MSc Program
Environmental Technology & International Affairs

Austrian Electric and Electronic Wastes Flows Relevance of WEEE-Scrap Metal Losses due to Illegal Flows of WEEE for Austria's Steel Industry

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
Prof. Dr. Paul H. Brunner

Anna Peer

0738238

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Affidavit

I, **ANNA PEER**, hereby declare

1. that I am the sole author of the present Master’s Thesis, "AUSTRIAN ELECTRICAL AND ELECTRONIC WASTE FLOWS: RELEVANCE OF WEEE-SCRAP METAL LOSSES DUE TO ILLEGAL FLOWS OF WEEE FOR AUSTRIA'S STEEL INDUSTRY", 61 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master’s Thesis as an examination paper in any form in Austria or abroad.

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Abstract:

Waste electrical and electronic equipment (WEEE) is one of the fastest-growing streams of waste. These waste flows contain hazardous as well as critical materials, which have the potential to negatively impact the environment, human health and socioeconomic development of a region. The goal is to gage the relevance of misplaced metal scrap of the WEEE category large appliances for Austria’s steel industry. Using a material flow analysis (MFA), the potential impact on Austria’s steel industry will be estimated. The aim is to show, if the amount of E-waste has a relevant or measurable effect (positive or negative) on Austria’s economy, regarding the recovery/misplacement of valuable/critical materials (iron scrap) stemming from large electrical appliances in the steel industry. Further, a literature review will be given to portray the state of the art of research. Data used originates from the Elektroaltgeräte Koordinierungsstelle (EAK) and the Austria Ministry for Environment. A case study review portrays negative environmental impacts abroad, in order to highlight the importance of proper WEEE-management to the domestic society. The outcomes point toward a certain portion of WEEE of the category large electrical appliances entering illegal waste streams, however, the steel industry does not appear to be negatively affected by the current amount of missing metal scrap from WEEE of large appliances. Similarly, while the missing scrap could in theory require the steel industry to compensate with higher inputs of primary resources, which may potentially lead to an increase in the emission of GHG, a relevant increase in GHG emissions due to missing scrap cannot be verified. Nonetheless, the losses to the economy could continue to accumulate. There is a chance to decrease these losses utilizing and further developing public awareness, education regarding WEEE-recycling, and education of impact of illegal waste transfers in less developed countries, in order to further decrease the misplacement of WEEE scrap. To this end, awareness raising campaigns educating the domestic population about potential negative impacts abroad might be useful.

Keywords: WEEE, illegal waste flows, MFA, steel production

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List of abbreviations

CWIT	Countering WEEE Illegal Trade
EAG	Elektroaltgerät (E-waste)
EAK	Elektroaltgerät Koordinierungsstelle
EEE	Electrical and Electronic Equipment
EoL	End of Life
EPR	Extended Producer Responsibility
E-waste	Waste Electrical and Electronic Equipment
FWMP	Federal Waste Management Plan
GHG	Greenhouse Gases
LDCs	Least Developed Countries
MFA	Material Flow Analysis
MSW	Municipal Solid Waste
PoM	Put on Market
RoHS	Restrictions on Hazardous Substances Directive
STAN	Substance Flow Analysis
WEEE	Waste Electrical and Electronic Equipment
WPs	work packages

1. Introduction

"Waste is a global issue. If not properly dealt with, waste poses a threat to public health and the environment. It is a growing problem that results from the way we produce and consume. It concerns everyone."

-- Global Waste Management Outlook, ISWA 2015

The proper management of waste is one of the most essential utility services, which has become more and more important within the context of modern global consumption patterns. However, due to its, for a lack of a better term, unglamorous image, waste management is not as present within the public eye as other utility services, such as transportation or business.

An increase in production goes hand in hand with an increase in waste materials produced, and this waste has to be taken care of in a manner appropriate to its specifications. Wastes, especially hazardous wastes, when treated inappropriately, can negatively impact the environment, leading to diminished human health, destruction of ecosystems, losses in biodiversity and hindering economic development.

Proper regulations for waste management are needed, in order to prevent producers of waste, be they large corporations or households, from choosing any other than the appropriate option for disposing of wastes. In a lesser developed country's context, the cheapest and most readily available options for waste disposal tend to be illegal. These practices have a high potential to harm public health, the environment, and economies of the regions in question. Unlike, for instance, the pollution of air, the environmental impact of illegally dumped waste is not usually felt on a transnational level. Air pollution is disseminated by wind currents and can effect third parties.

Waste usually affects the local population and environment, making the effects a local problem. This puts emphasis on the existence of appropriate regional regulations of waste and waste management strategies. Achieving proper waste management requires administrative and technological capacities, which are more developed in some regions and countries than in others.

Industrialized countries, as well as least developed countries (LDCs), struggle to cope with the ever- increasing amounts of waste and disposal thereof, creating immense environmental costs. Without proper waste disposal, the substances accompanying increased production of goods, can lead to enhanced environmental degradation, which can be directly linked to poverty and indebtedness of LDCs (Clapp, 1994). Increasingly less expensive costs of transportation and an expanding demand coming from LDCs for foreign exchange earnings, have led many of these countries to excessively import hazardous waste from developed countries. These countries do not have the capacity to dispose of these dangerous imports, which can affect human populations, as well as flora and fauna. Therefore, developing countries appear to be suffering more from the division of global waste trade and its flows (Clapp, 1994).

More stringent regulations regarding the proper disposal of wastes have also increased the financial burden of disposal, thereby creating incentives to seek out cheaper disposal options. Companies in developed countries benefit from being able to cheaply dump wastes in the territories of developing countries, while at the same time the import of such materials is sought after within these territories to attract cash-inflow.

The majority of electrical and electronic equipment (EEE) is consumed in developed countries where consumption rates are higher and product life cycles tend to be shorter. There exist different categories of thread that can be distinguished when dealing with e-waste (UNEP, 2009). First, there are environmental disruptions, including pollution of soil and water, emissions of greenhouse gases (GHG) and thinning of the ozone layer, negative impact on flora and fauna. Secondly, there are substances that have negative impacts on human health, such as toxic metals, ultraviolet radiation affecting respiratory and digestive systems, cancers, etc. The third category is socio-economic impoverishment, including increased costs for public health, reduced agricultural productivity, food insecurity and poverty (UNEP, 2009). In order to analyze the extent of negative effects of e-wastes, the amount of WEEE (Waste Electrical and Electronic equipment) produced, used and disposed of, has to be analyzed in the light of resource conservation and environmental protection.

The thorough analysis of WEEE-flows within the Republic of Austria is of interest due to the unique properties of electrical and electronic equipment (EEE), which could result in impacts on the economy and the environment.

Unique properties of e-wastes include characteristics not commonly found in other types of waste products (Magalini et al., 2012). The most notable of these properties is based on the rapid pace of technological advancements in the electronics sector present over the last decade.

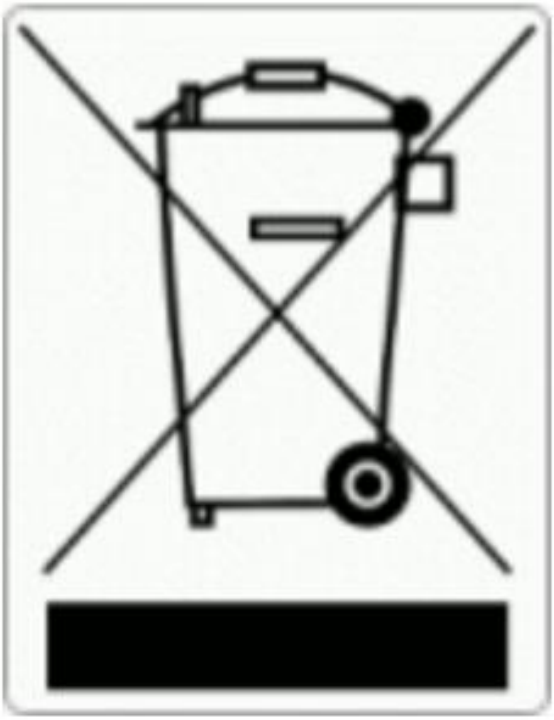


Figure 1. Waste Electrical and Electronic Equipment Symbol

New technologies, materials and a heavy focus on attractive product design to appeal to consumers, is leading to a reduction in product lifecycles.

Figure 2. Attractive product design, shorter product life cycles (Apple Ipod Nano)

The composition of EEE also sets them apart from wastes which are intended to enter the municipal solid waste (MSW) stream. They typically contain moderate to large amounts of critical and/or hazardous materials, thereby awarding the recycling and proper disposal of such products a high degree of importance.
Many electrical and electronic products are partially composed of hazardous materials, such as mercury and cadmium, or ozone depleting substances. At the same time, they contain product specific amounts of valuable and “critical material”. The latter are “critical” materials in the sense that their supply is governed by increases in demand, shortages and other supply risks, such as technological capabilities needed for resource extraction and recovery. Examples for such materials are indium, gallium, platinum group metals etc.

One of the specific characteristics of EEE is the shear amount of diversity of products in the category. They consist of varying materials, contain small to large size items, and are made up of diverse components. For instance, a refrigerator and a cell phone fall under the same over-ordering category of EEE, but are obviously very different in their composition, intended use, and life cycle. These two products are also treated differently according to consumer behavior, which governs the products’ end of life (EoL) process. As will become apparent later on, consumer behavior is an important factor in how EEE, and therefore also WEEE, is treated. The growth within the sector of EEE over the last decades has led to a continuing increase and development of collection and management processes for WEEE, which is still evolving and changing to adapt to the ever larger amount of wastes generated. Due to the diversity in components of the EE-products, the waste management covering their save disposal, recycling and so on, is also becoming more established and technologically sophisticated.

Another specific characteristic of the electrical and electronical sector is the different levels of market saturation. Large appliances, such as washing machines, refrigerators, television sets, have reached market saturation, while other products, especially in the IT and telecommunications, have not. According to Ongondo et al. (2011) the amount of WEEE appears to be continuously underestimated calling for an increase in awareness and transparency in nation’s WEEE-sectors and regulations thereof. In order to do so, a meaningful quantitative and qualitative analysis of the amount of e-waste produced, re-used and disposed of has to be undertaken.

Organizations such as the EAK or Countering WEEE Illegal Trade (CWIT) point out that there exists a gap between EEE sold and recycled, meaning that the EEE-products put on the market and WEEE treated/collected/recycled/disposed do not match. This is attributed to a lack of knowledge of how many products have been put on the market, how long they remain in use and how they are being disposed of. There are a number of possible explanations for why the input of EEE does not match the output of waste, which is an endeavor taken on by the Elektroaltgerät Koordinierungsstelle (EAK) in the Republic of Austria.

The results are of interest, since it can be assumed, that a hard to quantify amount of WEEE is disposed of in an inappropriate manner, potentially endangering the environment, human health and economic welfare. Additionally, it can be assumed, that a difficult to quantify amount of waste streams are leaving the country to enter informal waste sectors in other countries. Since these flows are, as stated above, illegal, the amount and composition of the waste flows are hard to gage, and potential negative impacts on environments, populations and socioeconomic welfare of receiving countries as well as the domestic realm are hard to predict.

E-waste should be disposed of by using specialized recycling facilities, however, often e-waste is sold overseas to countries in which only an informal waste management sector exists. Incentives to dispose of e-waste counter to regulations results from the profitability of side-stepping the costs of legitimate recycling and the payment one can get from the electric and electronic scrap equipment via alternative channels (UNEP, 2009). Other general factors which are influencing the flow of waste electrical and electronic equipment are administrative instruments, such as regulations related to recycling, reuse and disposal. In European countries, the EU Directive 2012/19/EU and national and state laws govern waste management practices.

Economic instruments, such as taxes, subsidies and disposal fee systems influence WEEE flows mainly through modifying producer- and consumer behavior (Clapp, 1994). Closely related to economic instruments are market conditions, meaning the supply and demand for EEE and thereby of WEEE. The individual countries', or regional, local and technical, conditions constitute the percentage of precious materials that smelters can extract from collected WEEE.

Further, legal conditions have a large impact on flows of WEEE. These are governed by EU legislations as well as national- and state legislations. They cover, for instance, amounts of

WEEE which have to be collected annually, penalties for illegal dumping, import/export duties and restrictions, etc. The Austrian authority in this field is the EAK.

Developing countries face additional problems when it comes to save and sustainable management of WEEE. Due to the lack of proper infrastructure for waste management in developing regions, especially in Africa and Southeast Asia, individuals employed in the informal waste management sectors, are routinely exposed to hazardous materials in unsafe working conditions (Nordbrand, 2009). Nordbrand (2009) states that workers in China, India, Ghana and Nigeria are exposed to hazardous materials and chemicals, which can result, for instance, in high lead contents in the blood, skin, stomach and respiratory illnesses. It is mainly the unskilled labor force, who is employed in this sector thereby exposing the weaker sphere of society to hazardous materials and a polluted work- and living environment.

The problem of hazardous materials in e-waste components reaching less developed countries has become more pressing, due to a rise in demand for EEE in these countries. Even though, the RoHS Directive has increased the safety in WEEE-recycling in the informal sector by restricting the use of certain harmful chemicals, the potential danger of certain materials, such as gallium, and their impact on human health are not well documented and hard to estimate (Nordbrand, 2009). However, the amount of greenhouse gases contained in certain pieces of EEE, such as freezing units, extent beyond the possible local polluting effects stated above, and could contribute to climate change in a global scale.
The general increase in e-waste production and its unaccounted flows, calls for an analysis of Austria's WEEE flows, inquiry into the possibilities of illegal flows of waste out of the country and an estimation of potential harm done to local regions dealing with the WEEE, in order to increase awareness of negative and difficult to predict impacts of WEEE to provoke a change in consumer behavior.

More specifically, however, the impact of a certain category of WEEE on the Austrian steel industry will be analyzed. A number of studies have been conducted on the impact of missing critical materials stemming from small electrical appliances has been conducted, due to the higher value of such materials. In this project however, the impact of missing WEEE-scrap metal stemming from large electrical appliances will be analyzed, since the composition of these specific WEEE flows is less complex than for others and can be assumed to be more or less directly usable in the production of steel. Furthermore, an analysis of missing WEEE-scrap in the production of steel in Austria has not yet been conducted. While it is probable that the amount of missing WEEE-scrap metal from large electrical appliances will not have a high impact on Austria's steel industry, an analysis can be helpful and be used in an effort to increase collection rates of these materials further.

In doing so, a contribution to research regarding the connection of EEE (large electrical appliance category) put on the market and WEEE (large electrical appliance category) collected, will be achieved. Due to the legal status of such flows, a high amount of uncertainty has to be accepted, when striving to reach an estimate on the environmental damage resulting from WEEE-flows. The existence of a well-organized WEEE-regulation and authorities, however, do make it possible to gage the impact of WEEE-flows on the domestic economy.

1.1.Goals

The aim is to achieve an, as accurate as possible, estimation of WEEE (large electrical appliances) produced within a given system (private household within the Republic of Austria), assessing the difference between EEE of the category, which are inputs in the system, and the WEEE of the category, which constitute outputs, if they enter the proper recycling and disposal systems, using a basic Material Flow Analysis and STAN-software. Should the outcome proof itself to be relevant, it will be used to achieve an estimation of potential harm done to the Austrian economy and environment, as well as harm done to receivers of illegal waste flows.

Relevant to the production of steel would be an amount of missing WEEE-scrap metal for the production of steel, that would require the steel industry to purchase WEEE-scrap metal for production or compensate with the use of more primary resources.

Due to the existence of uncertainty regarding illegal waste flows, especially regarding illegal waste flows bound for outside of Europe, an estimation regarding damage resulting from Austrian WEEE abroad is not practical for the scope of the project, however, in the spirit of global governance, it is important to explain the negative impacts illegal transfers can have abroad, in order to increase understanding help awareness raising of the problem that is exported to other nations.

Potential mitigating measures, which can be introduced via policy-avenue, will be explored, resulting in suggestions for policies and raising awareness. Awareness regarding WEEE entering illegal waste flows and the potentially resulting harm thereof, are expected to be important, since consumer behavior plays a large role in controlling the amount of properly recycled or disposed WEEE and is assumed to be able to increase the motivation of the population to do so.

It can be expected that not all WEEE (large electrical appliances) leaving the system are collected properly, and can therefore be assumed to have been misplaced or entered illegal waste flows. The composition of WEEE and its specific characteristic of containing hazardous as well as valuable or critical materials make these wastes both a desired commodity, as well as a potential danger to environment, human health and socioeconomic development.

In order to achieve a meaningful analysis, linkages have to be drawn between the amount and composition of inputs constituting the chosen EEE-products, and the output of waste material, which is either recycled, disposed of, or, in the case of illegal flows and hibernation, misplaced. The amount of missing WEEE will be estimated using Material Flow Analysis. In order to understand the potential impacts of illegal flows of WEEE, national and international legal aspects, such as the Basel Convention, will be discussed and incentives for illegal activities in waste management will be examined. To underline the importance of awareness regarding the international illegal flows of wastes a short review of a case study will be given. This is aimed at achieving an appreciation of the problems faced abroad due to illegal wastes.

The impact of illegal flows of WEEE (large electrical appliances) on Austria's economy will be highlighted by analyzing the steel industry and its use of WEEE- scrap metal. Electrical and electronic equipment of the category number 1 under the EAK-guidelines applied in Austria are comprised of large electrical appliances (EAK VO, 2005). These constitute roughly a fourth of WEEE in Austria.

There is a connection between the products which are put on the market and the waste generated from these products. Items are put on the market and enter into first-hand use. From there they can be given to another person or sold/given to a second-hand store. Either way, the products enter into second-hand use. Items can also enter storage, from which they can re-enter into second-hand use, if they are still functional. Direct entry from first-hand use to second-hand use is obviously also a possibility. While in first-, second-hand use or storage, the items stay within the system boundaries, which in this case is a private household in Austria.

There are two flows out of the system. All types of WEEE generated can leave the system via proper collection, which would be the most desirable outcome, heading for recycling or proper disposal. Secondly, especially small electrical appliances can leave via residual waste flows, due to misplacement of the WEEE in the domestic residual waste, due to lack of knowledge or convenience for the owners. Also, wastes can leave the system, but be not accounted for. Part of the flow of unaccounted WEEE likely enters into an illegal waste stream.

Important to note are the stocks within a system. Within a specific time period stocks are compiled or depleted, leading to a difference in initial inputs and outputs of a system. The simplification that a products put on the market within a year and WEEE collected should be the same is false, since EEE remain in the system for a certain amount of time (in stock or in use).

Assumptions on illegal flows are based on border spot checks and projects conducted by the EAK and Universities, such as the TU Vienna and other Austrian universities. From these data, calculations and assumptions are made. Since the exact amount of illegally transferred material and misplaced material is not possible to calculate exactly, the data sets are certain to have a high error potential, however, it is still valuable to use these assumed numbers in order to gage possible amounts of misplaced or illegally transported WEEE streams.

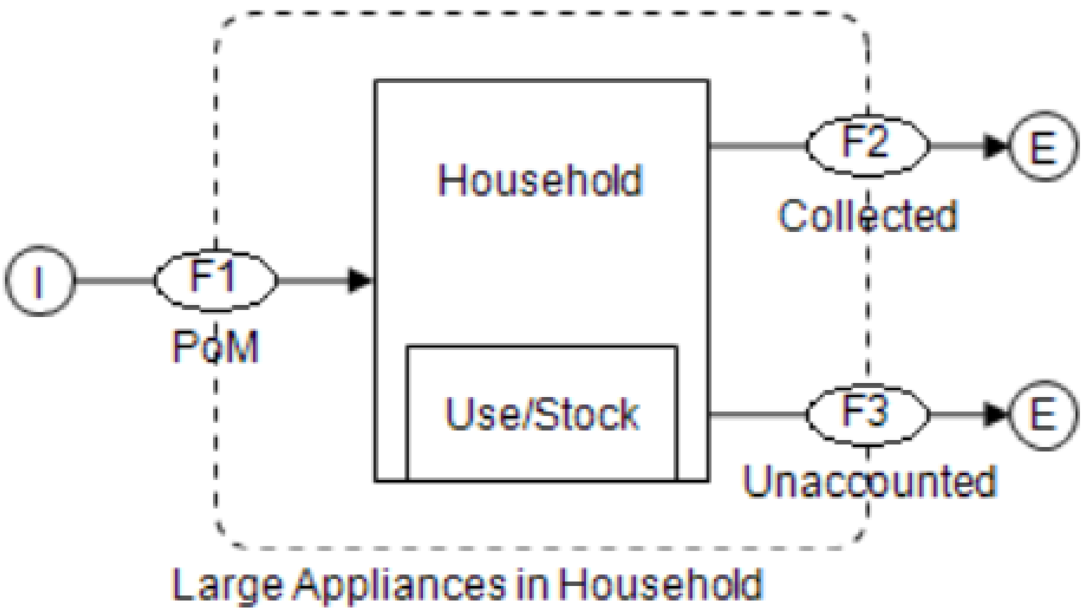


Figure 3. Simple MFA, own design

As an added note, since the focus is put on wastes resulting from the EAK category 1 (large appliances) the WEEE products ending up in *residual waste* can be neglected, since large appliances are highly unlikely to leave the system via residual waste streams.

1.2.Research Questions

Following the goals set out above, the following research questions are addressed in detail. First and foremost, the question of the relevance of an economic loss due to illegal flows of WEEE (large electrical applications) in Austria's steel industry will be answered. Secondly, if the missing WEEE-metal scrap should be relevant to the steel industry, the extend of the additional environmental costs resulting from illegal flows of WEEE on Austria and globally, due to the nature of GHG emissions, will be estimated, taking uncertainties into account. Following this, the research questions are positively related. If the missing scrap metal is not relevant to the steel industry, no environmental more-costs are assumed and vice-versa.

Research Questions

1. Is the economic loss resulting from missing metal scrap in steel production relevant to the Austrian steel industry?

2. Is the extent of environmental impact, which is to say increase of GHG-emissions, of illegal flows of WEEE large appliances on Austria, Eastern Europe countries, and globally relevant?

1.3. Structure of the paper

The legal framework governing the management of wastes of electrical and electronic equipment on the European and the Austrian level will be highlighted in order to create a baseline for the discussion of WEEE flows within Austria and the illegal flows leaving Austria. Producer responsibility, a concept enforced and monitored by the European Union and its evolution over the past legislation period will also be included, to give a historical background.

This is necessary to understand potential incentives for continued illegal trade in WEEE and shed light on possible explanations for recycling failures. Therefore, a special focus will be put on the Basel Convention on Trade in Hazardous Wastes and a short review of a case study will be given to outline possible effects of harmful components of WEEE in less developed regions.

The composition of EEE, recycling systems and treatment alternatives will be presented in order to show the main characteristics and problems which are posed by WEEE-management. A special area of focus will be put on the role that consumer behavior plays in creating a save and efficient management scheme and how an increased awareness of the harm potentials abroad can be utilized in a wealthy country, such as the Republic of Austria, in order to create a more responsible consumer response/reaction.

The behavior of consumers is seen as a key variable, since it is assumed to have a substantial impact on the amount of WEEE-collection. This includes awareness of proper disposal options, environmental awareness, but also accessibility of disposal sites or options, since convenience in WEEE-disposal can be assumed to have a large impact when it comes to proper disposal of old equipment.

The system used, as depicted in figure 3 will be explained in more detail and a chapter on data used will be provided. Due to the nature of illegal waste flows, assumptions and estimations regarding data will need to be made. (For accuracies sake, this will be pointed out whenever missing data occurs.)

2. Regarding WEEE

2.1. EU Waste Hierarchy

European waste management is built on the European Waste Hierarchy (Directive 2008/98/EC) ranking the Unions priorities regarding waste management into five categories. The goals of waste management are the protection of human health and the environment, conservation of resources and the provision of aftercare free disposal.

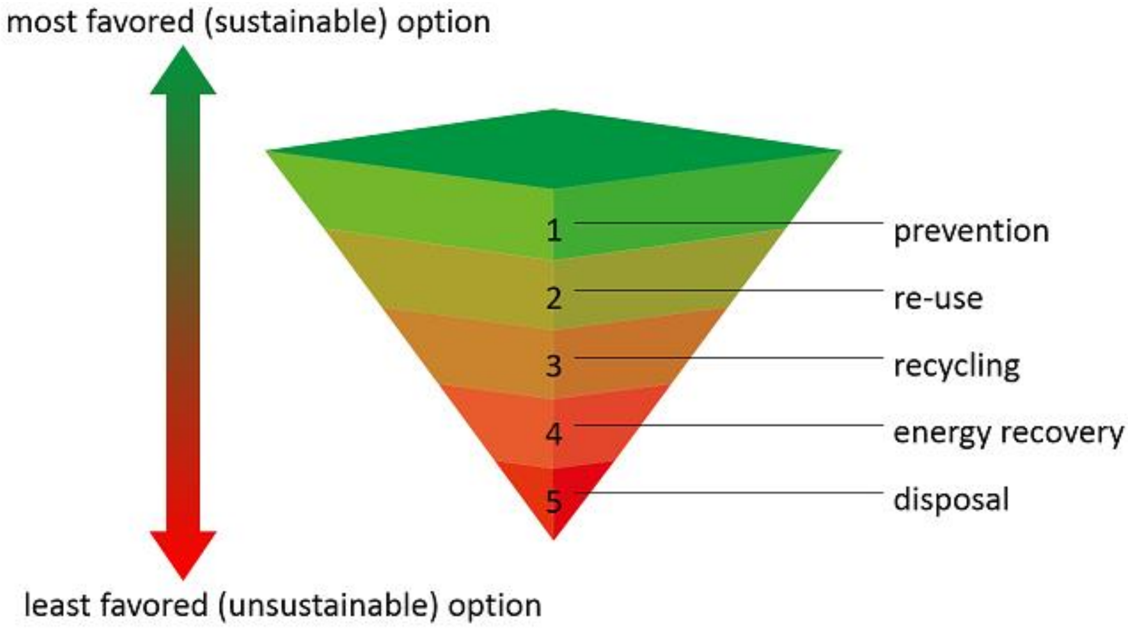


Figure 4. European Waste Hierarchy (Directive 2008/98/EC)

There further exist a number of EU directives on specific waste streams, such as the Directive 2012/19/EU on waste electrical and electronic equipment (WEEE), which has undergone a number of changes to adept to the individual EU members' positions.

2.2.Waste Legislation

2.2.1. Directive 2012/19/EU definitions and contents

Wastes, according to Krueger (2001), are by-products of industrial or household activity and they can come in gaseous, liquid and solid forms. Hazardous waste is a very general term covering a plethora of different materials, which are harmful to humans and the environment in one way or another. It is a by-product of manufactures or other types of production. Hazardous materials are commonly found in electrical and electronic equipment.

In this project the terms ‘e-wastes’, ‘WEEE’ and ‘electronic wastes’ will be used interchangeably. They all mean to denote WEEE as laid down in the EU WEEE Directive 2012/19/EU or in the EAK Waste Regulation, which states that “*electrical and electronic equipment (EEE) means equipment which depends on electric currents or electromagnetic field in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1000 volts for alternating current and 15000 volts for direct current*.” (EU Directive 2012/19/EU).

The focus is on WEEE stemming from private households, which are defined by the Directive 2012/19/EU as “*WEEE coming from private households and WEEE which come from commercial, industrial, institutional and other sources which, because of its nature and quantity, is similar to that from private households and users other than private households shall in any event be considered to be WEEE from private households*. “(EU WEEE Directive 2012/19/EU).

As mentioned at several occasions within this project, proper treatment, proper disposal or handling of WEEE is required. The member states of the European Union have to ensure that all separately collected WEEE undergoes the “proper” treatment, which, as a minimum, need to include the removal of all fluids and a selective treatment in accordance to Annex VII of the Directive 2012/19/EU. Furthermore, the Directive calls for an extension of producer responsibility beyond the end of life (EoL) of any EEE-product. “*Members shall ensure that producers or third parties acting on their behalf set up a system to provide for the recovery of WEEE using best available techniques*.” (Directive 2012/19/EU). However, the concept of producer responsibility will be outlined in more detail later on.

Very important for the project is the amount of knowledge and information the individual consumers of EEE regarding proper disposal options possess or have access to. Since it is assumed that awareness of the potential harmful impact of illegal waste flows to a receiving country’s environment, population and economic development will provide an additional incentive to make use of proper recycling facilities and services.

Article 14 of the Directive 2012/19/EU therefore concerns itself with information for users. It requires of member states that producers show purchasers, at the time of sale of new products, the cost of collection, treatment and disposal in an environmentally sound manner. It goes on to state the requirement “do not dispose of WEEE as unsorted municipal waste and to collect such WEEE separately” and it contains the phrasing “*member states shall ensure that users of*

EEE in private households are given necessary information about their role in contributing to re-use, recycling and other forms of recovery of WEEE". (EU WEEE Directive 2012/19/EU)

Important to mention is the extension of producer responsibility by the OECD, which is applied in the EU, and defined as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle.

The aim of the 2012-directive, is the reduction of WEEE-generation, which is in line with the EU's general approach to waste management of making waste prevention its main goal. Further focus lies on increasing the efficiency in collection, reuse, recycling and recovery of WEEE.

The directive aims to monitor WEEE by comparing the collected amount with the amount of products put on the market, which are to meet the collection targets set out in the directive. These were set at 4kg of WEEE per capita. However, a recent change has been introduced providing for individually calculated targets for each member state to adequately reflect their market conditions. A nation's market conditions obviously have a strong impact on the amount of EEE sold and therefore on the amount of WEEE produced. While the older version of the EU-directive still called for a collection quota of 4kg of WEEE collected per capita, problems arose due to the inability of a number of nations to reach the set amount of WEEE, leading to an increase in demand of foreign WEEE, to fulfill quotas and thereby possibly abating the increase of illegal flows of WEEE out of Austria.[1]

The directive further aimed at monitoring WEEE by comparing the collected amount with the amount of products put on the market, which are to meet the collection targets set out in the directive. A number of changes to the directive were included in the text and are now being introduced. For instance, the individual calculations for collection quotas have entered into force in 2016. Since the start of 2016 the collection quota for EU members is calculated individually. The minimum for WEEE collected is 45% of all EEE put on the market for the preceding 3 years, with the condition, that should the quota have already exceeded 45% in the past, that the collections rates are not reduced in the following years (EAK Tätigkeitsbericht, 2014). Starting from 2019 the percentile will be increased, so that 65% of the EEE put on the market during the preceding 3 years, have to be collected. Alternatively, 85% of the yearly generated WEEE need to be collected.

In prior years the EU-directive made use of 10 separate WEEE-categories listed below:

[1] Statement made by EAK during interview with EAK staff

1. Large Household Appliances
2. Small Household Appliances
3. IT and Telecommunications Equipment
4. Consumer Equipment
5. Lightning Equipment
6. Electrical and Electronic tools
7. Toys, Leisure and Sports Equipment
8. Medical devices
9. Monitoring and Control Instruments
10. Automatic Dispensers

This very comprehensive list of categories has been reduced to 6 categories:

1. Heat Exchange Equipment
2. Screens monitors, and equipment (with a surface >100cm^2)
3. Lamps
4. Large electrical appliances
5. Small electrical appliances (external dimensions<50cm)
6. Small IT and Telecommunications Equipment

Additionally, to this simplification of the EEE-categories, the producer responsibility already in place is extended. For instance, a producer has to have a branch within a country in which it intends to put its products on the market, which is also applicable for distance selling. The producers are also required to consider the recycling and/or final disposal options for their products, while developing them. The financing of the entire recycling and/or disposal cycle is also to be financed solely by the producers

The separation of WEEE from other forms of wastes, such as residual wastes, should be upheld to the best degree possible and EU member nations are required to readily provide disposal-recycle sites and options for a nation's EEE-consumers. Closely related, each member country is tasked with compiling a data sets including information of amounts, categories and respective producers of all EEE sold, recycled and disposed within the territory. The European Commission is to receive a thorough report on the WEEE-sector of each country every three years, outlining if the directive has been met. If the directive has not been met within one of these three year periods, the member countries are to devise sanctions for the breach (EAK Tätigkeitsbericht, 2014).

Due to the requirements put on producers and the simplification of the categories of WEEE, it has become easier to quantify the products which are put on the market and the WEEE generated from these products.

2.2.2. Austrian Waste Management in general

In the Republic of Austria, the Federal Ministry of Agriculture, Forestry, Environment and Water Management is in charge of all waste management related legislation. Under its obligations falls the drafting of the Federal Waste Management Plan (FWMP) in order to effectively implement the principles of the Waste Management Act of 2002 (Federal Act on Sustainable Waste Management).

In the general provisions of the Waste Management Act 2002, emphasis is put on the principles of precaution and sustainability in regard to national waste management. It states, for instance, that any harmful effects on humans, animals and plants, their base of existence and their natural environment shall be prevented or kept as low as possible. Provisions laid down in this legal text apply to the following: Waste quantities and their pollutant contents should be kept as low as possible, to conform with the goal of overall prevention of waste. '*Wastes should be* *recovered to the extent that this is ecologically reasonable and technically feasible, and that the additional costs of recovery are not disproportional by comparison with other methods of waste treatment and that there is a market or that a market can be created for the recovered materials.*’ (Waste Management Act, 2002, §1. (2)2.)

Should improper waste management lead to one or more of the following results, which are denoted as being:

- Hazardous to human health
- Hazardous to the natural loving conditions of animals, plants or soil
- Detrimental to the sustainable use of water or soil
- In excess of the inevitable pollution of the environment
- Fire or explosion risks
- Excessive sound or noise
- The appearance or multiplication of pathogens
- Disturbances of public order and safety, or
- A significant impairment of urban and rural landscape

then proper collection, storage, transport and treatment, as a public interest, is needed and should be provided.

The WEEE Ordinance (EAG VO) implements all requirements of the RoHS, it provides details on requirements for the content of CE conformity declaration for EEE, and regulates shipments of used EEE across the borders of Austria (ERA, 2014)

Federal Waste Management Plans are to be drafted at least every 6 years, after hearing the Federal Minister of Economic Affairs and Labor, the governors of the provinces, the Austrian Towns Association, the Austrian Municipalities Association, the Federal Chamber of Economics, the Diet of the Austrian Chamber of Labor, the Austrian Trade Unions Federation and the Conference of Presidents of the Austrian Chambers of Agriculture, the Federal Ministry of Agriculture, Forestry, Environment and Water Management. A Federal Waste Management Plan (FWMP) is comprised of (Waste Management Act 2002, § 8 (2)):

- An inventory of the waste management situation
- Regional distribution plants for the disposal of wastes
- Specific goals deriving from § 1
    - To reduce the quantities and pollutant contents of wastes

    - To provide the recovery of waste in a form that is environmentally sound and expedient to the national economy
    - To dispose of wastes that can be neither prevented nor recovered
    - To transport wastes to or from Austria for recovery or disposal, and
    - To promote the recovery of wastes, in particular with a view to the conservation of resources
- The measures planned by the federal government in order to reach the above goals
- Special measures for certain wastes, in particular treatment requirements and programs

FWMP can be seen as periodic amendments to waste management legislation, which are needed due to the inherent dynamism and constant development of the sector (FWMP, 2011). Electrical and electronic equipment in Austria is classified according to the Waste Electrical and Electronic Equipment Ordinance, Federal Gazette II No 121/2005, which is amended periodically.

2.2.3. EAK Waste Regulation

By the means of the WEEE Ordinance (2005), EU directives regarding WEEE have been transposed into Austrian law. In the following chapter the WEEE composition is going to be explained.

The EAK introduced the division of Austrian WEEE into 5 categories for collection and treatment:

1. Large Electrical Appliances
2. Cooling and Freezing units
3. Screens, Monitors, TV
4. Small Electrical Appliances
5. Lamps (Gas discharge lamps)

The exact break-up follows in the graphic below.

electronic appliances, each of which is characterized by complex designs and a wide range of different materials. Some of the more complex appliances can contain up to a 1000 different substances, ranging from hazardous materials such as mercury, cadmium, and lead which can have a negative impact on human, animal and plant life, as well as soils and water. Each category of equipment includes devices for specific purposes and of different material compositions.

Waste electrical and electronic equipment includes a large amount of different electrical and According to the FWMP published in 2011, large electrical appliances are composed of around 62.5% iron, 25% plastics and 12.5% non-ferrous metals with less than 1% of hazardous material, with the exception of monitors and refrigerators. This differs from the composition of small EEE, which display a higher amount of hazardous and critical material.

Table 1. EAG VO

Classification of equipment

Collection and treatment categories	Equipment categories pursuant to Annex 1	Recovery targets related to the average weight per appliance		Quantitative thresholds in kg for notifying pick-up needs
		Rate of recovery in %	Rate of re-use and recycling for components, materials and substances	
Large appliances*	Large household appliances (excluding cooling appliances, refrigerators, freezers and air conditioner appliances)	80	75	4000
	IT and telecommunications equipment (excluding display screen equipment)	75	65	
	Large lighting equipment (excluding gas discharge lamps)	70	50	
	Large electrical and electronic tools	70	50	
	Large toys, leisure and sports equipment	70	50	
	Automatic dispensers without refrigerating devices	80	75	
	Large medical devices	-	-	
	Large monitoring and control instruments	70	50	
Cooling appliances, refrigerators and freezers	Cooling appliances, refrigerators and freezers as well as air conditioner appliances	80	75	2000
	Automatic dispensers with refrigerating devices	80	75	
Display screen equipment, including appliances with cathode-ray tubes	IT and telecommunications equipment—screens (with cathode-ray tubes, LCD and plasma screens)	75	65	1500
	Consumer equipment—TV sets (with cathode-ray tubes, LCD and plasma screens)	75	65	
	Monitoring and control instruments—screens	70	50	
Small electrical appliances*	Small household appliances	70	50	1500
	IT and telecommunications equipment (excluding display screen equipment)	75	65	
	Consumer equipment (excluding display screen equipment)	75	65	
	Small lighting equipment (excluding gas discharge lamps)	70	50	
	Small electrical and electronic tools	70	50	
	Small toys, leisure and sports equipment	70	50	
	Small medical devices	-	-	
	Small monitoring and control instruments	70	50	
Gas discharge lamps	Lighting equipment (gas discharge lamps)	-	80	500

* "Large" appliances are those whose longest edge equals or exceeds 50 cm, and "small" appliances are those whose longest edge is less than 50 cm long.

Depending on the composition, different approaches regarding re-use, recycling have to be applied. Large electrical appliances, for instance washing machines and dryers, contain a large amount of common metals, such as aluminum an iron, important secondary sources of these metals for the steel industry. Large appliances are typically all appliances with a weight over 35 kg, such as washing machines, dishwashers, clothes dryers, automatic dispensers (without cooling units), electrical cookers, ovens and hobs (Huisman et al., 2007). To be better able to visualize the sheer amount of electrical appliances and better understand the need for choosing one specific category of focus, the following table, by Huisman et al. (2007), shows the average category composition of collected WEEE.

Table 2. Average category composition of collected WEEE in the EU, Huisman et al, 2007

No.	Description	Abbreviation	Subcategory	Category
1	**Large Household Appliances**	**(LHA)**		**49.07%**
1A	Large Household Appliances	(LHHA)	27.70%	
1B	Cooling and freezing	(C&F)	17.74%	
1C	Large Household Appliances (smaller items)	(LHHA-small)	3.63%	
2	**Small Household Appliances**	**(SHA)**		**7.01%**
2	Small Household Appliances	(SHHA)	7.01%	
3	**IT and telecom equipment**	**(IT&T)**		**16.27%**
3A	IT and Telecom excl. CRT's	(IT ex CRT)	8.00%	
3B	CRT monitors	(IT CRT)	8.27%	
3C	LCD monitors	(IT FDP)	0.00%	
4	**Consumer equipment**	**(CE)**		**21.10%**
4A	Consumer Electronics excl. CRT's	(CE ex CRT)	7.82%	
4B	CRT TV's	(CE CRT)	13.28%	
4C	Flat Panel TV's	(CE FDP)	0.00%	
5	**Lighting equipment**	**(Light)**		**2.40%**
5A	Lighting equipment – Luminaires	(LUM)	0.70%	
5B	Lighting equipment – Lamps	(Lamps)	1.70%	
6	**Electrical and electronic tools**	**(Tools)**	**3.52%**	**3.52%**
7	**Toys, leisure and sports equipment**	**(Toys)**	**0.11%**	**0.11%**
8	**Medical devices**	**(Med.)**	**0.12%**	**0.12%**
9	**Monitoring and control instruments**	**(M&C)**	**0.21%**	**0.21%**
10	**Automatic dispensers**	**(Aut.Disp.)**	**0.18%**	**0.18%**
	Totals		**100.00%**	**100.00%**

As seen above, large household appliances represent a large amount of the collected WEEE materials. Over the last years a steady increase in EEE put on the market could be observed. This, and the requirements regarding proper WEEE management that were introduced, such as mandatory separate collection of WEEE, obligation for municipalities, specialized retailers, manufacturers and disposal companies to take them back for no additional fees, and the increase in public relations work to increase awareness, have led to an increase of collected WEEE over the years. Market saturation in specific industry sections obviously affect collection rates as well.

In order to further increase the knowledge regarding the amount of EEE within Austria, section 23 Ordinance on Waste Prevention, Collection and Treatment of WEEE, manufacturers and importers of EEE are required to report the amounts they place on the market to the electronic register (EDM portal) by collection and treatment category (FWMP, 2011).

Collection of WEEE is fundamental in achieving an estimate of how many EEE-products are in use or hibernation. The waste is to be disposed of at collection centers, retailers or producers, and partially by the bulky waste collection for communities (Sperrmüll). Depending on material composition of WEEE, they might have to be disassembled in facilities which are able to prevent the release of possible harmful substances and have a high resource recovery rate. This process is specifically challenging for the small electrical appliances. For instance, within a single cell phone more than 200 chemical compounds can be included (Nordbrand, 2009). Large electrical appliances are commonly shredded, after all possible harmful substances are removed, and separated into ferrous and non-ferrous metals. WEEE contains many diverse appliances and therefore requires a high standard of waste management related technologies, however, there also flows in a high amount of manual labor, making it a costly affair.

The WEEE ordinance (EAK VO, 2005) firmly places the responsibility for wastes stemming from EEE with the producers. They are responsible for financing the collection (from the collection point) recovery of materials, and disposal. More specifically, the producers and/or importers need to ensure the environmentally sound recovery and treatment of the collected WEEE. Furthermore, producers also have to establish working public relation works to inform consumers and companies of disposal options.

Not all WEEE, however, is collected through the proper channels due to a number of reasons:

- WEEE with high waste iron components, especially large appliances, might be included in bulky waste collection (Sperrmüll), although this does not necessarily lead to a loss of resources, since such wastes will be collected with other waste iron. However, with recent enhancements to producer responsibilities, the amount of WEEE in bulky waste collection is declining

- Labeled “exports” by the FWMP (2011), some WEEE enter neighboring countries, especially WEEE components with high metal share, since it can be sold there. The amount of such flows of WEEE depend on the prices of materials in question

- Operational equipment, if still functioning, might be exported in order to be reused in other countries

- EAK estimates that around 1% of residual waste is made up of WEEE (small appliances, batteries and such)

- Hibernating equipment remaining in the household. If an appliance is still in working order, but has been replaced by a newer model, for instance, the old one might be kept at home as a backup or similar reason

- Product innovations generally leading the population to have more electrical appliances in a household

One of the more recent amendments to the WEEE ordinance (EAG-VO) includes the newly edited Restriction of Hazardous Substances directive (RoHS directive, 2002) encompassing additional restrictions regarding the use of hazardous materials.

2.2.4. RoHS Directive 2002/95/EC

The directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS directive) aims at an approximation of the laws of the member states on the restriction of the use of hazardous substances in EEE, in order to protect human health and the environmentally sound recovery and disposal of WEEE by reducing the amount of hazardous substances used in the production of EEE (RoHS directive, § 1). Ever since it became apparent that the improper disposal and treatment of WEEE could lead to negative impacts on human health and the environment, the RoHS directive has been revised to decrease the amount of WEEE that is disposed of in favor of reuse and proper recycling.

The new RoHS directive 2011/65/EU (RoHS 2) and following amendments to the directive, required the members of the union to transpose new provisions into national law by 2013, which Austria has been able to do.

2.2.5. Producer Responsibility

The principle of producer responsibility is a "concept that manufacturers and importers of products bear a degree of responsibility for the environmental impacts of their products throughout the products' life-cycles, including upstream impacts inherent in the selection of materials for the products, impacts from manufacturers' production process itself, and downstream impacts from the use and disposal of the products. Producers accept their responsibility when they design their products to minimize the life-cycle environmental impacts and when they accept legal, physical or economic responsibility for the environmental impacts that cannot be eliminated by design" (Davis, Gary, 1994).

Within the EU the principle of extended producer responsibility is applied. It is defined by the OECD as an environmental policy approach in which a producer's responsibilities are extended to cover the post-consumer stage of a product's life cycle (OECD, 2001; Widmer et al., 2005). The intention of extended producer responsibly is to encourage producers/designers of products to take the environmental aspects of all stages of a products life cycle into account, thereby reducing material use and increase re-usability and recyclability. Producer responsibility adheres to the 'polluter pays'- principle taking some of the burden of municipalities and distributing them to the producers of EEE. In the following table possible example for approaches to extended producer responsibility are listed.

Table 3. Possible approaches to EPR; according to Widmer et al., 2005

Type of EPR approach	Examples
Product take-back programs	Mandatory take-back
	Voluntary or negotiated take-back programs
Regulatroy approaches	Minimum product standards
	Prohibition of certain hazardous materials or porducts
	Disposal bans
	Mandated recycling
Voluntary industry practices	Voluntary code of practices
	Public/private paternerships
	Leasing and "servicizing"
	Labelling
Economic instruments	Deposit.refund schemes
	Advance recycling fees
	Fees on disposal
	Material taxes/Subsidies

The principle is included in the EU's WEEE directive and allocates responsibilities to producers, distributors and stakeholders involved in the production of EEE. It is transposed into the law of individual member states, at times applying different interpretations of the term "producer", which leads to deviations of producer responsibilities in the member states.

In Austria, producers are responsible for environmental impacts of their products starting from resource extraction to recycling and disposal. Furthermore, they are required to finance and arrange collection and all necessary activities of products that have reached the end of their life span, such as recycling treatments and disposal.

A producer of EEE in Austria is required to:

- Add the crossed out bin symbol on all EEE products
- Join a compliance scheme for household EEE (does not apply to all producers, exemptions are to be found in the WEEE ordinance)
- Register with the Electronic Data Management System
- Submit data and proof of compliance

- Treat WEEE in accordance with the Waste Treatment Obligations Ordinance (this is fulfilled with the joining of a compliance scheme)
- Comply with the RoHS directive
- Keep records to prove compliance with EU regulations

Furthermore, all products placed on the market must bear the EEE symbol, so consumers are aware of the need for separate collection of the product (Valpak, doing business in Austria).

2.2.6. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal

The motivation for the Basel Convention and the Basel Ban are rooted in the *concern that some countries' institutions are incapable of providing their citizens with their desired level of "environmentally sound management" of hazardous waste, and that those countries are better off limiting their imports through international treaties* (Kellenberg and Levinson, 2014).

The Basel Ban's guiding principles include the provision that hazardous waste should be reduced to a minimum, be managed in an environmentally sound manner, and be treated and disposed of as close to their source as possible (Aulston, N.J., 2010). Granted, this is formulated in a very general way, in order to reach an agreement that developed countries were actually willing to accept, but a reduction in hazardous waste trade was achieved. The complete eradication of illegal transfers between members to the convention, however, has not been achieved, and is not feasible.

There exist many different hazardous materials, many of which are components in the manufacturing of EEE. The list of hazardous materials is constantly updated, due to the fact that new substances and materials are developed frequently. The materials are grouped together in different categories, depending on their characteristics. The first group consists of wastes exhibiting one, or more, of the following properties: flammability, reactivity, corrosiveness, and toxicity. The second group contains materials which have been classified by the parties to the convention, as being hazardous for some reason or other. In the framework of the Basel Convention, hazardous waste classifications are laid down in Annex I, Annex II, and Article 3 of the convention.

The problems of trade in hazardous waste, and WEEE are classified as hazardous, arise from the specific properties of these wastes. Hazardous wastes cannot be easily dealt with through the use of resource recovery- or recycling operations, reclamation, direct use, alternative uses, or land fill operations (Aulston, N.J., 2010). In the Basel Convention the term hazardous waste is defined on the national level and are included in Annex I and Annex II to the convention. Further, article 3 requires parties to the convention to inform the secretariat of any other definition of hazardous material that is not already in the above mentioned annexes. Hazardous wastes include heavy metals, such as mercury, cadmium, or lead. Other hazardous wastes contain chemicals and organic wastes.

The Basel Convention's general obligations include a minimization of generation and transboundary movement of hazardous waste. The Basel Ban prohibits any transfers of hazardous wastes to non-countries. Article 10 of the convention, requires the parties to cooperate in the development and implementation of new low-waste technologies with a view to eliminating the generation of hazardous wastes (Kummer 1992).

3. Illegal Waste Flows in general

In order for a waste flow to be deemed illegal the following has to hold true in the Republic of Austria, as laid down in the Waste Management Act of 2002. As soon as the intention of disposal exists, and it is acted upon this intention, without providing a deed of purchase and proof that the device is still functioning, the export is deemed illegal (Waste Management Act of 2002).

Countering WEEE Illegal Trade (CWIT) is a project providing recommendations to the European Commission on how to assist stakeholders in countering illegal trade of WEEE, within and from Europe (CWIT Report, 2015).

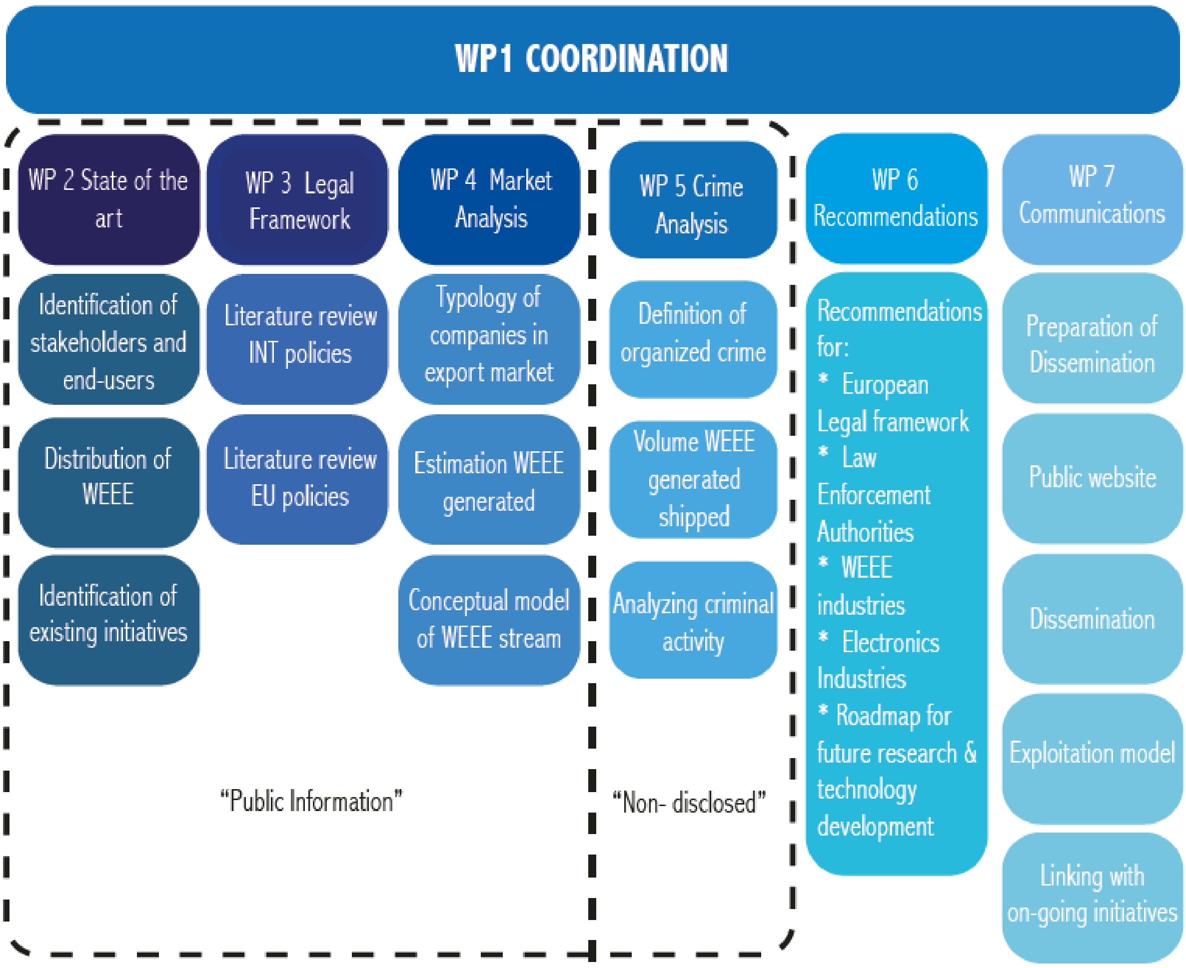


Figure 5. CWIT Work Packages, Source CWIT Report, 2015

The project involves estimating the volume of WEEE which is generated in Europe, identify actors in the WEEE-export sector, examine the legal framework related to WEEE and its implementation within and outside the European Union, analyze the involvement of organized crime in the global distribution of WEEE, and investigate the methods used in illegal WEEE trade in general. The project consists of 7 work packages each which its specific objective. The figure below gives an overview of the individual work packages (WPs) of the project:

The first WP is entitled management and coordination (Interpol). It coordinates and monitors the project. The second WP, WEEE Actors and Amounts (WEEE Forum), aims at providing an overview of the WEEE industries of the member states as well as relevant actors therein. WP3 covers the legal framework (compliance and risks) building on the data provided by the information gathered in the previous WP. WP3 compares the different national political and regulatory environments on best policies aimed at countering the illegal trade of WEEE. WP4 conducts market assessment and provides an analysis of the industries surrounding all things WEEE. WP5's objective is crime analysis and conducted a study on the involvement of organized crime groups in the global distribution of WEEE. WP6 provides for recommendations to policy makers, compliance and law enforcement authorities and industries.

To make certain that the project's results where to have an impact on the EU, WP7 works on dissemination of the project's results and findings.

Typical actors in the WEEE chain are depicted in the figure below.

The CWIT estimated that in the year of 2012 the total amount of WEEE generated in the EU-28 plus Norway and Switzerland, was 9.45 million tons. Of this total amount however, only 3.3 million tones are officially reported as collected and recycled. About 750,000 tons (small appliances) are estimated to have ended up in the residual waste (CWIT Report, 2015).

Form the overall amount another 2.2 million tons are assumed to stem from steel dominated consumer appliances which are collected and processed under non-compliant conditions with other scrap metals leading to potential losses of rare earths and precious metals. There are now still 3.2 million tons of WEEE unaccounted for, with a slightly over half of it assumed to be processed within the EU and the rest is assumed to be exported from the EU to third countries.

An example of how this can have and negative effect on individual economies due to loss of resources and also on the environment are fridge compressors, which are stolen before collection. CWIT estimates that about 84,000 tons of fridge compressors are stolen before collection, which is *equal to the CO_2 equivalent of 5 million modern passenger cars on the road annually* (CWIT Report, 2015).

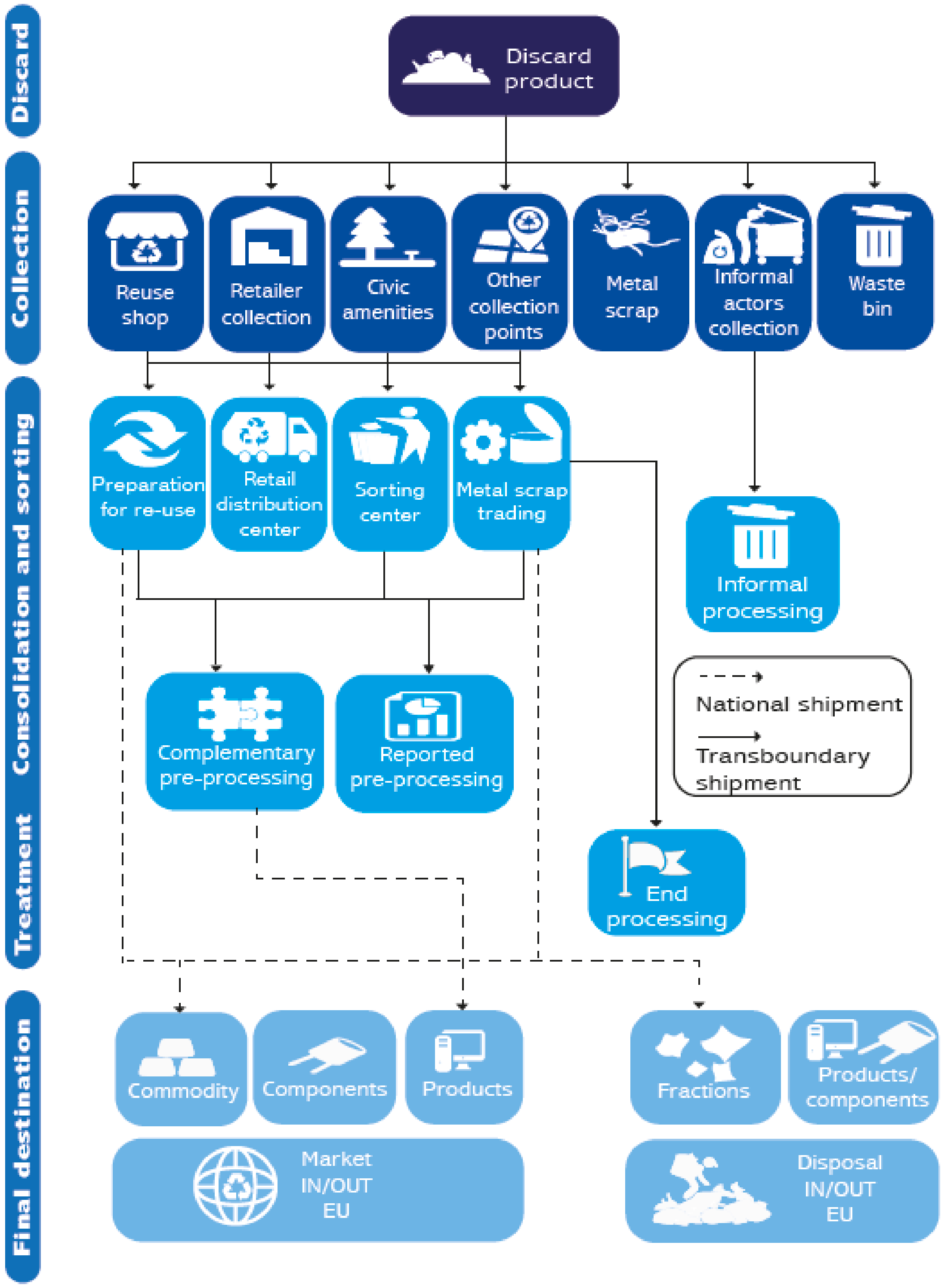


Figure 6. CWIT Project, Actors in WEEE chain, source CWIT Report, 2015

Even though there exist a plethora of regulations on how WEEE is to be collected, treated, recycled and disposed of, large amounts of e-wastes remain unaccounted for every year. A non-quantified number is illegally exported out of Austria. In this project the main focus is put on WEEE (category of large electrical and electronic appliances) which leave Austria and are predominantly bound to head east, toward the EEC and Balkans. However, it is important to also discuss illegal wastes streams of WEEE, which are bound for newly industrializing- and developing countries, predominantly situated in Africa or Asia. When arriving at such destinations, they can exhibit negative effects on human health and on economic development. While the effects of for instance mercury poisoning is felt "only" locally, it is important to raise awareness in the countries of origin to help decrease the amounts illegally shipped.

In both cases, the illegal transfer of Austrian WEEE consisting of large appliances and the international transfer of more hazardous WEEE to non-OECD countries, raising awareness at home is important, not because it is the individual household who conducts such activities, but they are in a position to demand more insight and monitoring in what happens to WEEE after it is collected by producers.

Just to clarify, export of waste, especially e-wastes and other hazardous wastes, to countries with sophisticated and save recycling and disposal capabilities may be economically as efficient as trade in any other normal good. However, if the waste is exported to a LDC, environmental problems can be created. In these areas recovery of components and WEEE disposal is carried out by informal sectors under unsafe working conditions and lacking environmental standards.

Developed countries, such as the EU member states and other OECD countries, are major generators of e-waste. The more stringent regulations in these nations results in higher disposal costs, which has led producers or authorities responsible for disposal of hazardous materials to seek for cheaper disposal options abroad, and developing countries import such wastes to attract money. *The poorest and weakest countries riddled with international debt and other problems such as famine and war, have been desperate for foreign exchange,* which they could get by accepting hazardous wastes into their countries (Clapp, 1994).

The incentives for illegal transfers of hazardous wastes is explained in more detail by Kempel (1999) who states that the reasons for illegal trade in hazardous waste can be traced back to the following.

- Producers of such wastes, who want to dispose of it as quickly and cheaply as possible
- Transporters of such wastes, who are having a hard time to officially import wastes due to public resistance, and the unwillingness of governments to deal with the unappealing and difficult question of dealing with hazardous wastes, which is unpopular, complicated and very costly.

Different countries have different regulations and the more developed the country, the more stringent are the regulations, as well as public scrutiny on local waste management facilities. For instance, in Austria, Germany and Switzerland a ban on landfills with untreated wastes is in force, requiring these countries to have adequate treatment facilities for waste, increasing costs of disposal, while benefiting society and the environment.

Generators of wastes, firms more so than households, have an economic incentive to side-step these stringent regulations and the connected costs. Alternatively, to dumping wastes domestically according to proper procedure, it is more profitable to make use of already established trade routes in order to move dangerous wastes to countries with less stringent restrictions or regulations (Aulston, N.J., 2010).

Trade in hazardous wastes, illegal and legal alike, have been encouraged by global economic relationships (Clapp, 1994). Just as trade in other goods has been made easier thorough the application of new technologies, such as in the areas of transport and communications, the reduction in costs of moving hazardous wastes around the globe, has increased the traded volume immensely. This would not be a problem per se, if all countries and regions shared the same capacity for appropriate disposal of hazardous wastes. Then it would be efficient to ship wastes to the location where its disposal was the most cost effective. However, since the cost advantage in waste disposal of developing countries stems from a lack of regulation and lower environmental standards, social costs of such trade is not included in the calculation, leading to trade distortions.

The 1980s and 1990s saw a huge increase in hazardous waste dumping operations conducted by firms of developed countries in poorer regions, especially Africa, Southeast Asia and Eastern Europe. Many such cases of toxic trade came at an immense social cost to the importing states. The populations of such areas where negatively affected and the illegal dumping practices attracted international attention. In order to escape scrutiny, imports were intentionally mislabeled and brought into countries as “goods for further use”, or even as international aid (Clapp, 1994).

Over the years a number of similar cases were found out and brought to the attention of the media. In 1998, 3000 tons of mercury-contaminated industrial waste was found in an open dump in Cambodia. The official import documents stated that the waste was “cement cake” (Krueger, 2001). A similar case occurred in 2000 when the Japanese government was forced to take back 122 containers of hospital wastes illegally exported to the Philippines as “waste paper for recycling” (Krueger, 2001).

3.1.Illegal Flows of Waste: Environmental Case study

The following section will give a more detailed overview of the impact of illegal transfers of hazardous wastes in developing countries.

The rise of trade in electronic waste is posing the newest challenge for LDCs and so far the Basel Ban has not been able to adequately address this problem (Aulston, 2010). One way of side-stepping regulations, as they are laid down in the convention, is the (intentional) miss-labeling of wastes or misleading classification of wastes as intermediary goods.

Especially in the rapidly growing sector or WEEE trade, this is leading to renewed problems with illegal, hazardous dumping sites located in LDCs. An exporter, for example, is looking to avoid fees associated with recycling hazardous electronics in the home country and the receiving country appears to be getting economic and technological opportunities, by being given these electronics from the advanced country. These electronic wastes are then recycled in countries using dangerous low-tech methods leading to health-and environmental damages. In order to identify illegal transfers of hazardous wastes it would be necessary to comb through the databases in question, such as Comtrade and Eurostat, and check for inconsistencies with customs authorities of the countries in question. Then there are also other possible explanations for data inconsistencies, rather than illegal trade. For instance, wrong or different product codes might have been used. This can happen easily due to differing categorizations of hazardous materials by the different nations. Time lags in data reporting can also result in discrepancies, as well as the wrong indication of the country of origin instead of the country of dispatch by importing countries, especially in the UN-comtrade database (EC Report, 2015; Eurostat Eurostat, 2015). Exporters, however, can also intentionally mislabel the commodity in question, in order to side-step the regulations and illegally export hazardous materials.

There exist three categories of thread that can be distinguished when dealing with e-waste. First, there are environmental disruptions, including pollution of soil and water, emissions of greenhouse gases (GHG) and thinning of the ozone layer, negative impact on flora and fauna. Secondly, there are substances that have negative impacts on human health, such as toxic metals, ultraviolet radiation affecting respiratory and digestive systems, cancers, etc. The third category is socio-economic impoverishment, including increased cost for public health, reduced agricultural productivity, food insecurity and poverty (UNEP, 2009).

E-waste should be disposed of by using specialized recycling facilities, however, often the waste is then sold on the black market, due to a lack of oversight and the general profitability of such operations. Incentives to dispose of e-waste in this fashion is the possibility of side stepping the costs of legitimate recycling and the payment one can get from the scrap equipment via alternative channels (UNEP, 2009). The European Union promotes recycling to reduce the amount of e-waste with the Waste Electrical and Electronic Equipment Directive, in order to reduce the amount of e-waste in landfills within the Union. The main sources of e-waste, however, still are the EU, the US, and Japan. The destinations can mainly be found in Asia, Southeast Asia and India.

UNEP estimates that around 70% of scrap electronics are brought to China, meaning that about 8 million tons of e-waste are smuggled into China very year, even though trade in e-waste is covered by the Basel Convention and Basel Ban, as well as other agreements aimed at the reduction of trade in hazardous wastes between developed and developing countries. Information regarding flows of e-waste are based on seizure data and reports by media and NGOs. Official sources of information of government agencies are either incomplete or confidential. The Secretariat of the Basel Convention is supposed to receive information from parties (Article, 13, 16), however, the practice of reporting is sporadic and not comprehensive. Krueger (2001) similarly stated that the quality of information available to the Convention Secretariat is dependent mostly on reports from parties – *who may or may not be able to detect and report cases of illegal trafficking – and therefore the state of knowledge about actual volumes of trade flows in hazardous waste is sketchy at best*.

The problem surrounding WEEE is further complicated, since the proportion of legally traded goods ending up in landfills properly treated, and the illegally traded waste flows can both not be accurately estimated. At the same time, it is of great concern to populations and the environment, due to the presence of toxic materials which can be hazardous. For instance, CRT monitors contain up to 2kg of lead, but additionally to this highly toxic metal it contains commercially valuable elements (copper, gold…). In the US, the save removal of lead from such a device costs around 18$, while disposing of it illegally can yield between 200-400%

saving compared to proper disposal. It is also pointed out that the profitability of e-waste smuggling is largely due to the ease and low cost of shipping containers from the US or EU, to China (UNEP, 2009).

Mercury is also commonly found in WEEE. It occurs naturally and has broad application in everyday objects and is released to the atmosphere, soil and water from a variety of different sources. It is a metallic element occurring in the environment and finds application in industries for the production of chemicals or as a catalyst for chemical processes (Honda and Li, 2008). LCD backlights, lamp components, display panels and many other e-wastes contain mercury in relevant to dangerous amounts.

A number of developed countries have started to phase out the use of mercury in electronic devices, due to rising environmental awareness of hazardous chemicals within the population. Honda and Li (2008) make an account of the dangers of mercury contaminated or containing waste and the improper handling thereof. Once mercury has been released into the environment, it stays there permanently and cannot be converted to a non-mercury compound. Mercury over-exposure is especially dangerous for infants and easily penetrates through the food chain.

3.2.Case Study Review: Health Impacts of illegal WEEE flows abroad

In order to mitigate the negative effect of mercury contamination as a result of illegal trade in hazardous waste, according to Honda and Li (2008) is, to create a public-private partnership under a legal framework and through investment in environmentally sound technologies. The countries most affected by the degradation of their environment due to such illegal activities would benefit greatly from an extension of technology transfers, in order to equip their informal recycling sector with environmentally sound technology.

Another grave problem is that the people working in these informal sectors on a local level, are usually poor and lack access to proper education and therefor suffer from a lack of knowledge regarding the danger that working with mercury contaminated materials encompasses. By not knowing how to properly handle sensitive materials, it is very likely that the people working with them cause breakages and releases of the dangerous material themselves, therefore suffering from the effects themselves and unknowingly spreading the material themselves.

The informal recycling industry is a key factor in waste management in developing countries. While the recycling industry in developed countries is fully established and regulated, it continues to not be controlled, or only weakly controlled, by legal systems in developed countries. It repairs, and refurbishes e-waste in small workshops. They deal with hazardous wastes as well as general wastes in an environmentally unsound manner, due to a lack of education, technology and knowhow. This informal sector needs to be complimented by a governmentally run environmental education program, which will help educate people on the dangers of the materials they work with, so they can implement protective measures.

Since it appears obvious that a country which has to rely on an informal sector for waste management, that there is a problem to finance such programs, this has to be covered by international organizations, NGOs, and donors. Honda and Li (2008) further state that it would be wise to aim at a division of competences of sorts, between a countries informal sector and public sector. An example would be wastewater treatment. The informal sector does not have the resources to employ waste water treatment facilities and with the uncontrolled discharge of waste water contamination of soil, ground water and the food chain follow. Same applies to landfill sites. If the public sector would be able, with international help or on its own, to provide treatment facilities, such contaminations could be reduced. All of this suggestions for solutions are of course highly optimistic, nonetheless, it is good to review them and, with time, it might be possible to gather enough international momentum to achieve such programs.

All of this still does not, entirely, address the problem of illegal transfers. While most of the material that is processed by the informal sectors in developing countries, undoubtedly got there via some kind of shady activity, within the country this is usually a relatively well-established sector.

To achieve this, it is proposed by Honda and Li (2008) to actively support the informal recycling industry of developing countries, in order to build them up, with possible implications that these sectors will over time become established as part of the formal sector.

4. Methodology

4.1. Data: Official EAK Data and EAK Interview

Due to the illegal nature of trade in WEEE it is difficult to gather accurate data for the use in models such as a Material Flow Analysis. Across the EU, individual member states employ a diverse range of legislative and national instruments to implement EU directives, which results, in addition to many other factors, in variations regarding data of EEE put on market, WEEE collected and recycled.

Within the Republic of Austria, the EAK is responsible for data collection regarding EEE, collection of WEEE, recycling and disposal of WEEE, as well as gathering data on missing WEEE-materials. Data regarding illegal transfers are estimated making use of spot-checks at borders, which are carried out by members of the EAK and the executive organs, or academic institutions such as University departments in cooperation with the executive. The data used in this project stems from official EAK-data which are modified with factors discussed during a meeting with members of the EAK.

An EAK-official stated that roughly one quarter (24%) of the WEEE of the category large electrical appliances are leaving Austria illegally. It was pointed out that the amounts of larger electrical appliances that are illegally transported out of the country varies and is especially sensitive to changes in prices of resources which make up the appliances. For instance, when the prices for steel are high, it can be assumed that the amount that goes missing will increase and vice-versa.

The model used for visualizing the flow of WEEE, in this project large electrical appliances, through an Austrian household will be a Material Flow Analysis.

4.2.MFA- Model (input-stock- output model)

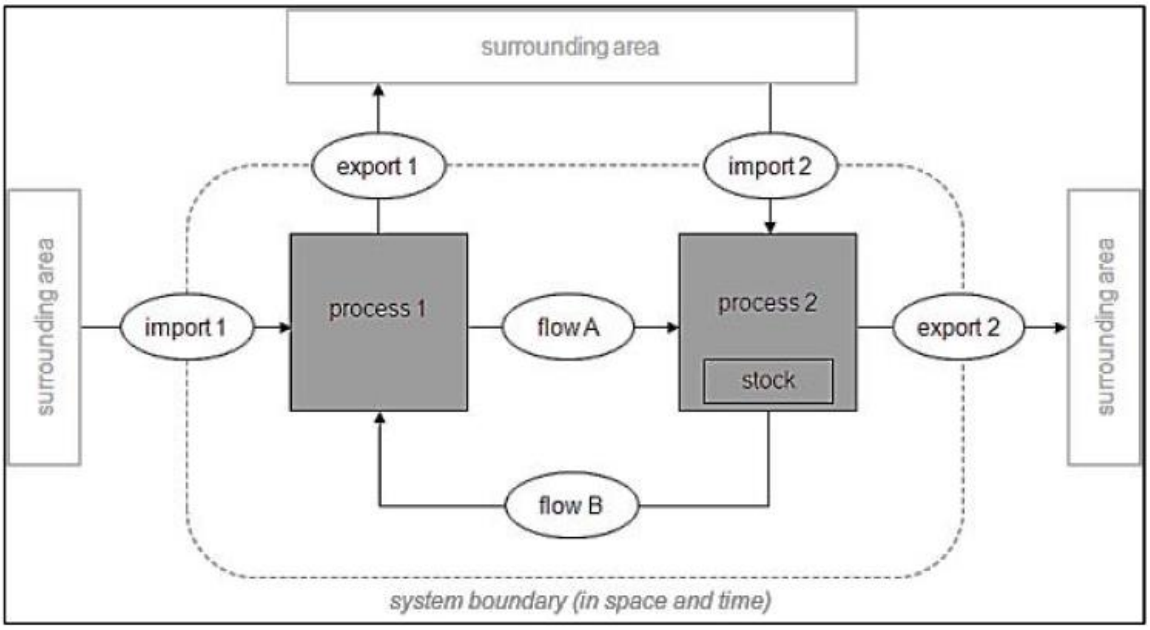


Figure 7. Typical MFA, source Cencic, 2012

The model after Baccini and Brunner (2012), Mass flow analysis (MFA) is an assessment of goods and substances, which flow through a given system with set boundaries. Brunner and Rechberger (2004) state that a MFA is a systematic assessment of the flows and stocks of materials within a system defined in a certain space and time.

MFA is used in the quantification of stocks, flows, inputs, and losses of resources. When it comes to studies regarding WEEE, the use of MFAs has proven to be popular, mainly because MFAs can involve a number of aspects, such as environmental, economic, infrastructural, social and legal ones (Kiddee et al. 2013; Panuzzo, 2014). Often it is used to quantify the flows of a specific resource or substance, but it can also be used for mixed materials.

MFAs are heuristic procedures which are modeled by computer-based-models, such as STAN, short for substance flow analysis.

This methodology is employed for a number of reasons such as:

- Analytical reasons (early recognition, monitoring)
- Decision support
- Problem solving
- Designing new/improved processes and systems

4.3. Definition of the Material Flow Analysis

System borders have to be defined in order to establish the boundaries of an MFA. In this project the system will be simplified. The (Austrian) private household is choses as the system boundary. A household is important since it is the consumer who decides which large electrical appliances are purchased and therefore the private household determines the how many larger electrical appliances are supplied by producers. Once a large electrical appliance enters the system, the household, it enters into use or stock and is exported out of the system afterwards.

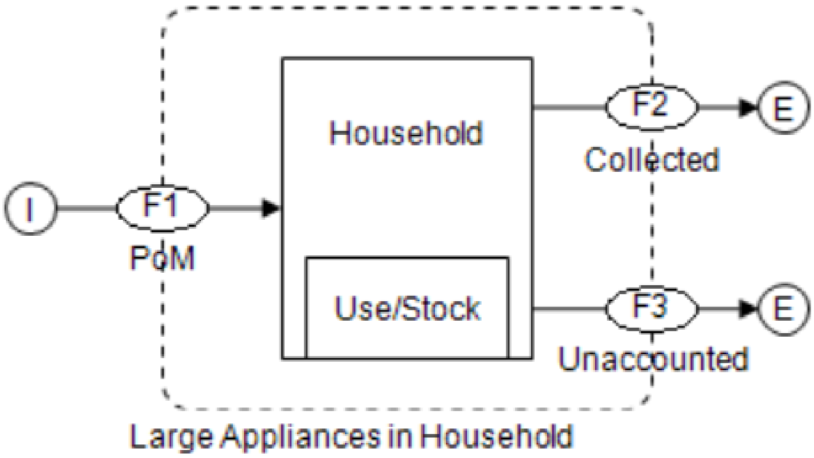


Figure 8. Simple MFA, own design

The time period applied here is one year (2014), however, the lifespan of a large electrical appliance within a private household is approximately 12 years. As a further simplification, the 12-year life span is omitted and the data for large electrical appliances put on the market and collected for the year 2014 will be used. The amount that remains in the system as stock within the time period is uncertain, due to a lack of data for this project. This has to be noted to be a weakness of this project. To not be able to include stocks within the analysis does falsify the outcomes.

The amount of appliances put on the market is known with a quite high degree of certainty, as well as the amount of collected appliances. In order to gage the amount which enters the illegal flows the following approach is used. Since the EAK estimated that about one quarter of large electrical appliances enter illegal flows, a simple methodology will be used, assuming that 24% of the initial input minus the collected output will enter into the unaccounted WEEE flow. Unaccounted does not necessarily mean they that the WEEE has been transported out of the country, but could be unaccounted for other reasons, such as improper disposal of the old equipment.

The legal definition of private household important for WEEE- management are laid down in the WEEE Ordinance (EAG VO) includes all EEE:

- EAG VO, article 7: electrical and electronic equipment intended for private households means:
  - Intended for private households
  - For commercial, industrial, institutional and other users which, because of its nature and quantity, is similar to that for private households
  - Electrical and electronic equipment which is not similar to electrical and electronic equipment for private households at the time it is put on the market, but which is comparable with WEEE from private households with regard to potential waste generation (dual-use equipment)
- EAG VO, article 8: waste electrical and electronic equipment from private households means:
  - EEE for private households which is considered waste

4.4.Material Flow Analysis of WEEEE (large electrical appliances) in Austria

The time frame for consideration are the years 2013 and 2014, during which an increase in collection of WEEE has been achieved. The data has been provided by the Elektroaltgeräte Koordinierungsstelle Austria GmbH (EAK). For the MFA and the estimation of missing WEEE of the category large electrical appliances only the year 2014 will be considered.

Due to EU- and national legislation the data for EEE put on the market and collected available are quite comprehensive.

The amount of EEE put on the market has been increasing over the past years. From 2013 to 2014 it rose by 5,63% (EAK, 2014). The Amount collected in the same time period has increased by 0.96%. In 2014 about 73.375 t of WEEE were collected, with 18.559 t belonging to the category of large electrical appliances.

Once the EEE enter the system, which is a private household in Austria, it becomes difficult to estimate the total exports that leave the system. This is due, first and foremost, to the fact that the large electrical appliances will remain in the system for a certain time span. Electrical and electronic equipment have a life span of approximately 12 years for large appliances. It is difficult to estimate how much of WEEE is leaving the system and enters an illegal waste stream, and how many appliances are currently in use, or possibly even hibernating within the system. Additionally, the stocks that have already been accumulated prior to the year 2014 are unknown.

Due to the amount of uncertainty within the data, a simplification will be assumed and applied, but it has to be kept in mind that the resulting numbers for illegal flows remain rough estimates.

Since hibernation is not assumed to be much of an issue when it comes to large appliances it will not be considered here. During an interview with the staff of EAK, it was estimated that about 24% of large electrical appliances sold in Austria enter into an illegal waste flow. Therefore, it will be assumed that 24% of the number of EEE put on market minus the amount of the properly collected WEEE, enters the illegal flow of WEEE, while the rest remains in the system.

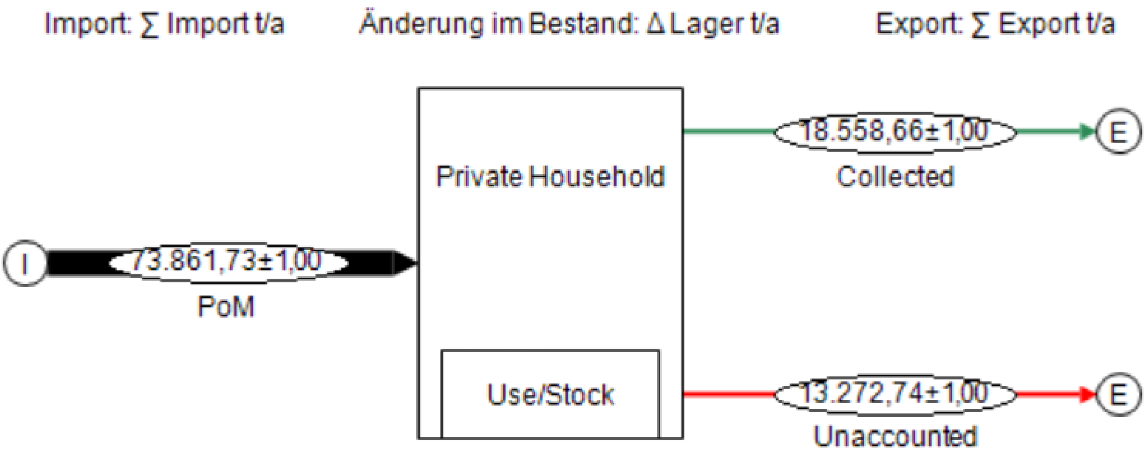


Figure 9. MFA, Large Electrical Appliances in Austrian Households

The amount of approximately *13273* tons of large electrical appliances per year is estimated to enter some form of illegal waste stream.

5. WEEE Recycling

The proper recycling of WEEE is challenging and important due to the presence of hazardous materials in the products and the potential for re-use of materials in industries, leading to more cost effectiveness and less environmental impacts. The notion of sustainable use of natural resources as inputs centuries ago, when increasing industrial activities consumed large amounts coal and wood (Winterstetter et al., 2015). The effectiveness of resource recovery, or urban mining, from WEEE depends on a number of factors, such as legal conditions as present on a European and state level, the collection system, and the recycling system. The recycling chain includes a number of steps through which the WEEE has to go. Usually these steps include sorting, dismantling, pre-processing, and end-processing, with the application of different treatment technologies, according to the type of material that needs to be treated (Winterstetter et al., 2015; Chancerel et al. 2009). The higher the prices for the output fractions are on the market, the more efficient the recovery of the materials in question will be, since the market price covers the treatment costs and-or the costs of disposal are avoided.

Handling WEEE does not only have a potential harmful effect when it enters the informal sector in a country without proper waste management capabilities, but also when WEEE are recycled in the EU or Austria. According to Julander et al. (2014), only about 10% of the e-wastes produced globally are recycled in plants that are appropriately designed to reduce exposure of harmful substances, both on a technical scale and from a worker's health point of view.

The amount of hazardous material in e-waste is quite large and range from toxic and allergenic metals and chemicals, such as brominated flame retardants, polychlorinated biphenyls, antimony, arsenic, beryllium, cadmium, chromium, cobalt, indium, lead, mercury, nickel, and. It was shown that workers employed in three Swedish WEEE-recycling plants were exposed to higher air concentrations of the metals tested for than officer workers employed within the same plants thallium (Julander et al., 2014). This again shows how important adequate handling of WEEE is, and how much potential for negative impacts on human health and the environment improper management of illegally exported WEEE holds.

WEEE consist of heterogenic materials including hazardous and critical materials, especially in regard to products that find use in the IT- and communications sectors. The precious metals and critical materials used in such products are gold, silver, palladium, indium, selenium, tellurium, tantalum, bismuth, antimony, etc.) However, the focus of this project lies on WEEE consisting of the category large appliances, which consist mainly of iron, other nonferrous metals, and plastic. As can be seen in the simplified recycling chain for WEEE by Chancerel et al. (2009), an integral part of WEEE-management encompasses the recovery operations of raw materials from the WEEE. First, e-waste is collected, then preprocessed and then disposed of. The step of preprocessing encompasses the generation of materials from the collected WEEE in recovery facilities. In order for the materials recovered from the processed WEEE to be able to be sold on, they have to be concentrated to create a material stream to the end-processing stage, which in the case here would be the Austrian steel industry.

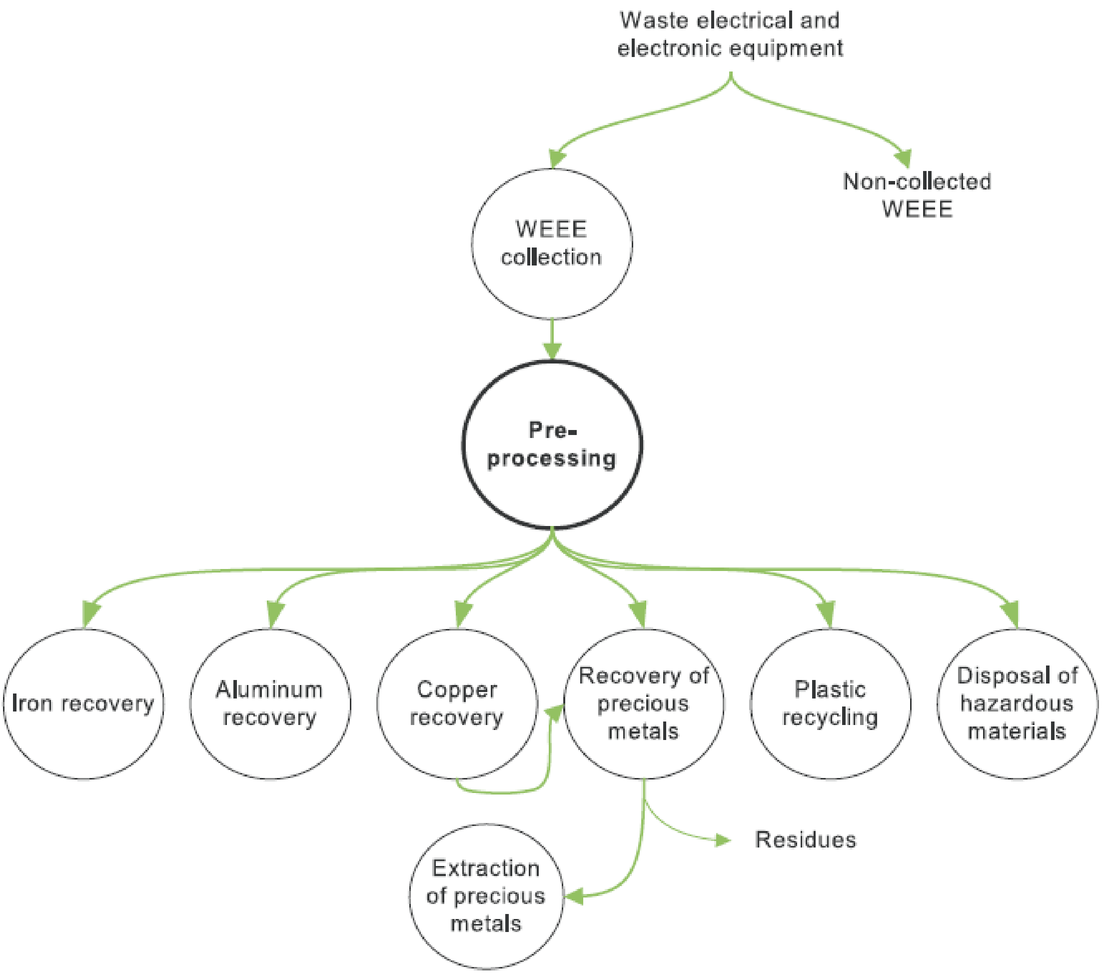


Figure 10. Simplified WEEE recycling process, Source: Chancerel et al. (2009)

In order to achieve good recycling rates, preprocessing is essential, since it includes the proper separation of materials into the correct streams. When substances enter the wrong treatment streams they will not be recoverable and thereby they reduce the recovery efficiency of the recycling system. Large electrical appliances, for instance, tend to be shredded and then sold on, however, if other metals, especially precious metals, find their way into the WEEE-portion headed for shredding, these are non-recoverable and become lost.

The recycling rates vary depending on product category and geography. It is more likely that small electrical appliances do not enter the recycling system, because they are easily stored at home. If they are still functional and simply replaced by a newer product, it frequently happens that the products are kept as backups. This, however, is not likely to occur with large electrical appliances, such as washing machines and dryers, and these will therefore either enter the proper disposal channels and go for recycling and resource recovery or to illegal flows.

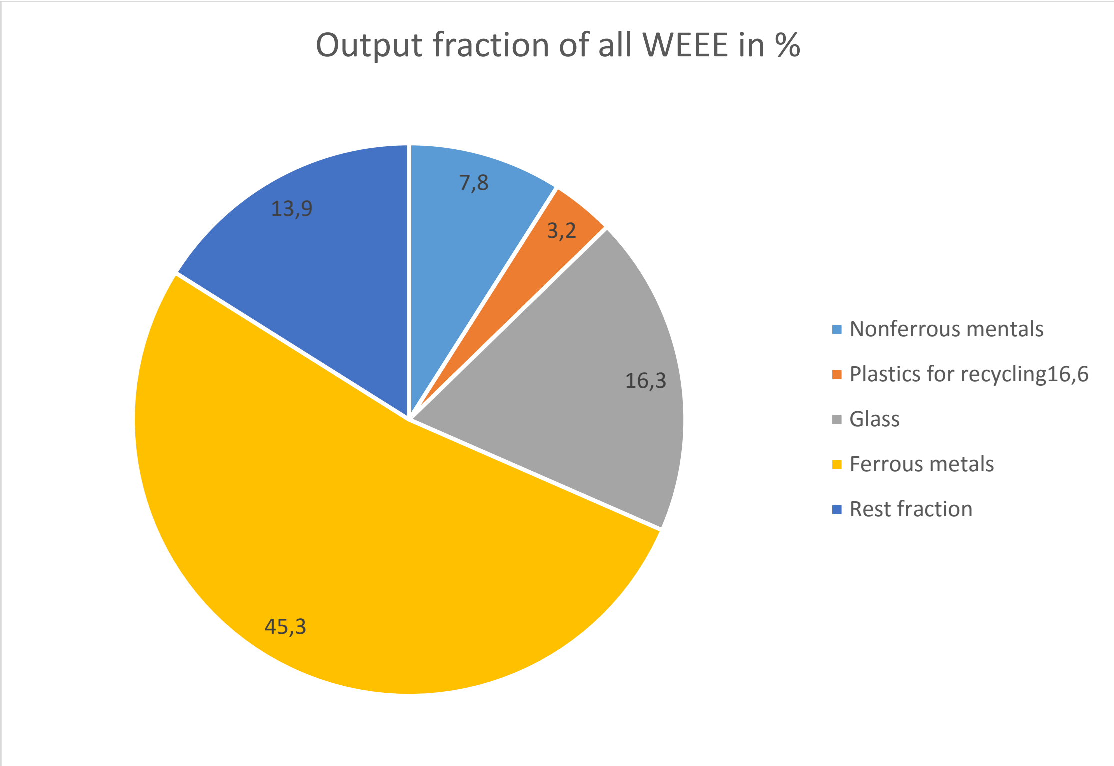
Recycling of WEEE leads to the recovery of resources used in production and industry. Secondary resources, or anthropogenic resources, are stocks and flows of materials created by humans or caused by human activity (Winterstetter et al., 2015). The recycling process of WEEE in Austria is explained in detail by the EAK. Electrical and electronic equipment have a life span of approximately 12 years for large appliances and approximately 5 years for gas discharge lamps. When they reach their end of life, they are collected and processed in order to remove hazardous materials from the products in adequate facilities.

Collection and initial treatment happens according to the 5 categories of large appliances, cooling devices, monitors, small appliances, and lamps. During this process, materials and substances harmful to humans and the environment are removed from the devices. This includes for instance CFCs (chlorofluorocarbons), PCB (polychlorinated biphenyl), asbestos, etc. After hazardous materials have been removed, WEEE reaches the recycling facilities, in the case of large appliances, a shredding facility.

Figure 11. Large Electrical Appliances, Source technomarkt.de

Figure 12. Shredding Facility (TSG Tirol), Source EAK

With the completion of the recycling process of large electrical appliances, secondary resources are won and sold on, after separation into the different output fractions. The output fractions for WEEE after recycling are quantified in the graph below.



Output fraction of recycled WEEE of all categories, EAK numbers (Tätigkeitsbericht, 2014)

The rest fraction is unrecoverable material which is incinerated and disposed of in landfills. From the other output fractions, secondary resources can be won and used in many industries. Especially in the metal industry secondary resources are important since primary resources are more expensive and a higher amount of energy is needed for their recovery.

5.1.Metal Recovery from WEEE Recycling

When recycling metals, the life cycles of metals have to be considered. It starts out with the design of the individual product, which materials go into producing it, it's intended use, and how it is produced. What goes into a final EE-product, in terms of metals, is driving the demand for these metals and have a lasting impact on the recycling process (Graedel et al., 2011).

After production, the products are sold and enter the stock of metals in use within a given system. Once they enter their end of life phase they enter the different metal streams, however, at each stage of the end of life process, metals are lost. Graedel et al. (2011) designate these losses of metal resources as residues, as can be seen in the following figure.

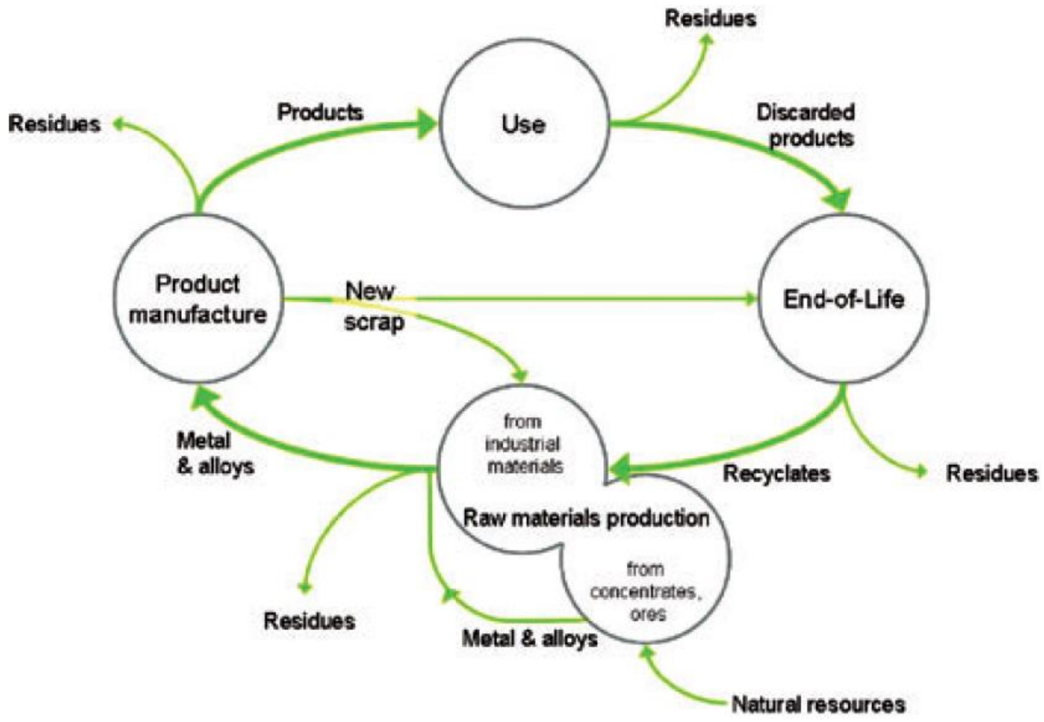


Figure 13. Simplified metal life cycle, source: Graedel et al. (2011)

This results in a closed cycle, if the recovered metals from waste is entering the appropriate recycling chains, which results in scrap metal used to replace primary metals in production and industry. If metals recoverable from waste do not enter the recycling chain, or, if the waste is not collected for treatment to begin with, the metal life cycle is open. This can be a result of products being discarded at landfills, and products which are processed inappropriately, for instance when precious metals enter the same stream as iron wastes for shredding.

Loss of metals in EEE, and also other consumer goods, occur due to (Graedel et al. (2011):

- Product designs which are difficult to disassemble, making separation of material more complex or even impossible.
- High mobility of products caused for instance by changes in ownership
- Generally low awareness about the loss of resources, and missing economic recycling incentives due to low intrinsic value per unit. Nevertheless, the overall mass flows have a big impact on metal demand (Hagelüken and Meserkers, 2008)
- In developing countries: absence of appropriate recycling infrastructure for EOL management of complex products

- In developed countries: existence of hibernating goods and small appliances which are disposed of with the household's residual waste. (This is not so much the case for large electrical appliances)
- Recycling technologies are not in sync with the latest products and their complex composition

Other factors which influence the effectiveness of metal recycling are based on economics, since the value of the waste material to be recycled must be high enough to justify the cost of recovery of the materials. Technology is also highly important due to the complexities of the products, materials and the technologies needed to adequately treat them. The behavior of people does also have a large impact on recycling habits of a society. If a habit of recycling has been established, the system will undoubtedly benefit and work more smoothly. Increasing public awareness and education can enhance a societies readiness to recycle and higher rates of recovery can be achieved.

The risks regarding resource supply for the European Union been analyzed by the Fraunhof Institute in 2010 and identified the metals with the highest and lowest supply risks. Steel has a high value for the economy, however, there is not much of a supply risk. The table below shows the types of metals and their supply risks. The vertical axis indicates supply risk and the horizontal axis indicates economic value of a type of metal.

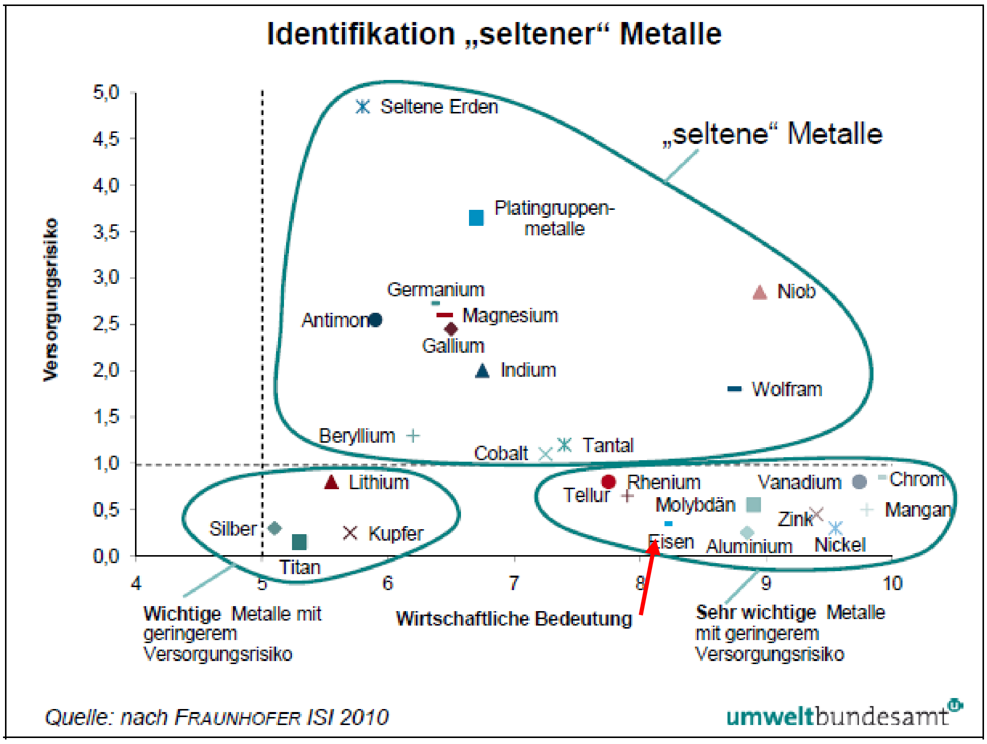
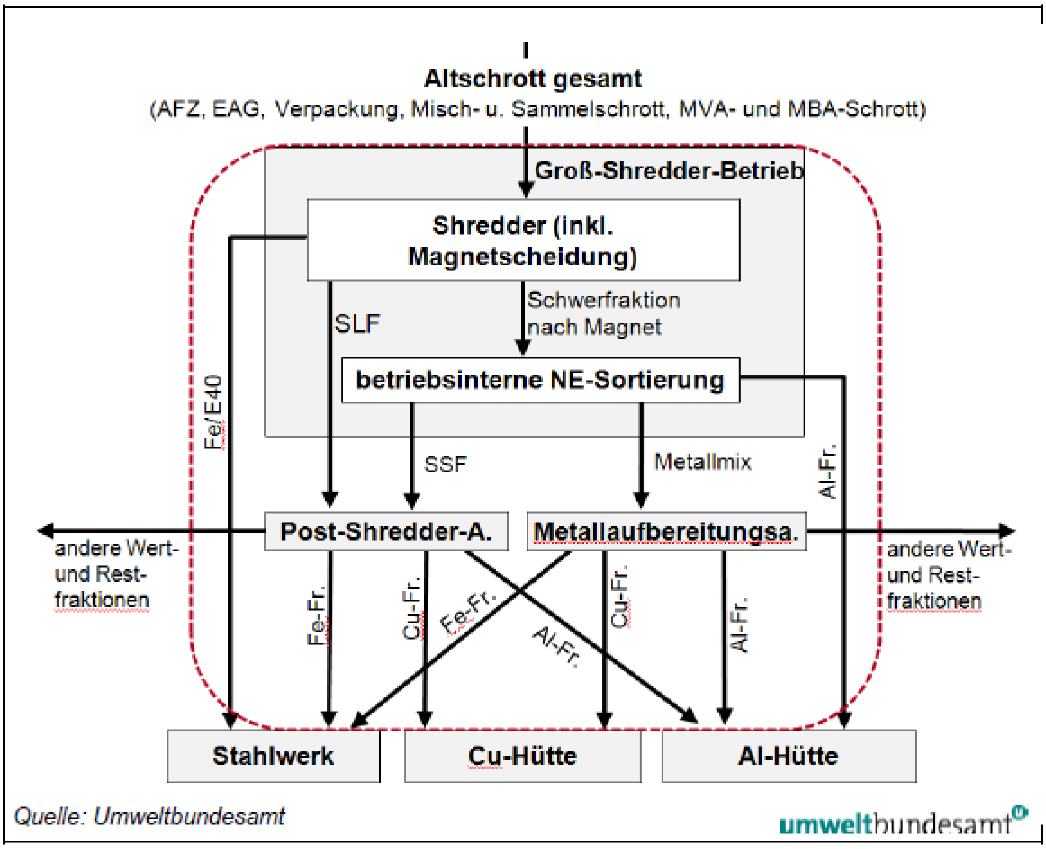


Figure 14. Supply risks of metals, Source Umweltbundesamt, Report 0363

This projects focuses on the potential impact on the economy of missing metal scrap in the production of steel. The use of metals in Austria is assumed to reach a volume of about 16 million tons in 2030, with crude iron, steel, and ferrous alloys reaching about 10,5 million tons. The entire amount of iron ore used in steel production was estimated by Krutzler et al. (2012) in the Umweltbundesamt Report 0363, to be 8,6 million tons a year, for 2009, while metal scrap used in the amounts to about 2 million tons a year, for the same time period. The industries which consume the largest amount of the crude iron, steel and ferrous alloys being the steel industry, construction sectors and mechanical engineering industry (Krutzler et al.,2012).

Scrap metal as a secondary resource is used in Austria's steel economy. The following figure shows how scrap metals are won from Austria's waste, all wastes including WEEE, which in the graph is designated as the stream "EAG", which is the German abbreviation for WEEE.



SLF…Shredderleichtfraktion	*AFZ…Altfahrzeuge*
SSF…Shredderschwerfraktion	*EAG…Elektroaltgeräte*
Fe/E40…Shredderschrott	*MVA-Schrott…Fe-Fraktion aus Müllverbrennungsschlacke*
Fr…Fraktion	*MBA-Schrott…Fe-Fraktion aus der mechanisch biologischen Behandlung von Restmüll*

Figure 15 Metal recovery from waste (all wastes including WEEE), Umweltbundesamt, 2010)

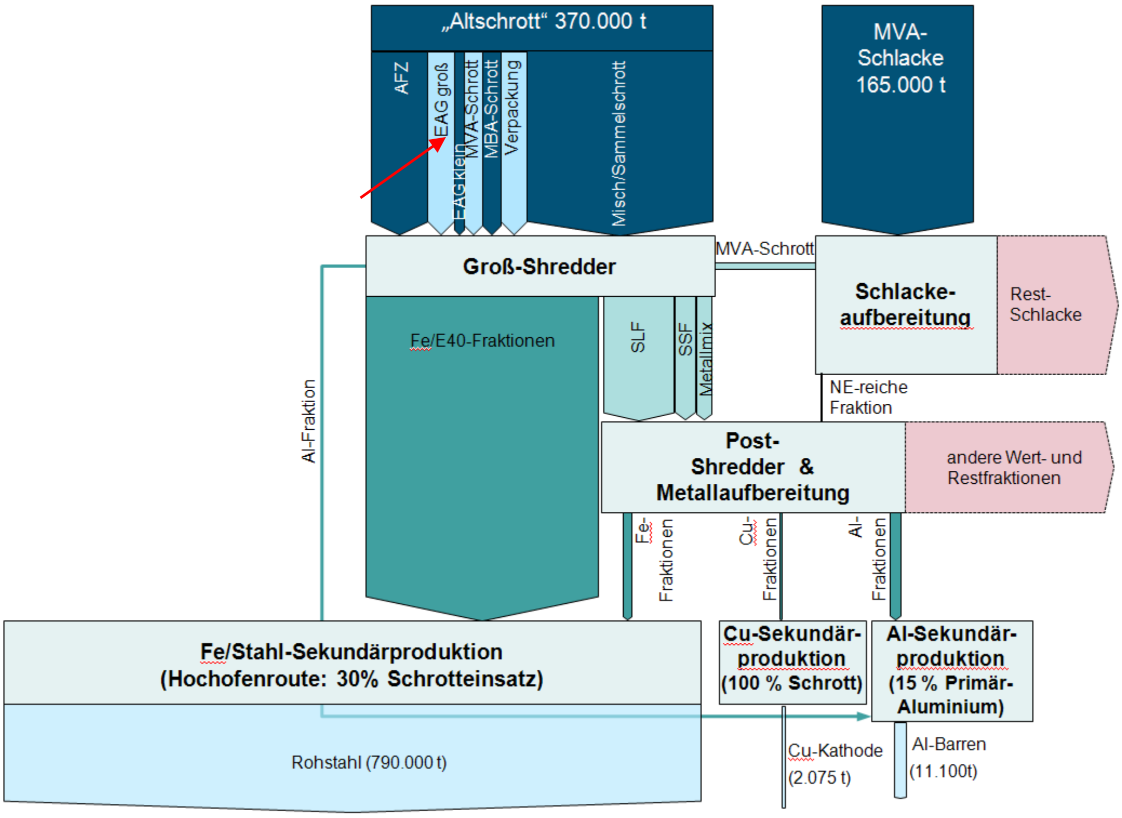


Figure 16. Material Flows of recycled metal scrap, Umweltbundesamt, Report 0363

The figure above shows the flow of metal scrap through the recycling chain. For the end product steel the graph assumes that a blast furnace is used. In a blast furnace 30% metal scrap is used as a secondary resource and 70% is made up of primary resources (iron ore and micaceous iron oxide).

In order for WEEE scrap to be used as a secondary resource it has to be processed properly to its specifications, for instance in a shredding facility. The Austrian Umweltbundesamt collected data for the average amount of WEEE scrap throughput of 6 large shredding facilities in Austria for the years 2008 and 2009, which amounted to about 370.000 tons per year. Metal scrap can be recovered from a variety of waste streams such as packaging material, small- and large electrical appliances, old road vehicles, and other waste streams.

Table 4. Individual fractions of metal-scrap, Umweltbundesamt, Report 0363

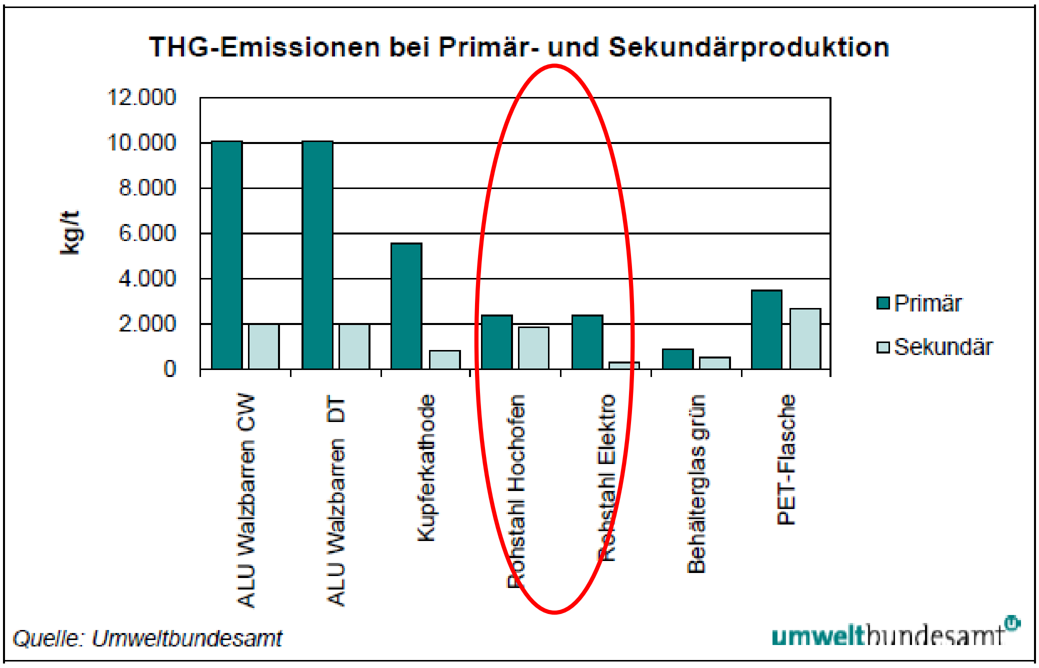
Abfallart	Anteil am „Altschrott gesamt“
Verpackungsmetall (inklusive stoffgleiche Nichtverpackungen)	28.000 t (8 %)
Elektroaltgeräte groß	30.000 t (8 %)
Elektroaltgeräte klein	10.000 t (3 %)
Altfahrzeuge	60.000 t (16 %)
Misch- und Sammelschrott	202.000 t (55 %)
MVA-Schrott	20.000 t (5 %)
MBA-Schrott	20.000 t (5 %)

The percentage of scrap metal won from large electrical appliances are 8% of the entire metal scrap throughput, which amount to 30.000 tons a year. In the FWMP published in 2011, large electrical appliances are composed of around 62.5% iron, 25% plastics and 12.5% non-ferrous metals with less than 1% of hazardous material, with the exception of monitors and refrigerators. It is therefore assumed that about *18750* tons of iron per year stem from large electrical appliances. This number is calculated from the 30.000t of metal scrap from large electrical appliances multiplied with their material compositions percentage (62,5% iron).

This is a gross simplification, since the exact composition of ferrous- and non-ferrous metals, as well as other inputs in the production of steel is not considered, however, in this project the amount of iron stemming from large electrical appliances, which has been calculated to be 18750 tons per year, is assumed to be funneled entirely into the production of steel in Austria.

Connected to recycling of large electrical appliances and the recovery of resources to use as inputs in the steel industry, is the energy needed for transport and treatment of the WEEE-scrap. This contributes to the emission of GHG, however, the amount of GHG-emissions differs between the use of primary- and secondary resources in steel production.

Table 5. GHG emissions in primary- and secondary production, Umweltbundesamt, Report 0363



CW ...Closed well Ofen *DT ...Drehtrommelofen*

Abbildung 15: Spezifische THG-Emissionen bei der Primär- und Sekundärproduktion marktfähiger Zwischenprodukte (in kg/t)[16].

The use of secondary resources in the production of steel, results in lower GHG- emissions, especially if an electro furnace is used to produce steel. This is due to the fact that electro furnaces can use 100% secondary resources, which results in lower GHG emissions compared to the use of primary resources. That is to say, the fraction of secondary resources that can be used in the production of steel varies with the type of furnace that is used. An electro furnace can use up to 100% secondary resources. A traditional blast furnace can use 30% secondary resources, and 70% primary resources.

A reduction of 86,5% can be achieved when using secondary resources instead of primary resources in an electro furnace. When a blast furnace uses secondary resources than a reduction of 20% is reached (Krutzler et al. 2012).

6. Discussion of results

6.1.MFA results

The amount of approximately 13.273 tons of large electrical appliances per year is estimated to enter some form of illegal waste stream. This outcome appears to be in line with prior estimations made by the EAK and other institutions in Austria, for instance the BOKU Vienna. While this is an estimate derived via a simplified model, the amount of approximately 13.000 tons of missing large electrical appliances is similar to an estimate based on a project on illegal waste flows conducted by the BOKU (University of Natural Resources and Life Sciences) in 2012, which concluded that between 11.000 to 16.000 tons of large electrical appliances are illegally exported annually (Krutzler et al. 2012). Nonetheless, an exact amount of large electrical appliances lost to the Austrian economy cannot be given and it has to be born in mind that these 13.273 tons are not without uncertainty.

6.2.Economic relevance

The Austrian steel industry uses metal scrap from large electrical appliances in its production. Each year the amount of metal scrap used varies due to fact that production also does not remain constant, however, the 30.000 tons of large electrical appliances which go to a shredding facility used in the Report 0363 are used as a bench mark value. Since the general composition of a large electrical appliance is 62.5% iron, the material useable as secondary resource in the steel industry is estimated to be 18.750 tons of iron. It is very unlikely that this entire amount is material which can be utilized in the production of steel, not least due to the loss of recoverable material which occurs at each step of the recycling chain. However, since it is difficult to estimate the losses of secondary resources during the recycling process, the 18.750 tons are assumed to be used entirely in the production of steel.

The production of steel in a blast furnace utilizes 30% metal scrap and 70% primary resources. If it is assumed that the 30.000 tons of scrap metal from larger electrical appliances are to be used annually in the production of, however only approximatley18.560 tons are collected and funneled in the correct waste streams, then a difference of about 11.440 tons WEEE is missing from the steel production. The average total use of scrap metal is 370.000 tons estimated by the Umweltbundesamt (2010), with the 11.440 tons making up about 3% of the average total use.

The lower fraction of scrap metal from large electrical appliances is likely offset by the stock of metal scrap of a steel production plant, scrap metal resulting from production itself and from imports. Statistik Austria published a yearly statistic of metal scrap industry in Austria from which it can be seen that the total of useable metal scrap amounted to 2.318.757 tons while the actually used metal scrap was 2.026.611 tons. This left 292.146 tons of scrap metal from which 188.721 tons are designated to be deliveries and the rest (103.425 tons) comprised the stock at the end of the year. The compatibility of the data of Statisik Austria with the data of the Umweltbundesamt and the EAK is questionable, however, it appears that a loss of 11.440 tons of WEEE scrap from the steel industry, which represents only slightly over 10% of the end-year stock, is not significant.

The loss of WEEE-scrap is not of relevance to the steel industry at the moment, however it warrants further efforts to decrease the amount of unaccounted WEEE. This might be more relevant to WEEE containing larger amounts of critical material, since these come at a greater cost to the economy.

6.3.Relevance to the Environment

It has to be differentiated between effects on the environment at the domestic level and the effects to the environments receivers of illegal exports. Additionally, it has to be mentioned that there is difference in pollution which is felt on a local level or globally, such as GHG emissions.

The production of steel in a blast furnace uses 30% metal scrap and 70% primary resources, which leads to a reduction of GHG-emissions by 20%, compared to steel production using only primary resources. However, since there is no shortage of metal scrap in Austria, the missing scrap metal amounting to 13.273 t per year do not result in additional problems. Potentially, the emissions connected to the transport of the missing WEEE can be considered, however, this is not part of the project and not feasible due to a lack of data.

It might even be possible that illegally transported WEEE large appliances end up as metal scrap in other countries, where it can be funneled into the local production of steel, thereby contributing to a decrease in other places. This, however, this is the author’s assumption which is not backed by data and can also not be verified.

The environmental impact of larger electrical appliances on Austria’s steel industry is not relevant, however it can be assumed that due to the application of less sophisticated treatment facilities or shredding facilities, the loss of resources is higher abroad, especially in less developed countries. This can contribute to the overall loss of resources and can goes against a sustainable approach to resource use.

Other environmental impacts which can result from WEEE containing hazardous materials do present a very interesting topic for future research. The composition of WEEE varies from product to product, and especially small electrical appliances contain high quantities of different chemical compounds, as well as critical materials.

6.4.Sources of error

The illegal nature of WEEE-transfers out of Austria make it difficult to gather data which accurately represents the amount that goes missing. The ranges of estimates regarding e-waste, depending on the year in question, lies between 11.000 to 16.000 tons a year.

Further, a number of simplifications have been used in the devising of the material flow analysis as well as the processes of the steel industry in Austria. The outcomes therefore have to be understood as estimates that do not reflect accurate amounts of WEEE, rather numbers that represent potential relevance to the economy and environment of Austria.

The failure to include stocks adequately in the MFA-model results in highly biased numbers, which has to be highlighted. The project would deeply benefit from an integration of data regarding stocks in order to receive more accurate data regarding unaccounted flows out of the MFA-system (Flow F3).

Due to the simplification to the MFA the outcomes cannot be seen as having a high degree of certainty, which results in the possibility that the answers to the research questions based on the conducted analysis might be fallacious.

This study’s weakness therefore lies in the uncertainty of the data, neglecting of stocks and simplified approach to the model and the production of steel and its parameters.

7. Conclusions and Recommendations

The relevance of illegal exports of WEEE of the category large electrical appliance to the Austrian steel industry is not given. A sizeable portion of WEEE in this category, 13273 t, does go missing and measures to decrease this should be undertaken, however, the steel industry does not appear to be suffering from the loss of WEEE-scrap of this category since the losses of scrap metal are more than covered by existing scrap metal stocks in the steel industry.

In connection to this, as stated in the sections containing the research questions, since relevance to the steel industry cannot be shown, increased environmental damage due to the missing WEEE is not relevant either.

Even if no relevant negative impact could be shown, it might be beneficial for both the environment and the economy to combat illegal transfers of WEEE. Especially since potential negative impacts of WEEE of other categories can be assumed to be much higher, and an effort to decrease illegal exports is applied to all categories of WEEE.

The best way to combat the illegal transfer of WEEE is a continued and targeted information and awareness raising effort. The EAK has already implemented a number of projects in this area, which have contributed to more awareness and understanding when it comes to WEEE and proper recycling thereof.

One example for education regarding WEEE is the so-called "Schulkoffer" which is used to teach school children about resources, sustainability and WEEE-recycling. This is especially fruitful considering that current school children grow up with a large amount of electronic gadgets and can appreciate the proper handling of such materials differently than the generations who did not have these products growing up and are at times not in possession of all the knowledge regarding WEEE collection and treatment processes. The "Schulkoffer"-project is continually expanded and gaining popularity with teaching staff at schools all over Austria.

One reason why citizen might give a large electrical appliance or an old freezer to an informal collector is because they assume to be doing something that will help poorer people, which obviously is an admirable thing to do. However, more often than not, these collectors are looking for profits and do not intend to distribute older EEE to people in need abroad. It is therefore important to be aware of this practice of organized illegal transfer of WEEE.

Efforts to decrease the amount of illegally transferred WEEE on an EU wide basis have been undertaken recently by the CWIT report, aiming at a harmonization across the EU regarding facilitating investigations, prosecution and sentencing to create a disincentive for smugglers of WEEE.

It is advisable to continue research in the area of losses due to missing WEEE to European economies utilizing a better developed MFA. Especially in the sector of small electrical appliances, which contain critical materials and which are displaced easily, more research and attached awareness raising could be beneficial. The amount of WEEE which is transferred to less developed countries do have more potential to affect local populations. Awareness of the potential harm done to poorer nations and its population should be raised in order to increase the demand for transparent and easy to follow domestic WEEE-management.

In conclusion, the Austrian WEEE sector is highly developed and reaches a high degree of collection for proper treatment and recycling. It is however possible to continue with citizen-education and public awareness raising to further improve the collection. Potential for increased cooperation between Austria and its neighboring countries, especially towards the East, appear promising. While the amount of WEEE large appliances going missing is not currently a large problem in Austria, continuous efforts to increase the effectiveness should be aspired to, in order to assist in the building of a society conscious of the need for sustainable resource management.

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Appendices

Appendix A: Elektroaltgeräte Koordinierungsstelle, Tätigkeitsbericht 2014: Numbers PoM

EAK Data, Tätigkeitsbericht 2014, Products put on the market, Household

SubCat	Large	Cooling	Display	Small	Lamps	Results EEE	Change %
PoM 2013	69.879	22.472	13.388	40.224	1.577	147.540	5,63%
PoM 2014	73.862	22.976	13.870	43.494	1.648	155.850	

PoM, (t)
EAK data

Appendix B: Elektroaltgeräte Koordinierungsstelle, Tätigkeitsbericht 2014: Collected WEEE

EAK Data, Tätigkeitsbericht 2014, WEEE collected, Household

SubCat	Large	Cooling	Display	Small	Lamps	Results EEE	Change %
Collected 2013	18.564	12.264	16.822	27.373	982	76.005	0,96%
Collected 2014	18.559	11.757	15.410	30.118	892	76.736	

Collected (t)
EAK data