92	3.56	2.04	3.87	3.44	2.27
1993	3.68	4.67	4.28	3.09	3.52	2.01	3.86	2.92	2.02
1994	3.54	5.64	4.60	3.38	3.64	1.98	4.04	3.12	2.08
1995	3.48	5.29	4.68	3.67	3.68	1.94	3.83	3.24	2.04
1996	3.29	4.91	3.70	3.35	3.40	1.79	3.47	3.09	1.98
1997	3.94	4.32	5.32	3.54	3.84	1.80	3.79	3.02	1.82
1998	2.21	4.87	3.25	4.24	4.43	2.23	3.08	3.79	2.07
1999	2.92	5.40	3.60	6.15	4.14	1.75	3.95	3.31	1.76

	Netherlands	Belgium	Portugal	Finland	Sweden	UK	EU15	Iceland	Norway
1990	0.94	0.52	0.25	0.76	0.95	0.61	0.51	0.67	0.50
1991	4.38	3.14	2.39	3.10	4.23	3.15	3.63	0.66	2.72
1992	3.82	3.16	2.65	2.58	3.92	3.09	3.63	0.66	2.87
1993	3.70	3.03	2.53	2.71	3.70	3.21	3.53	0.61	3.07
1994	4.02	3.08	2.53	2.84	4.10	3.25	3.72	0.59	3.69
1995	3.45	2.89	2.66	2.93	3.42	2.83	3.61	0.60	3.15
1996	2.57	2.44	2.35	2.85	2.07	2.26	3.09	0.60	2.53
1997	2.14	2.41	2.33	2.60	2.87	2.08	3.51	0.58	2.41
1998	0.85	2.48	2.73	3.31	3.37	3.92	3.39	0.56	2.71
1999	1.47	2.56	2.43	3.14	3.79	2.48	3.32	0.56	2.48

The potential quantity of the five types of appliances included in this report is estimated at 3.3 - 3.6 kg per inhabitant for EU15.

Greece, Luxembourg and Portugal seem to have the lowest potentials in kg per inhabitant, but while the potential in Portugal seems to remain fairly constant the potential in Greece and Luxembourg seems to decline.

On the other hand, Denmark, Sweden and France seem to have the highest potentials of WEEE. In Ireland the potential seems to be growing rapidly from 3 to 6 kg per inhabitant.

#### **5.4.2. Projection 2000-10**

Table 5.4 shows the projected waste potential for four appliances of WEEE for 2000-10 (refrigerators, TV sets, personal computers and photocopiers).

It is worth noticing that the projections are carried out using linear extrapolation of the trend for sales and stock figures for 2000-2010.

**Table 5.4: Total waste potential for four appliances (tonnes)**

	Austria	Denmark	Germany	Ireland	Spain	Greece	France	Italy	Luxembourg
2000	27 954		349 200	24 399	184 988	20 534	242 918	212 231	763
2001	28 915		329 142	26 328	188 504	21 092	239 363	220 062	752
2002	30 176		324 442	29 142	196 723	21 921	244 134	225 806	741
2003	31 441		320 039	31 961	204 903	22 754	248 635	231 381	729
2004	30 131		275 287	32 484	206 059	22 115	231 524	215 918	718
2005	31 316		270 053	35 239	214 212	22 891	235 742	220 764	707
2006	32 502		264 820	37 994	222 365	23 667	239 960	225 610	696
2007	33 687		259 586	40 749	230 518	24 442	244 178	230 456	685
2008	34 872		254 353	43 504	238 672	25 218	248 396	235 303	673
2009	36 058		249 119	46 259	246 825	25 994	252 615	240 149	662
2010	37 243		243 886	49 014	254 978	26 770	256 833	244 995	651

	Netherlands	Belgium	Portugal	Finland	Sweden	UK	EU15	Iceland	Norway
2000	12 073	25 288	27 520	19 384	38 270	187 369	1 475 127		13 925
2001	9 138	24 914	27 602	19 322	39 391	176 467	1 460 133		13 547
2002	9 422	26 097	28 339	20 287	45 318	180 029	1 499 663		14 081
2003	9 701	27 312	29 065	21 245	51 243	183 606	1 539 022		14 613
2004		24 258	27 849	19 271	53 812	167 583	1 437 058		13 345
2005		25 288	28 505	20 102	59 683	170 590	1 472 992		13 841
2006		26 317	29 161	20 932	65 554	173 597	1 508 927		14 338
2007		27 346	29 818	21 763	71 424	176 604	1 544 861		14 834
2008		28 375	30 474	22 594	77 295	179 611	1 580 796		15 331
2009		29 405	31 130	23 425	83 166	182 618	1 616 730		15 827
2010		30 434	31 786	24 256	89 036	185 625	1 652 665		16 324

There are no projections available for Iceland and Liechtenstein. Nor is there any data for refrigerators and TV sets for the Netherlands. For Luxembourg there is no data available for personal computers and photocopiers. For photocopiers projections are only available for 2000-2003.

Furthermore, the results for some countries (TV sets: Greece, Belgium and Sweden; refrigerators: Sweden; PCs: the Netherlands) show negative values. The reason for these obviously inaccurate calculations must be deviations in future market penetration data for televisions, which was obtained by linear extrapolation of developments up to the present. Data sets with negative values are not included in the projections presented in Tables 5.4 and 5.5, but are presented in Annex II.

Despite the negative values and the lack of some data sets, the potential for EU15 seems to increase by 12 % or 200 000 tonnes, to 1.6 million tonnes.

The total potential in Germany, the Netherlands and Luxembourg seems to be declining, while it seems to be increasing in the other countries. The potential seems to rise fastest in Sweden, Ireland, Spain and Denmark.

Table 5.5 shows the potential per inhabitant for four appliances for 2000-10.

**Table 5.5: Total waste potential for four appliances (kg per inhabitant)**

	Austria	Denmark	Germany	Ireland	Spain	Greece	France	Italy	Luxembourg
2000	3.46	19.18	4.25	6.41	4.69	1.94	4.09	3.65	1.94
2001	3.58	20.48	4.01	6.91	4.78	2.00	4.03	3.78	1.91
2002	3.73	21.97	3.95	7.65	4.98	2.08	4.11	3.88	1.88
2003	3.89	23.45	3.89	8.39	5.19	2.16	4.18	3.98	1.85
2004	3.73	24.40	3.35	8.53	5.22	2.09	3.90	3.71	1.82
2005	3.88	25.45	3.30	8.95	5.40	2.15	3.89	3.81	1.77
2006	4.03	26.90	3.24	9.65	5.60	2.23	3.96	3.89	1.74
2007	4.17	28.35	3.17	10.35	5.81	2.30	4.03	3.98	1.72
2008	4.32	29.80	3.11	11.05	6.01	2.37	4.10	4.06	1.69
2009	4.47	31.25	3.05	11.75	6.22	2.45	4.17	4.14	1.66
2010	4.63	32.18	3.01	12.21	6.41	2.51	4.16	4.29	1.62

	Netherlands	Belgium	Portugal	Finland	Sweden	UK	EU15	Iceland	Norway
2000	0.76	2.47	2.75	3.74	4.32	3.15	3.91		3.12
2001	0.58	2.44	2.75	3.73	4.44	2.97	3.87		3.04
2002	0.59	2.55	2.83	3.92	5.11	3.03	3.98		3.16
2003	0.61	2.67	2.90	4.10	5.78	3.09	4.08		3.28
2004	0.00	2.37	2.78	3.72	6.07	2.82	3.81		2.99
2005	0.00	2.46	2.82	3.85	6.68	2.84	3.88		3.02
2006	0.00	2.56	2.88	4.01	7.33	2.89	3.98		3.13
2007	0.00	2.66	2.95	4.17	7.99	2.94	4.07		3.24
2008	0.00	2.76	3.01	4.33	8.65	2.99	4.17		3.35
2009	0.00	2.86	3.08	4.49	9.30	3.04	4.26		3.46
2010	0.00	2.95	3.12	4.61	9.88	3.05	4.34		3.51

The projected potential for EU15 seems to rise steadily from 3.9 to 4.3 kg per inhabitant. The development is the same for Norway, but at a lower value, from 3.1 to 3.5 kg per inhabitant.

## 5.5. Conclusions

A general conclusion is that the data necessary to carry out the calculations is rather poor. Especially data regarding sales, market saturation, import and export is lacking. The absence of reliable data implies that the estimated potentials of WEEE are of limited value and should be used only with great caution focusing more on the trend shown and not on the absolute quantities. Furthermore, the appliances selected here only cover a fraction of the total WEEE potential included in the proposal for the WEEE directive.

According to the proposal for the WEEE directive (COM(2000)347 final), various estimates of the quantity of WEEE indicate that the collection target of 4 kg per inhabitant constitutes only 25 % of the overall annual generation of this waste.

One of the objectives of the project was to provide a first insight in the complex waste stream of WEEE, by trying to estimate current and future potentials. For the EU15 the average potential quantity of the five types of appliances shows a downward trend from 3.6 - 3.3 kg per inhabitant. The projected potential quantity for four types of appliances seems to rise steadily from 3.9 to 4.3 kg per inhabitant.

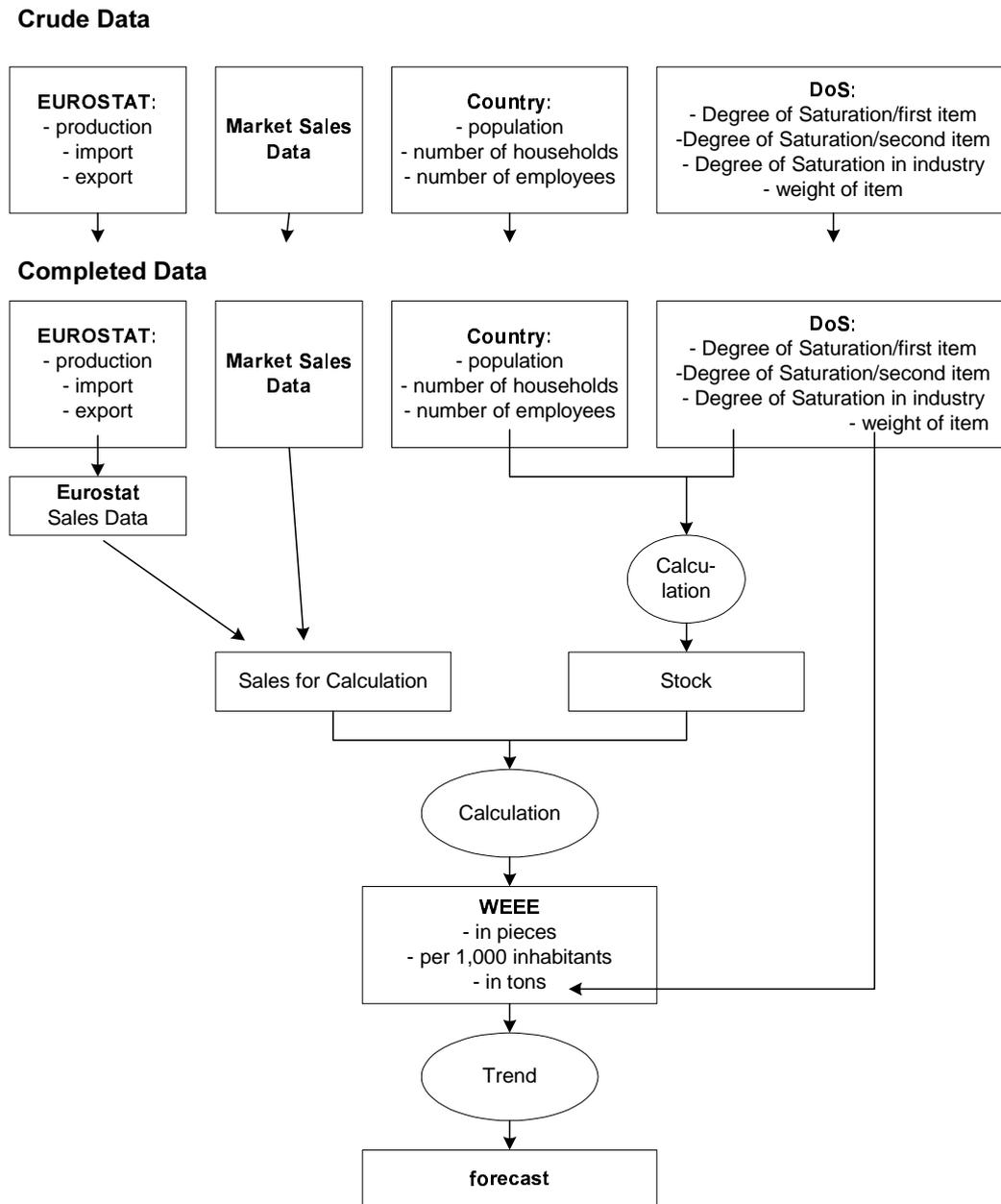
Among the selected appliances, the highest potentials for EU15 are found for TV sets with figures of 1.2 - 1.7 kg and refrigerators with a potential of approximately 1.1 kg per inhabitant.

With respect to the projections, the most interesting factors are trends and tendencies of how each appliance as well as the total potential may develop in the future, as it is considered to be too unreliable to forecast the actual quantities. The projections are estimated by using linear extrapolation which does seem not to work very properly in this case. Instead of using only historic data for sales, market saturation, etc. to estimate the future quantities it might be considered to include other variables such as economic development.

## 5.6. Data flow

Figure 5.2 schematically summarises the data flow from input and completion of crude data until calculation of WEEE and forecasts.

**Figure 5.2: Data flow from input and completion of crude data until calculation of WEEE and forecasts**



## 6. Dangerous substances and emissions

### 6.1. Introduction

The WEEE stream is treated in various ways. The specific allocation of WEEE to recycling, recovery, treatment and disposal technologies differs from country to country. Allocation is also dependent on the actual prices for treatment and disposal. In recent years, an increasing amount of WEEE is treated in thermal industrial processes.

### 6.2. Waste composition

According to investigations carried out in Germany, 40 % of total WEEE comes from industrial goods, 40 % from large household appliances and 20 % are electronic consumer goods, including 5 % end-of-life computers.

The composition of WEEE is specific for each appliance. In order to handle this complexity the parts/materials found in WEEE have been divided into six categories:

- iron and steel, used for casings and frames;
- non-ferrous metals, especially copper used in cables, and aluminium;
- glass used for screens, windows;
- plastic used as casing, in cables and for circuit boards;
- electronic devices mounted on circuit boards;
- others (rubber, wood, ceramic etc.).

Table 6.1 provides an overview of the composition of the six appliances selected for the present project.

**Table 6.1: Average weight and composition of selected appliances**

Appliances	Average weight (kg)	Fe % weight	Non Fe-metal % weight	Glass % weight	Plastic % weight	Electronic components % weight	Others % weight
Refrigerators and freezers	48	64.4	6	1.4	13	-	15.1
Personal computers	29.6	35.3	8.4	15	23.3	17.3	0.7
TV sets	36.2	5.3	5.4	62	22.9	0.9	3.5
Photocopiers		58	8	7	9	2	16 (10 rubber)
Fluorescent tubes	0.2	0.6	1.4	93.9			4.1
Small appliances		38	21			49	

### 6.3. Dangerous substances in the selected appliances

Dangerous substances are present in all appliances in varying amounts. The appliances selected for further investigation are generally representative of the dangerous substances present in all categories of WEEE. The most important parts that may contain dangerous substances are considered as follows:

#### **Ferrous metals**

- Steel is used for frames. The hazardous potential of iron and steel for the environment is low.

#### **Non-ferrous metals**

- Copper and its alloys are used for wires, conductors for electricity and heat, and as pigments in plastic. The toxicological risk for human health is not considered to be significant. It may leach from landfills.
- Aluminium is used for frames. Its hazardous potential is low.

#### **Glass in screens (cathode ray tubes)**

- Screens containing lead components.

- Fluorescent material in screens (Cd in old screens, Y, Eu, Se, Zn), the average amount of fluorescent material is about 6 g per screen.
- Various components hindering recycling.

#### **Electronic components/circuit boards**

- Solders containing Sn, Pb.
- Semi-conductors (B, Ga, In, As).
- Flame retardants; up to 5-10 % by weight.
- Mercury in batteries, switches.

#### **Plastic**

- Plastic containing pigments and stabilisers (Cd, Pb, Ni, Cr, Sb, Sn, Ba).
- The relative quantity of plastic with flame retardants (FR) depends on the appliance category and, within the category, on the type of the appliance. Circuit boards as well as thermoplastics are treated with flame retardants. FR includes organic halogenated compounds (esp. brominated flame retardants (BFR) such as deca bidiphenylether (10-BDE)), antimony oxide (as a synergist), phosphorous organic compounds and other materials. Due to environmental problems, particularly in relation to 10-BDE, industry has taken steps to minimise FR contents or to substitute 10-BDE with tetrabrombisphenol A, which has a lower dioxin generation potential. Nevertheless, WEEE still contains significant quantities of BFR.

#### **PCBs**

- PCB capacitors have been used in electric motors for white goods and in fluorescent tubes (average capacitor weight: 100-300 g, 30-90 g PCB).

#### **Others**

Special problems are related to the following.

- Freezers and refrigerators containing CFCs in the cooling circuit and in the insulation foam. CFCs contribute to global warming.
- Fluorescent tubes contain mercury (modern tubes 3-20 mg, others 15-30 mg), energy efficient compact fluorescent tubes about 6 mg.
- Small appliances (coffee grinders, irons, hair dryers): An investigation<sup>6</sup> carried out in Germany showed that the amount of small EEE, which is disposed of together with municipal waste in the rubbish bin is about 1 % by weight (see Figure 6.1). The group 'others' also includes single parts such as pumps, small motors and components that cannot be assigned to a specific appliance. Small appliances have differing amounts of components with dangerous substances. For instance, in certain cases, batteries/accumulators are not removed. Appliances with a high percentage of electronic components, with plastic containing flame retardants and with heavy metals should also be considered as potentially harmful.

### **6.4. Emissions from treatment of WEEE**

At present, most WEEE is collected as part of municipal waste and is therefore disposed of at landfill sites or in incineration plants depending on the local/national practices. In some countries or regions, certain products such as refrigerators and freezers are collected separately, but this is not a widespread practice. Where WEEE is separately collected, special treatment processes tend to be used for the different WEEE subgroups. An overview of the various treatment schemes for WEEE is provided in Annex IV.

The following sections consider typical emissions resulting from:

- Landfilling or incineration of WEEE together with municipal waste;
- Recycling/recovery processes;
- Disposal of residues from recycling/recovery processes.

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<sup>6</sup> Kommission der Niedersächsischen Landesregierung zur Vermeidung und Verwertung von Abfällen, Abschlußbericht des Arbeitskreises 13, Elektronikschrott, 1997.

#### **6.4.1. Landfilling and incineration**

Landfilling and incineration are the predominant practices in waste management with major differences between countries.

##### **Landfilling**

The degradation processes in landfills are very complicated and run over a wide time span. At present it is not possible to quantify environmental impacts from WEEE in landfills for the following reasons:

- Landfills contain mixtures of various waste streams;
- Emission of pollutants from landfills can be delayed for many years;
- According to climatic conditions and technologies applied in landfills (e.g. leachate collection and treatment, impermeable bottom layers, gas collection), data on the concentration of substances in leachate and landfill gas from municipal waste landfill sites differs with a factor 2-3.

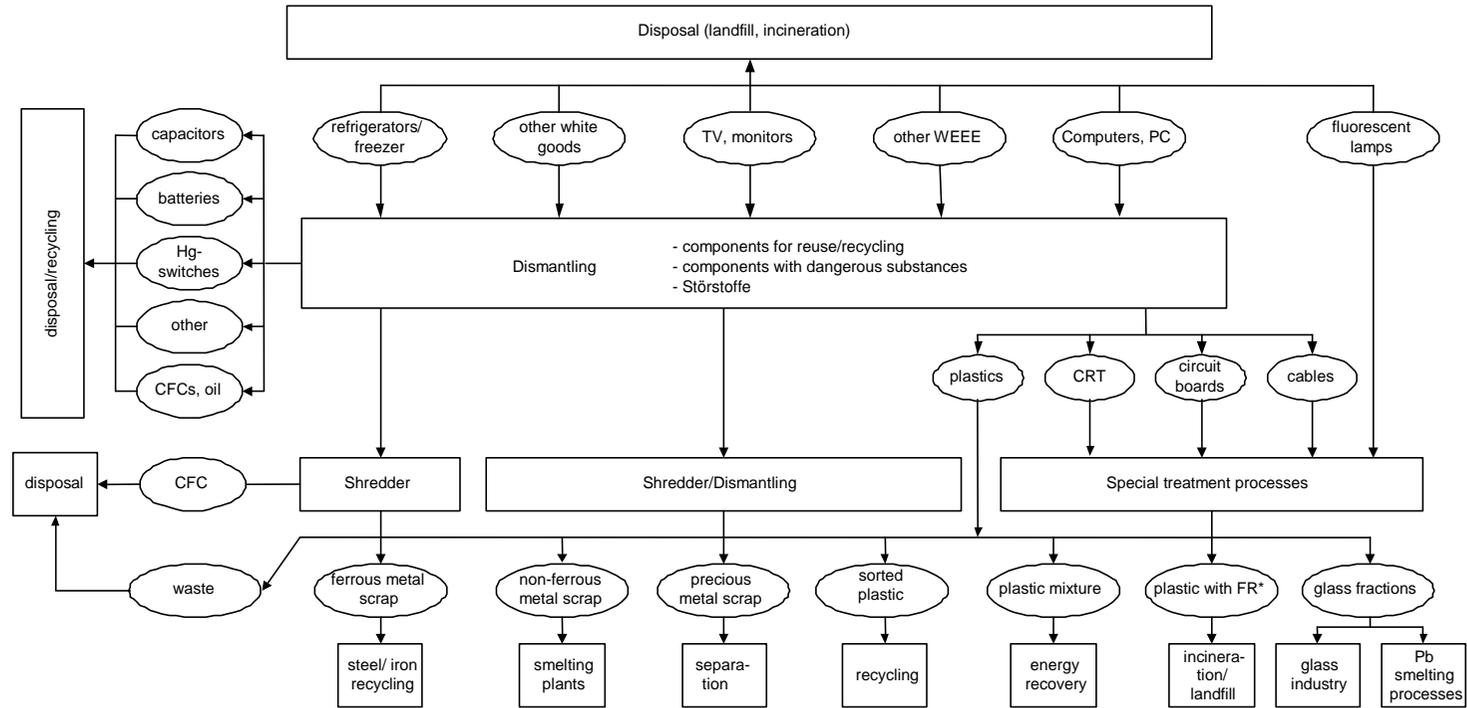
As a study states<sup>7</sup>, the environmental risks from landfilling of WEEE cannot be neglected because the conditions in a landfill site are different from a native soil, particularly concerning the leaching behaviour of metals. In addition it is known that cadmium and mercury are emitted in diffuse form or via the landfill gas combustion plant.

Although the risks cannot be quantified and traced back to WEEE, landfilling is not an environmentally sound treatment method for substances which are volatile and not biologically degradable (Cd, Hg, CFC), persistent (PCB) or with unknown behaviour in a landfill site (brominated flame retardants). As a consequence of the complex material mixture in WEEE it is not possible to exclude environmental (long-term) risks even in controlled landfilling.

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<sup>7</sup> Tema Nord 1995:555, Environmental consequences of incineration and landfilling of waste electrical and electronic equipment, Nordic Council of Ministers, Copenhagen, 1995.

**Figure 6.1: Treatment schemes for WEEE**



\* FR = flame retardant  
 CFC = chlorofluorocarbon

## Incineration

Advantages of incineration of WEEE are the reduction of waste volume and the utilisation of the energy content of combustible materials. Some plants remove iron from the slag for recycling. By incineration some environmentally hazardous organic substances are converted into less hazardous compounds. Disadvantages are the emission to air of substances escaping flue gas cleaning and the large amount of residues from gas cleaning and combustion.

There is no comparable data indicating the impact of WEEE emissions into the overall performance of municipal waste incineration plants. Waste incineration plants contribute significantly to the annual emissions of cadmium and mercury. In addition, heavy metals not emitted into the atmosphere are transferred to slag and exhaust gas residues and can re-enter the environment on disposal. It is inevitable that WEEE incineration will increase these emissions, if no reduction measures are taken.

### 6.4.2. Recycling and recovery

Overall, recycling/treatment schemes are similar for all kinds of WEEE.

- *Dismantling*: Removal of parts containing dangerous substances (CFCs, Hg switches, PCB); removal of easily accessible parts containing valuable substances (cables containing copper, steel, iron, precious metal containing parts, e.g. contacts).

Potential emission to the environment: There is a risk for contamination of the soil through improper storage of WEEE, removed parts or improper handling of liquids (e.g. oil). There is also a risk of emission of CFC to the atmosphere.

- *Segregation of ferrous metal, non-ferrous metal and plastic*: This separation is normally done in a shredder process.

Potential emission to the environment: This depends on the input, but there is a risk for emission of a number of volatile components.

- *Recycling / recovery of valuable materials*: Ferrous metals in electrical arc furnaces, non-ferrous metals in smelting plants, precious metals in separating works.

Potential emission to the environment:

At steel/iron recovery there is a risk of emission of dioxins from electric furnace steel plants, depending strongly on operation conditions; if scrap preheating is applied, dioxin emissions are up to five times higher<sup>8</sup>. Electric arc furnaces also contribute to the emission of Cd (13 % of the total Cd Emission in the 15 EU countries)<sup>9</sup>.

At copper recovery plants there is a risk for emission of a number of heavy metals, as well as volatile metals and their oxides. Also secondary copper production contributes significant to PCDD/F emissions in Europe.

At aluminium recovery plants there is a risk for emissions of PCDD/F and fluorides, SO<sub>2</sub> and NO<sub>x</sub>.

- *Treatment / disposal of dangerous materials and waste*: Shredder light fraction is disposed of in landfill sites or sometimes incinerated (expensive), CFCs are treated thermally, PCB is incinerated or disposed of in underground storages, Hg is often recycled or disposed of in underground landfill sites.

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<sup>8</sup> The European dioxin inventory, Final Report, LUA NRW, 1997.

<sup>9</sup> The European atmospheric emission inventory of heavy metals and persistent organic pollutants for 1990, published by German EPA (Umweltbundesamt)

## 6.5. A study on dangerous substances and emissions

In the following, a study prepared by the Topic Centre on estimation of emissions of dangerous substances from a number of appliances is described.

### 6.5.1. Objective

The objective of this survey is to provide a computer-based method to calculate emissions of dangerous substances and materials from WEEE treatment. The substances are limited to: Hg, Pb, Cd and POPs contained within five selected appliances: refrigerators, PCs, TV sets, fluorescent tubes and small household appliances. The survey focused on information from five countries: Austria, Denmark, Germany, Ireland and Spain.

### 6.5.2. Method

The model is based on substance and material flows analysis. Substance flow analysis tracks the flow of a substance through a technical system. At its simplest, it is an input-output balance, where the distribution of a specific input stream on several output streams is determined. For inorganic substances the input mass is equal to the output (mass conservation), in the case of organic substances, material can be destroyed or new material generated. A comprehensive description of the model is found in Annex V. The method consists of four steps:

**The first step** in conducting a substance flow analysis is to define the system boundaries. The system starts with the treatment of WEEE and ends when treatment is completed.

In this system all emissions to air, water and waste related to the treatment of specific WEEE appliances are considered. Emissions from 'unauthorised' treatment of waste are not considered. (The system boundaries for this step are illustrated in Annex V)

**The second step** is to define the unit operations within the system boundaries. This means that a specific treatment scheme is designed for each of the selected appliances. The unit operations are technical processes such as dismantling, shredding or metallurgical treatment. A system can be very simple e.g. in the case of disposal technologies it is limited to a single process. In the case of recycling the system can be complex and may comprise several unit processes. (The system boundaries for this step are illustrated in Annex IV).

**The third step** is to describe the transfer of substances in the various unit operations. Assigning transfer factors for each substance and each unit operation does this. They are defined as follows:

$$t_i = \frac{m_{out,i}}{m_{in}}$$

i = index for output paths (e.g. air); out = output; in = input  
m = mass

The input vector for a particular substance also includes input of the substance from sources other than the appliance, such as process materials that are required to run the process.

**The fourth step** is to carry out the calculations. This was done using a commercial computer software package UMBERTO<sup>10</sup>.

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<sup>10</sup> Umberto has been developed by ifu, Institut für Umweltinformatik Hamburg GmbH and ifeu, Institut für Energie- und Umweltforschung Heidelberg GmbH, Heidelberg/Germany.

### 6.5.3. Definition of factors

Various factors are defined that allow comparison of emissions from the different treatment schemes. In Annex V all factors used in the estimation are defined. Below are given the definitions of recycling factors and air emission chosen for the presentation of some of the results.

The **recycling factors** ( $f_r$ ) are calculated as the ratio of kg recovered material (e.g. metals and plastic) per 1000 t input of appliance (e.g. refrigerator, PC etc).

$$f_r = \frac{kg_{recycl.}}{1000t_{input}}$$

In addition, for the state-of-the-art treatment schemes the **recycling quota** is calculated using the EU definition from the proposed WEEE directive as the ratio of kg recycled material per average weight of appliance. For each appliance this quota is compared with the targets set by the EU in the proposed directive.

**Air emission factors** ( $f_e$ ) are calculated as the ratio of kg emitted dangerous substance per 1000 t input of appliance.

$$f_e = \frac{kg_{ds}}{1000t_{input}}$$

To assess and compare the emissions generated by the state-of-the-art treatment, various scenarios were set up. The emissions from state-of-the-art treatment are compared with emissions from the incineration of 1000 t of the appliance and the incineration of 1000 t municipal waste.

### 6.5.4. Required data and availability

To calculate the emissions, various data is necessary:

1. The amount of WEEE as input to treatment.
2. The composition of the input stream and location of dangerous substances.
3. National treatment schemes - The same treatment scheme was used for each appliance for all countries and is regarded as the state-of-the-art at present.
4. Emission and transfer factors for waste treatment facilities.

For further information see Annex IV.

### 6.5.5. Calculations and results

The following presents the results estimated by using the developed substance flow model. The presented results focus on the recycled quota and the fraction of emission of a number of dangerous substances. All results are from the five selected appliances.

Table 6.2 illustrates the recycling quotas for the five appliances. The **recycling quota** is calculated using the EU definition from the proposed WEEE directive as the ratio of kg recycled material per average weight of appliance. For each appliance this quota is compared with the targets set by the EU in the proposed Directive.

**Table 6.2. Recycling quota for selected appliances using state-of-the-art recycling schemes**

	<b>Refrigerators % weight</b>	<b>TV % weight</b>	<b>Fluorescent tubes % weight</b>	<b>PC % weight</b>	<b>Small appliances % weight</b>
Metals	45 % (Al, Cu, steel)	14 % (Al, Cu, Fe (steel), Pb)	1.6 % (steel, Al/Cu + Hg)	40 % (Al, Cu, Steel, Pb)	54 % (Fe, Al, Cu)
Plastic	18 % (PS, PU, PVC)	1,4 % (PVC)		3.3 % (PVC)	1.7 %
Glass	1,8 %	41 % (screen glass) 18 % (cone glass, without Pb)	88 %	9.7 % (screen glass) 3.8 % (cone glass)	
Compressor	10 % (reuse) 10 % (recyc.)				
Batteries					0.2 %
Sum	85 %	75 %	90 %	57 %	56 %
EU minimum rate of component, material and substance reuse and recycling <sup>11</sup>	75 %	65 %	80 %	65 %	50 %

The table shows that the EU minimum rate of component, material and substance reuse and recycling is achieved by using the so-called 'state of the art' recycling schemes for all selected appliances except for PCs.

It should be noted that the recycling rate for plastics is rather low due to problems with the recycling of plastic. This problem is likely to increase due to increased use of plastic in the production of EEE.

<sup>11</sup> According to proposal for directive on WEEE