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Evaluation of informal sector activities in Germany under consideration of electrical and electronic waste management systems

Ulrike Lange

Dissertation

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Vorwort

Frau Dipl.-Ing. Ulrike Lange hat eine Promotionsarbeit vorgelegt mit dem Ziel, die informellen Sammler in Deutschland zu ermitteln und den Einfluss der Erfassung von elektrischen und elektronischen Geräten auf das Abfallwirtschaftssystem zu beschreiben.

Die Dissertation wurde im Rahmen des Forschungsvorhabens „TransWaste“, gefördert von der EU durch das Central Europe Programm, erstellt. Mit Partnern aus Österreich, Ungarn, Polen und der Slowakei wurden wichtige Grundlagen ermittelt und eine gemeinsame Methodik zur Mengenbestimmung ausgearbeitet.
Die informell gesammelten elektrischen und elektronischen Altgeräte stellen mit dem hohen Silber- und Goldgehalt einen hohen wirtschaftlichen Wert dar. Auch Kupfer und die verschiedenen Seltenen Erden sind von hohem abfallwirtschaftlichem Nutzen. Durch die informellen Sammelaktivitäten werden ca. 77.000 Jahrestonnen an Altgeräten erfasst und auf Flohmärkten weiter verkauft oder für die Rohstofferfassung demontiert.

Frau Ulrike Lange stellt überzeugend dar, dass die Sammlung und Weiterverwendung in Bezug auf die CO_2-Bilanz im europäischen Kontext gesehen von Vorteil ist. Die Abschöpfung des Rohstoffes aus der Sicht der deutschen Industrie ist dagegen ein Nachteil, da das preiswerte Recycling nicht im eigenen Wirtschaftsraum stattfindet und damit für die Wertschöpfung verloren ist und nur durch Neuware auf dem Weltmarkt ersetzt werden kann.

Frau Ulrike Lange zeigt mir ihrer Massenbilanz für die Altgeräte, dass die Verordnung (WEEE) nur zu einer Erfassung von ca. 50 % der anfallenden Altgeräte führt. Die restlichen Mengen von ca. 700.000 Mg/a (Bezugsjahr 2010) u.a. nach Übersee verschifft werden oder über den informellen Sektor außer Landes gehen.
Mit dieser Dissertation hat Frau Dipl.-Ing. Ulrike Lange ein sehr aktuelles Thema aufgegriffen und mit interessanten Ergebnissen vorgelegt.
Ich wünsche der Dissertation viele Leser mit einer Rückmeldung an die Autorin.

Dresden Juni 2013

Prof. Dr.-Ing. habil. Dr. h.c. Bernd Bilitewski

Danksagung

Mein Dank gilt dem CENTRAL EUROPE Programm, welches das Projekt „TransWaste – Formalisation of informal sector activities in collection and transboundary shipment of waste in and to Central and Eastern Europe“ förderte. Dieses ermöglichte erst die Arbeit an der vorliegenden Dissertation. Gleichsam danke ich dem Team des Projektes TransWaste für eine stets inspirierende und konstruktive Zusammenarbeit.

Mein besonderer Dank gilt meinem Doktorvater, Herrn Prof. Dr.-Ing. habil. Dr. h.c. Bernd Bilitewski, für seine konstante Unterstützung, seinen fachlichen Rat und die vielen kleinen Lebensweisheiten. Frau Prof. Christina Dornack danke ich für die Übernahme der gutachterlichen Tätigkeit und die vielen hilfreichen Ratschläge.

Dem gesamten Kollegium des Instituts für Abfallwirtschaft und Altlasten möchte ich für die vielen schönen Stunden und Runden danken, insbesondere Eva, die immer mit aufmunternden Worten zur Stelle war. Darüber hinaus bin ich froh, die AG Bio als ständigen Begleiter gehabt zu haben. Ihre Freundschaft und der ununterbrochene Rückhalt sind nicht selbstverständlich und dafür danke ich Euch wirklich sehr!

Ein herzliches Dankeschön möchte ich an meine Eltern und Großeltern richten, die mich zu jeder Zeit unterstützt, aufgebaut und stetig begleitet haben. Auch meiner Dresdner „Ersatzfamilie“ danke ich für die Ablenkungen und die Unterstützung in jeglichen Situationen. Nicht zu Letzt gilt ein großes Dankeschön U.M. - die vielen Aufmunterungen, Diskussionen, Tipps und Hilfestellungen waren und sind Gold wert!

Zusammenfassung

Informelle Sektoraktivitäten in der Abfallwirtschaft stellen eine weltweit verbreitete Abfallsammlung- und Behandlung ohne offiziellen Charakter dar. Sowohl Risiken als auch Vorzüge für Umwelt und involvierte Stakeholder gehen mit besagten Tätigkeiten einher und erklären anhaltende, kontroverse Diskussionen in der Politik, Wissenschaft und Gesellschaft.

In Deutschland stehen Verbringungen von elektrischen und elektronischen Altgeräten (EAG) im Fokus der Kritik. Neben informellen Exporten über den Hamburger Hafen werden informelle Verbringungen von EAGs in osteuropäische Nachbarstaaten seit Jahren beobachtet. Die vorliegende Arbeit beschreibt Untersuchungen bezüglich der Charakterisierung informeller Personengruppen, verbrachter EAG Mengen als auch der resultierenden Ökoeffizienz informeller Tätigkeiten osteuropäischer Sammler. Ausführungen konzentrieren sich auf die Verbringung von Gebrauchtgütern zum Verkauf.

Analysen zeigten, dass eine deutliche Mehrheit informeller Sammler aus Polen, Ungarn, Rumänien und Tschechien stammen und bundesweit agieren. Eine hohe Sammelspezialisierung auf EAG ist festzustellen, wobei sich verbrachte Mengen auf durchschnittlich 77.000 Jahrestonnen belaufen. Diese Mengen werden teilweise zur Wiederverwendung auf Flohmärkten verkauft. Das Verhältnis zwischen Lebenszykluskosten und bilanzierten CO_2 – Emissionen weist Vorteile der Wiederverwendung durch informelle Sammler auf. Im Gegensatz zur Weiterverwendung eines Fernsehers in Polen, verursachen informelle Sammlungen (Sammlung in Deutschland und Wiederverwendung in Polen) geringere spezifische Emissionen von 8,34 kg $CO_{2, eq}$ pro verbrauchter Kosteneinheit (€). Im Vergleich zur Wiederverwendung in Deutschland liegen die spezifischen Emissionen um 2,2 kg $CO_{2, eq}$ je verbrauchter Kosteneinheit (€) höher.

Die Arbeit zeigt, dass informelle Sammlungen positive Effekte bezüglich einer Wiederverwendung verursachen können. Zukünftige Produkte höherer Energieeffizienzklassen unterstützen einen Reuse - Trend, wobei bereits stark verkürzte Lebenszyklen von Produktgruppen durch informelle Sektoraktivitäten verlängert werden. Ein genereller Ausschluss dieser Personengruppe ist aus sozialer Sicht zu kritisieren. Darüber hinaus eröffnet eine kontrollierte und strukturierte Durchführung erörterter Aktivitäten neue Möglichkeiten, das angestrebte (bereits existierende) Konzept der Wiederverwendung auf internationaler Ebene zu erweitern.

Abstract

The informal sector is described as groups of persons who act in parallel to official waste management systems without official authorisation. Such informal activities can result in risks as well as benefits both to the environment and involved stakeholders, which explains the continuing lively discussions in politics, science and society.

Transhipments of waste electrical and electronic equipment (WEEE) are increasingly focused in Germany. In addition to informal exports via the port of Hamburg to countries such as China, Ghana or Nigeria, informal transports to Eastern European countries have been recognised for decades. This paper describes investigations regarding the characteristics, transhipped amounts as well as the eco-efficiency of informal sector activities originating from Eastern European countries, while thereby highlighting transhipments of used appliances to destination countries and a corresponding sale for reuse.

Investigations reveal that a majority of informal collectors originate from Poland, Czech Republic, Hungary and Romania and are recognised across Germany. A high WEEE specialisation was determined, whereby average annual transhipped amounts are estimated at 77,000 tons. Collected materials are transhipped and partially sold for reuse. A case study considers the example of Polish informal collectors. The ratio between economic and environmental performance reveal that informal sector reuse activities in Poland achieve a higher environmentally sound performance in comparison to further usage of appliances under consideration. The informal collection of a television in Germany (and subsequent reuse in Poland) causes 8.34 kg less specific CO_2 emissions per spend-costs (€) than the production, usage and further use in Poland. Conversely, a further use of a television in Germany only results in 2.2 kg less CO_2 emissions per spend-costs (€).

These results demonstrate that reuse as a result of informal sector activities can have a positive effect. Future electrical and electronic products available for reuse will have lower energy consumptions. A positive contribution to resource protection is thereby achieved while extending already short life cycles. Taking into account a dependency on collections with respect to their income, a pure ban of informal sector activities would therefore be socially counterproductive. A structured and controlled accomplishment of informal collection processes would open up new opportunities to enlarge the (already existing) concept of reuse at an international level.

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A……………………….Austria
AbfVG………………Abfallverbringungsgesetz
Ag…………………..Silver
Al…………………….Aluminium
am………………….Ante meridium
Apr………………….April
AS………………….Australia
Au…………………..Gold
Aug…………………August
BC………………….Border crossing
BMU………………..Bundesministerium für Umwelt
BSR……………….. Berliner Stadtreinigung
CBO………………..Community based organisation
CFC……………….. Chlorofluorocarbon
CG………………….Collection group
CO_2……………….. Carbon dioxide
Cu…………………. Copper
D…………………….Germany
d…………………….Day
DCF……………….. Daily correction factor
Dec…………………December
EAR……………….. Stiftung Elektro-Altgeräte Register
'EAR'……………….Scenario composition of CG according to EAR statistics
EC…………………..European Commission
EE………………….Eco-efficiency
EEE………………...Electric and electronic equipment
e.g. ……………….. Exempli gratia
ElektroG…………...Elektro-und Elektronikgerätegesetz
Equal_Comp………Scenario equal composition of collection groups
EPR……………….. Extended Producer Responsibility
et al. ………………Et alia
EU………………….European Union
EUR……………….. Euro
Fe…………………..Iron
Feb…………………February
Fri…………………..Friday

GTZ………………. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GWP………………. Global warming potential
HCFC……………… Hydrochlorofluorocarbon
high_Fe…………… Scenario high proportions of ferrous metals
high_Pl……………. Scenario high proportions of plastics
high_PM…………...Scenario high proportions of precious metals
hr………………….. Hour
IC………………….. Informal collector
Impel………………European Union Network for the Implementation and Enforcement of Environmental Law
IS…………………...Informal sector
ISHS………………. International Second Hand Service
ISO………………… International Organisation for Standardisation
IT…………………...Information technology
Jan…………………January
Jul………………….July
Jun…………………June
KrWG……………… Kreislaufwirtschaftsgesetz
kg………………….. Kilogram
LCC……………….. Life Cycle Costing
LCD……………….. Liquid Crystal Display
LF…………………..Loading factor (%)
LV…………………..Load volume
m^2…………………..Square metre
m^3…………………..Cubic metre
Mo…………………. Monday
Mar………………… March
N…………………… Number of counted vehicles per border counting
NGO………………..Non-governmental organisation
No…………………..Number
Nov………………… November
NZS………………...New Zealand
Oct…………………October
OECD……………...Organisation for Economic Co-operation and Development
P…………………....Probability factor (%)
PBDE………………Polybrominated diphenyl ethers
PC…………………. Personal computer
PCB……………….. Polychlorinated biphenyls

Pd…………………..Palladium
pHH………………...Private household
PL…………………..Poland
pm………………….post meridium
PPP………………...Public private partnership
PUR……………….. Polyurethane
RoHS……………… Restriction of certain hazardous substances
Sat………………….Saturday
SCF………………...Seasonal correction factor
SEAP……………… Sustainable Energy Action Plan
Sep…………………September
SRD……………….. Stadtreinigung Dresden
Stb………………….Stadtbrücke
Sun…………………Sunday
SWM……………….Solid waste management
t……………………..Metric ton
Thu…………………Thursday
Q_{LFx}……………….. Transhipped quantity per filling rate scenario
Tue…………………Tuesday
TV…………………..Transhipped volume
TVhr……………….. Transported volume of informal collected items (m3/hr)
UBA……………….. Umweltbundesamt
UNEP………………United Nations Environment Programme
US………………….United States
VDI…………………Verein Deutscher Ingenieure e.V.
VT…………………..Type of vehicle (-)
WBCSD……………World Business Council for Sustainable Development
WCF……………..…Weekly correction factor
WCC……………….Waste collection centre
Wed……………….. Wednesday
WEEE……………...Waste electric and electronic equipment
WMA……………….Waste management association
$þ_x$…………………...Density
°C………………….. Degree Celsius
Ø……………………Average

1 INTRODUCTION

The informal sector is a contemporary issue in waste management. Groups of persons conduct collection and treatment of wastes and materials without official authorisation, assignment or trading license [Wilson et al., 2006]. As a consequence, risks arise for environment and human health because state-of-the-art techniques are not applied. Conversely, environmental benefits arise. Informal reuse, recovery and recycling foster a closing of raw material cycles [Scheinberg et al., 2010].

Informal transhipment of electrical and electronic equipment (WEEE) depicts a source of materials out of Europe, which are subject to informal treatment processes. [Leonhardt, 2006] emphasises a curbing of shipments to ensure an adequate collection and treatment within European recycling infrastructures. With regard to Germany, informal shipment of WEEE is estimated to be 277,000 tons per year [Sander/Schilling, 2010; Janz/Bilitewski, 2009a]. Amounts are either transhipped to developing countries via the port of Hamburg or informally collected and transported to Eastern European countries. Shipments are conducted under the cover of second-hand trade. Nevertheless, appliances already come under the definition of waste in the German Closed Substance Cycle Act (§ 3, KrWG) [Jaron, 2009]. Conversely, there exists evidence that informal collected items are subject to reuse processes. For instance, the structure of flea markets of informal collectors is highly developed in Eastern European countries. Items informally collected are offered for resale at flea markets. This displays a sustainable approach in accordance with the targets of the waste hierarchy (§ 5, KrWG) [Obersteiner et al., 2011].

The rapid technological development of electrical and electronic equipment brings about shorter appliance life cycles. Replacement of old items leads to accelerated resource consumption based on the availability of products of higher technology standard [Rotter et al., 2006]. Recycling techniques close material cycles but use additional energy and produce additional CO_2 emissions. The decision between reuse and recycling is often dependent on the characteristics of the appliances considered and the incentives of the stakeholders involved. Rising market prices of valuable materials such as iron and steel, in particular, but also precious metals like gold, silver or platinum, lead to a preference of recycling processes [Dornack/Bilitewski, 2006].

Stakeholders handling WEEE criticise informal activities because missing valuable materials depict a financial loss. Conversely, costs are reduced for collection and treatment. The relation between both is highly dependent on boundary conditions such as considered products or market prices. Moreover, the decision between reuse and recycling is dependent on environmental and economic effects caused by informal sector activities. The present work aims to investigate the influences of informal sector structures on the German system of WEEE management.

1.1 Aim and scope of the thesis

This work is based on the EU - Project TransWaste, which investigates possible formalisation strategies to integrate informal sector processes into formal waste management [TransWaste, 2012].

Comprehensive information is available in literature on informal transhipments overseas and further processing performed by the informal sector. Less information, however, is available on the informal sector originating from Eastern Europe. In general, informally collected items from western European countries are transhipped to eastern European countries. Afterwards, a resale of old appliances takes place at flea markets or the items are dismantled for the purpose of selling valuable materials [Obersteiner et al., 2011]. Nevertheless, the data available is insufficient to draw an overall conclusion on the status quo of described activities in Germany.

Estimates have assessed the transhipped amount of WEEE towards Eastern Europe to be up to 122,000 tons per year [Janz et al., 2009]. The database is based on interviews with municipalities and literature data and is subject to high fluctuations. Verification of presented data can acknowledge estimated transhipped amounts.

From an economic point of view, costs and revenues of actors responsible for collection and treatment of waste, particularly WEEE, are influenced by informal sector activities. Rising market values of materials, such as ferrous metals, non-ferrous metals, precious metals and rare earths increase revenues and improve the return of processed secondary raw materials into production cycles. Informally extracted items display a financial loss, criticised by involved stakeholders.

Conversely, treatment (and also transportation) costs can fall based on informally collected materials. A clear negative influence of informal sector activities is not obvious on costs and revenues of official actors.

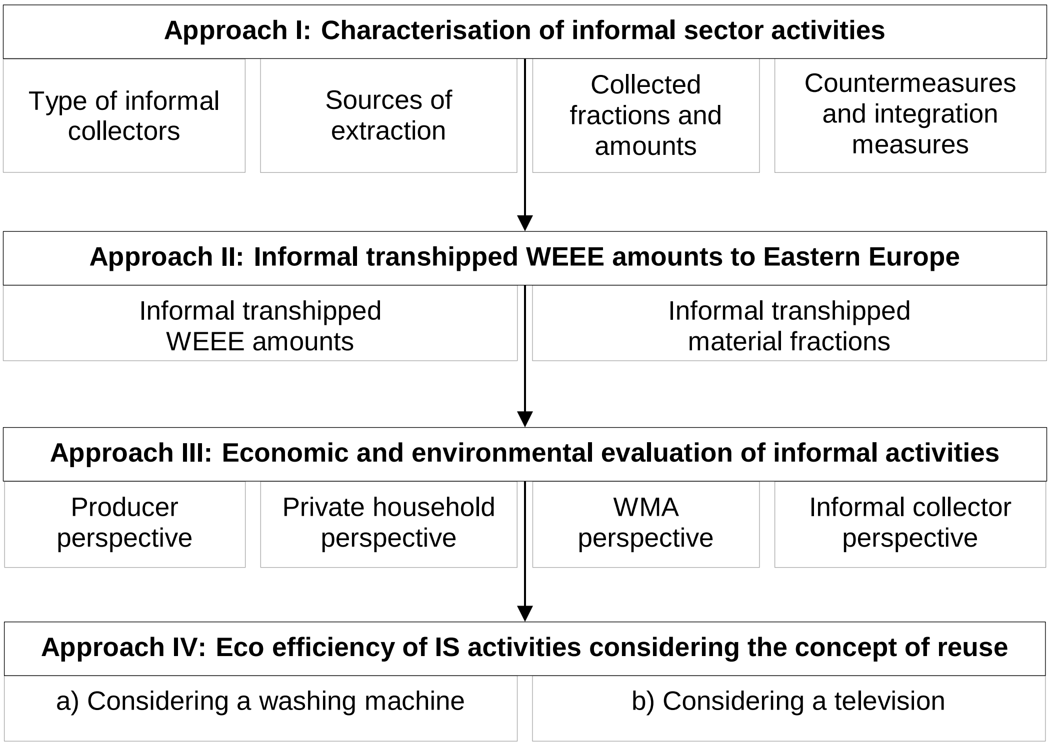
Moreover, the idea of reuse is supported by informal sector activities. Items still usable are offered for resale at flea markets, which can be favoured with regard to the waste hierarchy. An analysis of economic and environmental effects of informal sector activities aims to draw a clearer picture while applying a life cycle costing and CO_2 accounting. The analysis will provide recommendations regarding the feasibility of reuse activities from an economic and environmental perspective in Germany.

In summary, the aim of the present work is to:

- characterise informal sector activities carried out by Eastern European collectors
- verify data on transhipped amounts of WEEE across the entire eastern border of Germany
- analyse informal sector activities regarding their economic and environmental influence on different perspectives (producer, household, waste management association, informal collector)
- evaluate the concept of reuse performed by the informal sector in relation to its eco-efficiency

1.2 Conceptual outline of the thesis

The present work is divided into four approaches, which refer to the key points listed above. Figure 1 graphically displays the conceptual outline.



IS = Informal Sector

Figure 1: Conceptual outline of the thesis

Chapter 2, "State of scientific knowledge", presents literature analysing the procedures and characteristics of informal sector activities and provides information on WEEE management in Germany.

From the considerations made, the methodology is explained for each approach in *Chapter 3, "Methodology of investigations"*. It includes the presentation of a survey of stakeholders concerned, the method of quantifying transhipped amounts of WEEE and corresponding fractions, the parameters used for the economic analysis and CO_2 accounting from different perspectives (producer, private household, waste management association, informal collector), as well as the aggregation of economic and environmental performance to reveal the eco-efficiency of reuse activities of informal collectors.

Subsequently, results are presented in Chapter 4, *"Results of investigations".* It is similarly divided into four sections depicting the typical characteristics of informal collectors appearing from Eastern Europe, transhipped amounts of WEEE and fractions across the eastern border of Germany, economic and environmental influences caused by informal collection as well as the eco-efficiency of reuse activities by consideration of a used washing machine and a used television.

The final Chapter, *“Conclusions and outlook”,* contains conclusions regarding the outcomes of applied analyses and supplies recommendations regarding the handling of informal sector activities.

2 STATE OF SCIENTIFIC KNOWLEDGE

The following chapter presents characteristics of informal sector activities. It outlines knowledge concerning informal transhipped amounts of WEEE and describes ecological as well as economic impacts.

2.1 Characterisation of informal sector in waste management

The informal sector is a group of persons who act parallel to official waste management systems [Ali/Ahmed, 2004]. It neither holds an official assignment with formal waste management nor owns an authorisation to collect and treat waste. It does not pay taxes, it has no trading license and it is not included in social welfare or government insurance schemes [Wilson et al., 2006]. Nevertheless, informal sector activities are recognised at a global scale. Thereby materials are transferred to industries such as the automobile sector, the information technology (IT) sector, the construction sector or textile sector [Scheinberg et al., 2006].

[Furedy, 1987] defines the term `informal sector' as unregistered, unregulated or casual activities, which are accomplished by individuals and/or family or community enterprises using local materials and labour-intensive techniques. They are involved in value-adding activities on a small-scale basis using minimal input of capital [Van de Klundert, 1995]. Alternatively, it is described as the ‘unorganized sector’, ‘unregistered economy’, ‘third economy’, ‘parallel economy’ and the ‘shadow economy’ [Arvin et al., 2010].

Informal sector businesses offer viable profit margins and provide significant economic benefits especially to economies of developing countries [Porter, 2002]. They are often highly skilled at identifying wastes with potential value [Scheinberg et al., 2001]. Consequently, the choice of collected types of materials is decided in the first place by its value and in the second place by its ease of extraction, handling, and transport [Van de Klundert, 1995].

A variety of efforts are implemented to integrate the informal sector into existing formal waste managements in developing countries; mostly by the establishment of organisations and associations. Conversely, the slow modernisation processes of waste management systems force official stakeholders to avoid informal sector activities in order to keep valuable materials in formal waste streams. Moreover, the informal sector does not often act in accordance with state-of-the-art technologies, which lead to negative ecological impacts on the subjects of protection such as water, soil and air.

Modernisation of waste management systems has already taken place in Germany. Other basic requirements predominate when considering informal sector activities. Detailed EU guidelines result in a high standard of waste treatment. Nevertheless, informal sector activities have been recognized for decades in Germany [Janz et al., 2009]. WEEE, in particular, is subject to an informal collection. The sale of the materials contained and whole appliances for reuse can bring high revenues. The effects of informal sector activities are hardly comparable with the effects incurred in developing countries.

2.1.1 Legal background

Legal requirements are highlighted regarding WEEE management and transhipment to evaluate informal sector activities. Included are the German Closed Substance Cycle Act (Kreislaufwirtschaftsgesetz, KrWG), the Electrical and Electronic Equipment Act (ElektroG) and several acts on transboundary waste shipment.

2.1.1.1 German Closed Substance Cycle Act

The KrWG aims to improve the environment and climate protection as well as the efficiency of resources in a sustainable way. The avoidance and recycling of wastes, in particular, are to be strengthened. It is constituted within the waste hierarchy (Figure 2).

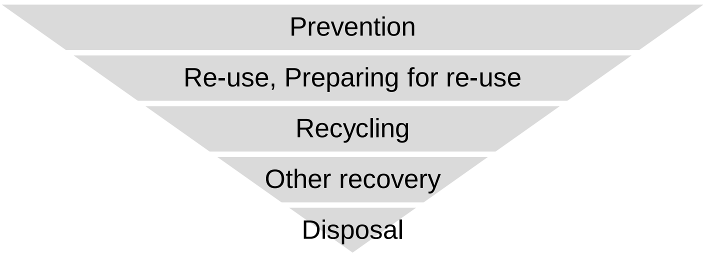


Figure 2: Waste hierarchy in accordance with § 6, KrWG [§ 6, KrWG]

Informal reuse of old appliances is in line with current legal objectives considering ‘re-use and preparing for re-use’. Conversely, § 3 (1) states that “*waste means any substance or object, which the holder discards or intends to or is required to discard*”[1]. According to § 17 (1), KrWG, the intention of discarding on the part of the holder or producer of waste from private households obliges them to make such waste available to legal entities (handover obligation). Legal entities are committed to carry out waste management to the extent that such producers or holders are unable, or do not intend, to carry out recovery themselves. Punishment is regulated by law considering informal collection of items that already come under the waste definition in accordance with § 3 (1), KrWG.

Conversely, waste can lose its status if several requirements laid down in § 5, KrWG are met. If waste is subject to recovery and/or recycling operations and is commonly used for specific purposes, a market or demand exists, fulfils technical requirements and meets existing legislation and standards, it can cease to be waste under certain circumstances [§ 5(1), KrWG]. Repair processes of informal sector activities may alter the status from waste to product. Thereby execution shall be conducted in the country of origin. Otherwise, legal requirements apply regarding the transhipment of waste (refer to Chapter 2.1.1.3)

2.1.1.2 Electrical and Electronic Equipment Act

Specific guidelines exist regarding WEEE. The EU has implemented two directives dealing with environmentally sound disposal (WEEE Directive 2012/19/EU) and with restrictions regarding contained substances (RoHS Directive 2012/65/EU). The transposition of the RoHS directive into German law is currently underway but is not part of the further considerations.

[1] German Closed Substance Life-Cycle Resource Management Act (KrWG), Article 3(1), 2012

The WEEE directive is transposed into German legislation via the ‘Act Governing the Sale, Return, and Environmentally Sound Disposal of Electrical and Electronic Equipment’ (ElektroG). According to § 3 (1), ElektroG electrical and electronic equipment “*means equipment, which is dependent on electrical currents or electromagnetic fields 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 voltage and 1,500 volts for direct voltage*”[2]. The ElektroG refers to § 3 (1), KrWG regarding WEEE.

Extended producer responsibility

The principle of extended producer responsibility (EPR) is one of the main pillars of the ElektroG, which is in the special case of WEEE shared between municipalities and producers. In that system of a shared producer responsibility, municipalities have to provide collection systems for WEEE from private households at no costs to citizens. Producers have the responsibility to ensure a WEEE return system and an environmentally and legally sound treatment of the collected WEEE. Moreover, producers are obliged to set up and register at a clearing house in accordance with § 6 (1) and (2), ElektroG. The privately operated *Elektro-Altgeräte Register* Foundation (EAR foundation) represents the implementation of the specified paragraphs. Each producer selling electrical and electronic products has the obligation to register and forward data concerning annual amounts put on the market. The EAR foundation coordinates the collection of WEEE at collection points and forwards pick-up requests and provision orders to producers. Data on collected and treated WEEE is transferred by the EAR foundation to the competent governmental authority (*Federal Ministry for the Environment, Nature Conservation and Nuclear Safety*, BMU). Thereby an economic activity only takes place between producer and waste processing company regarding the treatment of WEEE (Figure 3). The return system is accordingly a competition-oriented compliance approach.

[2]Act of Governing the Sale, Return and environmentally sound Disposal of Electrical and Electronic Equipment (ElektroG), Article 3 (1), 2005

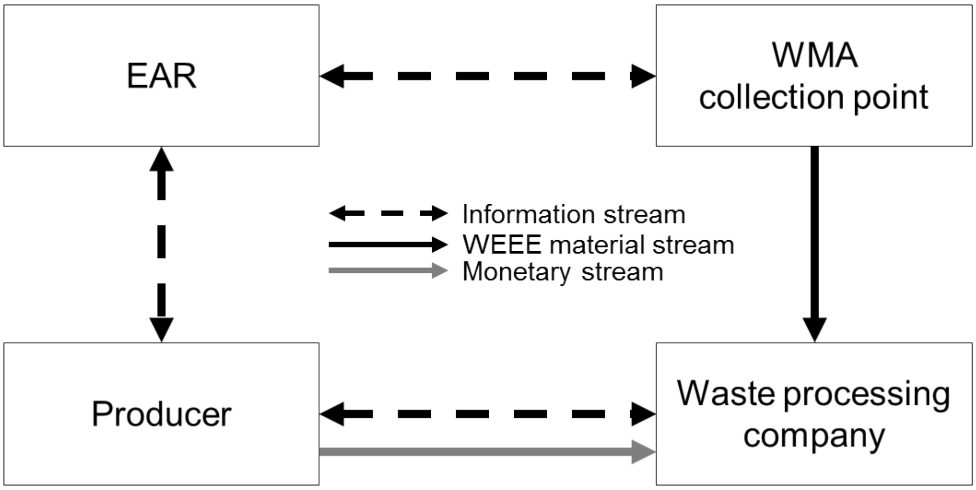


Figure 3: Concept of German take-back system of WEEE [Frey, 2006]

In addition to fees for pick-up requests, provision orders or data updates, producers are obliged to transfer an annual monetary guarantee to the EAR foundation (Appendix A1) [Annex 1, ElektroGKostV]. This ensures the financing of WEEE treatment in case of insolvency [§ 6 (3), ElektroG]. The amount is calculated according to the following equation.

$$\text{Guarantee } [€] = \text{Amount put on the market } [t/a] * \text{Return rate } [\%] * \text{Treatment costs } [€/t] \quad [2.1]$$

The return rate is an average value of returned amount of WEEE. The legal binding determination of return rates and treatment costs is based on recommendations of committees involved, expert assessments and experiences of third parties (Appendix A1) [Regelsetzung 02-003, 2012].

Collection and treatment of WEEE

The shared producer's responsibility illustrates a difference in comparison to the requirements of the European WEEE Directive 2012/19/EU. According to § 9 (3) ElektroG, the public waste management authorities are obliged to assume the WEEE household collection and offer returning points at no charge to the public. Public waste management authorities are legally advised to collect WEEE according to defined collection groups (CG) (Table 1). In addition, Table 1 includes WEEE categories in accordance with § 2 (1), ElektroG and provides appropriate examples.

Table 1: Classification of WEEE into categories and collection groups [ElektroG]

Category as laid down in § 2(1), ElektroG	Examples	No. of category	No. of coll. group
Large household appliances	Large cooling appliances, refrigerators, freezers, washing machines	1	1, 2
Small household appliances	Vacuum cleaners, carpet sweepers, other appliances for cleaning	2	5
IT and telecommunications equipment	Personal computers, notebooks, telephones	3	3
Consumer equipment	Radio sets, television sets, video cameras, video recorders	4	3
Lighting equipment	Straight fluorescent lamps, compact fluorescent lamps	5	4
Electrical and electronic tools	Drills, saws, sewing machines	6	5
Toys, leisure and sports equipment	Electric trains or car racing sets, hand-held video game consoles	7	5
Medical products	Radiotherapy equipment, cardiology equipment, dialysis equipment	8	5
Monitoring and control instruments	Smoke detectors, heating regulators, thermostats	9	5
Automatic dispensers	Automatic dispensers for hot drinks	10	1

Waste management authorities can take up an option on the treatment of WEEE instead of the producers and can put the recyclables on the market by themselves in accordance with § 9 (6), ElektroG. In this case, responsibility is borne for a minimum one year period and legal notification to the EAR foundation required.

2.1.1.3 Legislation of transboundary shipments of waste

Different requirements apply, if waste is subject to a transboundary shipment. Various laws at national and international level define the rules and restrictions.

International level

- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal of 22 March 1989
- Decision of the OECD-Council C(2001)107/Final on the Control of Transboundary Movements of Wastes Destined for Recovery Operations
- EC Regulation No. 1013/2006 on waste shipments

- Commission Regulation (EC) No. 1418/2007 of 29 November 2007 concerning the export for recovery of certain waste listed in Annex III or IIIA to Regulation (EC) No. 1013/2006 of the European Parliament and of the Council to certain countries, to which the OECD Decision on the control of transboundary movements of wastes does not apply.

National level

- Waste Transposition Act (AbfVerbrG)
- Revised Correspondents' Guidelines No. 1 regarding Shipments of Waste Electrical and Electronic Equipment (WEEE)
- Correspondents' Guidelines No. 4 regarding Classification of Waste Electrical and Electronic Equipment and Fly Ash from Coal-fired Power Plants according to Annex IV part I note (c) of Regulation (EC) No. 1013/2006 on Shipments of Waste

In summary, a transboundary shipment is subject to either information requirements, to a prior written notification and consent, or to a prohibition. The type of proceeding is dependent on the method of waste treatment applied, country of destination and the classification of waste concerned. Table 2 provides information on the classification of requirements concerning shipments of waste [UBA, 2012b].

Table 2: Regulations concerning transhipment of wastes [UBA, 2012b]

	Transboundary shipment between EU member states	Import into EU	Transit through EU	Export out of EU
Waste for disposal	Consent required	Consent required	Consent required	Prohibited
"Green waste"for recovery (Annex III, IIIA, IIIB of No. 1013/2006 not containing hazardous substances)	Information requirements	Information requirements	Information requirements	Information requirements or special provisions
Other wastes	**Consent required**	Consent required	Consent required	Prohibited

Export of WEEE is subject to a notification process (consent required) within European countries. Continuative, informal collectors transporting WEEE into Eastern European countries are obliged to undertake a notification process, if transported items are covered by § 3(1), KrWG.

2.1.2 Classification and informal sector activity fields

The following chapters present information regarding types of informal collectors, sources of extracted materials and handling of informal sector activities in Germany.

2.1.2.1 Types of informal collectors

Observations revealed that informal collectors acting in Germany partially originate from countries in Eastern Europe. Two different types of actors are differentiated between:

- Individuals (conduct collection for livelihood maintenance)
- Organised groups (collectors are part of an informal organisation)

However, no specifications are available regarding the structure of organised groups. The information is based on observations and statements of German municipalities [Janz et al., 2009].

Besides the collectors originating from Eastern European countries, illegal shipments take place via the port of Hamburg. In most cases, shiploads are declared as second-hand products or secondary raw materials, whereas they already come under the definition of waste in accordance with § 3 (1), KrWG [Jaron, 2009]. Different stakeholders are involved in these actions [Sander/Schilling, 2010].

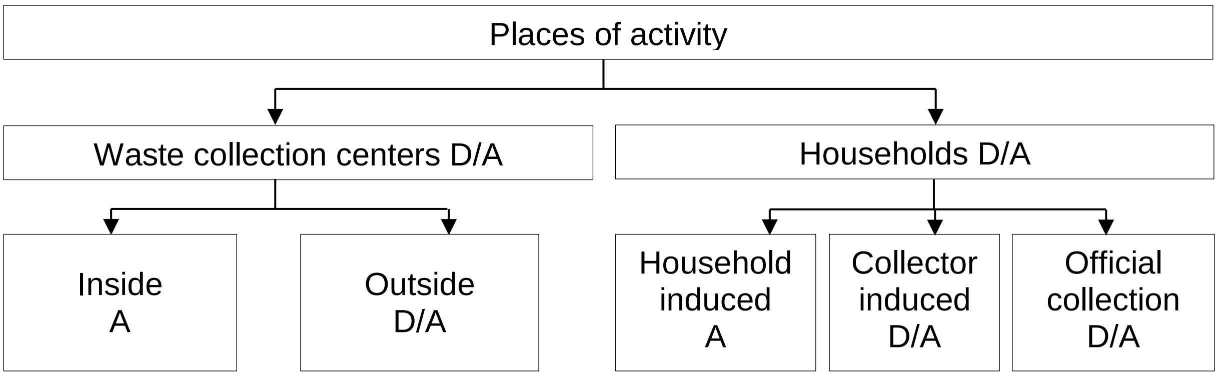
- Operators of used electrical and electronic products and WEEE collection points
    - trading with second-hand items (purchase and sale),
    - providing containers for collection,
    - providing intermediate specialised storage facilities on charges from businesses

- Agents
- Freight forwarding businesses
- Service providers of logistics and sea routes

2.1.2.2 Sources of extracted materials from informal sector activities

Eastern European collectors extract materials at two main sources in Germany. Either a collection takes place in front of waste collection centres or at a household level. The latter includes street collection, collection on request (official collection, Figure 4) or flyer announcements that promote informal collection of items at a specific date (collector induced, Figure 4) [Lange et al., 2010].

Furthermore, a classification of collection sources revealed places of activities inside and outside waste collection centres in Austria. In addition, a household induced collection was observed. This describes the case of households assuming informal sector activities. They put their waste in front of their property assuming that it will be collected by informal actors (or other residents) [Schmied et al., 2009].



A = Austria, D = Germany

Figure 4: Places of activities of informal sector in Germany and Austria [modified according to Schmied et al., 2009]

Waste and materials informally transhipped via the port of Hamburg originate from various sources, including ads in print media, flea markets, sale chains (end users sell items to used item traders who sell non-saleable items to exporters), reuse organisations, remarketing companies or delivery of items at businesses [Sander/Schilling, 2010].

2.1.3 Handling of informal sector activities

The handling of informal sector activities is divided into countermeasures and integration measures.

2.1.3.1 Countermeasures

Measures to avoid informal activities are often reported in literature [inter alia Mridu, 2009; Rouse, 2005; Dangi et.al, 2009; Chi et.al, 2001].

Several recommendations have been developed to provoke higher monitoring and control achievements of transhipments of WEEE on a legal and executive level in Germany. Table 3 presents selected measures [Sander/Schilling, 2010].

Table 3: Countermeasures avoiding informal transhipments of WEEE [Sander/Schilling, 2010]

Sources of informal collected items	
1	Street collection of waste to be conducted in a way that informal collections are avoided (collection on request)
2	Sensitisation of the public and their role in informal transhipments
3	Producers to develop and implement corporate policies regarding the export of EEE and WEEE
4	Quality labels and voluntary agreements for used-items operators to be developed and implemented
5	Corporate policies regarding the export of WEEE to be included in industry rankings
Legal requirements and controls	
6	Differentiation of waste and economic good to be deepened within the new WEEE guideline
7	Methodical ascertainment and development of criteria for identification and control of collection points
8	Further development of risk profiles regarding the export of second-hand EEE and WEEE as well as intensification of the exchange between relevant authorities
9	Initiating of investigations with the help of activities by the police in defined potential sources of origin of WEEE/EEE
Cooperation with destination countries	
10	Research regarding re-export of fraction manually and mechanically dismantled in destination countries
11	Support of development and implementation of adequate waste management systems in destination countries

Transhipments to Eastern European countries take place along the entire eastern border of Germany. This border is 1,153 kilometres in length when taking account of the Czech Republic and Poland as neighbouring countries. Hence, countermeasures are recommended to take place at sources of collection (refer to Chapter 2.1.2.2). They include the implementation of waste collection on request, parking bans in front of recycling centres and higher involvements of police actions [Janz et al., 2009].

According to literature studies, actions are mainly undertaken by municipalities, private companies responsible for waste management and authorities. No information is available on the success of the countermeasures. Conversely, studies have reported that countermeasures had no effect on informal sector activities [Rouse, 2005; Medina, 2005].

2.1.3.2 Integration measures

Effects such as access to finance and health care, knowledge of technologies, managerial efficiencies as well as local knowledge and job generation are subject to improvement regarding an integration of informal collectors into formal waste management [Ali/Ahmed, 2004]. Moreover, harmful emissions can be reduced by supporting a structured and controlled accomplishment of informal activities [Gonzenbach/Coad, 2007]. Literature studies highlight social advantages arising from integration as informal waste business offers employment and a livelihood for impoverished, marginalised and vulnerable individuals or social groups [Wilson, 2006].

No information is available on integration measures in Germany. However, Eastern European countries adapt waste management structures according to the given guidelines. Informal person groups dependent on the collection and handling of wastes are not included in the adaption process [Obersteiner, 2011].

Not considering these informal structures would lead to a depletion of already socially deprived classes. Moreover, informally collected items are partially offered at flea markets for reuse. Customers at used-item flea markets may also originate from socially deprived classes. An interruption of the current informal second-hand trade would adversely affect not only the livelihood of informal collectors but also of person groups with less purchasing power.

However, some waste management associations operate used-item markets themselves [BSR, 2012]. It can be assumed that these second-hand areas represent a legal access to reusable items of informal collectors acting as costumers.

In Hungary an association of informal used item collectors was legally established in 2012. The ‘International Second-Hand Service’ (ISHS) educates Hungarian informal collectors with respect to several topics such as legal requirements of western European countries or linguistic skills regarding the German language [Kozák, 2012].

2.2 Informal transhipped amounts

Determinations of extracted amounts are subject to wide fluctuations based on the informal nature of collection processes. Nevertheless, investigations have revealed that significant amounts are informally collected and transhipped by informal sector activities.

2.2.1 Informal collected amounts

Informal collection of WEEE is becoming increasingly focused. An annual average of 1.4 million tons of electrical and electronic products entered the market between 2006 and 2010 in Germany [EAR, 2012]. However, the amounts of WEEE returned into the official return system only add up to an annual average of 455,000 tons in the same years [DESTATIS, 2012]. Both types of data cannot be compared with each other for a given year. A usage phase of electrical products of 7.5 years on average relocates expectable amounts of WEEE to a later point of time [Brahms et al., 1989]. Therefore, collected amounts of WEEE have to be compared with amounts of products launched 7.5 years beforehand. Figure 5 contrasts launched products (‘Products put on the market’), officially generated amounts of WEEE (‘Generated WEEE’) and the corresponding trend lines. In addition, the curve progression of amounts of launched products is displayed taking into account a shift to a later point of time of 7.5 years (‘Products put on the market, excluding usage phase) to reveal actual missing amounts of WEEE.

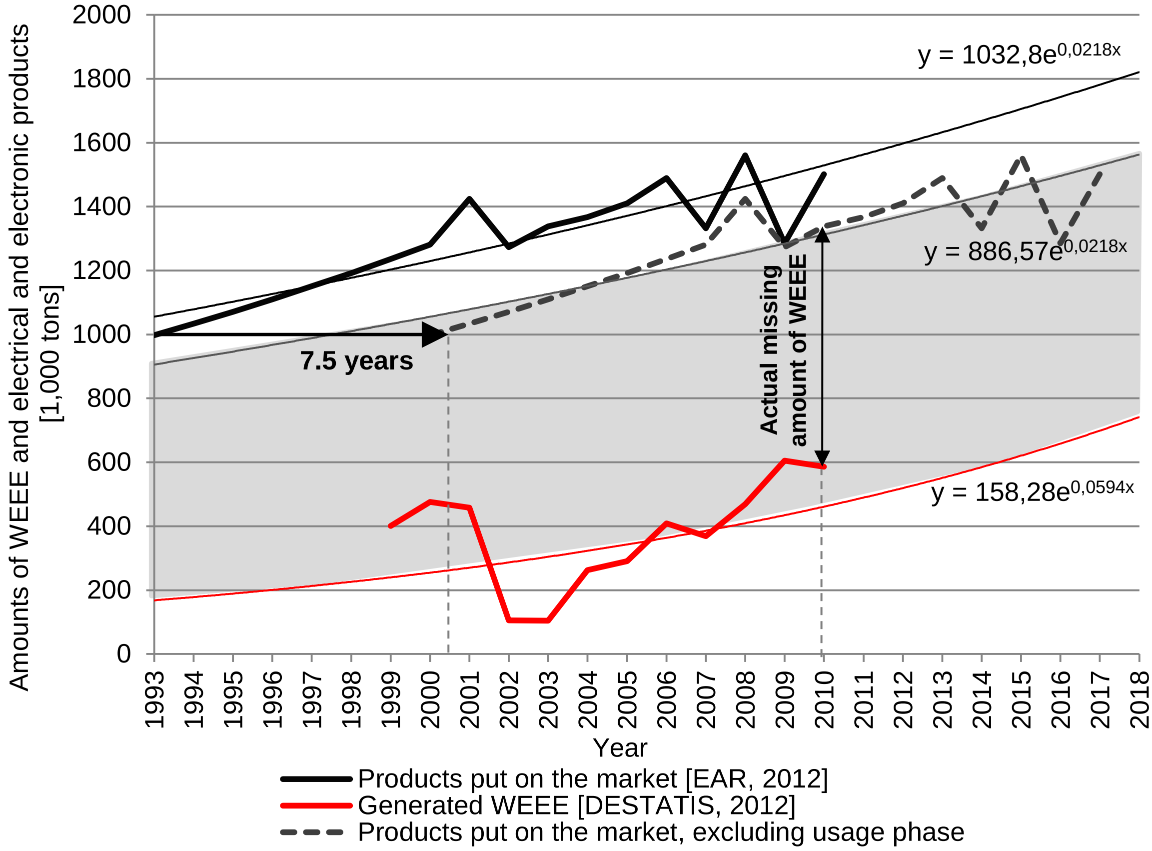


Figure 5: Comparison of electrical products put on the market, generated WEEE and products put on the market excluding usage phase [DESTATIS, 2012; EAR, 2012]

The distance between the trend lines of generated WEEE and products put on the market excluding the usage phase reveals actual missing amounts (grey shaded area). Exemplarily, formal collected amounts add up to 586 thousand tons in 2010 ('Generated WEEE'). Accompanied amounts of launched products are 1,338 million tons taking an average usage phase of 7.5 years. This leads to WEEE amounts of 752 thousand tons that do not end up in the official collection and treatment system.

Missing amounts are assumed to end up in the residual waste streams, stored in households or informally collected and transhipped [Rotter et al., 2006; Janz/Bilitewski, 2009b; Friege, 2012]. In 2008, a study estimated an amount of about 155,000 tons per year of WEEE informally transhipped via the port of Hamburg to countries such as China, India, Ghana or Nigeria [Sander/Schilling, 2010]. The transport of WEEE from Germany to Dutch and Belgian seaports displays another transhipment route and is roughly quantified at 50,000 tons per year [Sander/Schilling, 2010 in Friege, 2012].

An estimated annual WEEE amount ranging from 36,000 tons to 122,000 tons is informally transhipped to Eastern European countries [Janz/Bilitewski, 2009b]. Amounts refer to the overall area of Germany. Random interview checks with western German municipalities revealed collection activities in federal states such as Rhineland- Palatinate or Lower Saxony. Thereby the frequency of informal collection activities ranges from regular collection to rare collection (Table 4).

Table 4: Frequency of appearance of informal collectors at municipalities [Janz et al., 2009]

Informal collection is conducted	Number of municipalities
regularly	5
often	13
irregularly / sporadically	7
rarely / never	4

A European funded project has highlighted the topic of transhipments conducted by informal collectors originating from Eastern European countries. Investigations revealed an informal transhipped amount ranging from 89,000 tons to 124,000 tons per year at border crossing points between Hungary and Austria [Linzner et al., 2011]. Similar investigations were conducted at German-Polish border crossing points. Informal transhipped amounts add up to 44,000 tons per year on average. Investigations focused on transhipments to the Polish region of Lower Silesia and refer to an observed length of border of 100 kilometres [Lange et al., 2011b].

Informal collectors of Eastern European countries travel large distances (up to 1,100 kilometres) each day to reach their collection sources [SZ, 2009]. The use of passenger cars, vans as well as flatbed trucks results in high loading capacities and high transhipped amounts [Scherhaufer et al., 2011]. Alongside used vehicle types, amounts of informally collected items are highly dependent on [Linzner/Lange, 2012]:

- Type and density of collected material,
- Manual power,
- Infrastructure and corresponding distances to cover,
- Geographical conditions of area, and
- Accessibility of materials.

2.2.2 Collected fractions and density of transhipped material

The informal sector collects goods such as bulky waste, scrap metals and electrical and electronic appliances in Western European countries. A survey showed that mostly valuable electrical and electronic products and WEEE are extracted out of the formal waste stream in Germany. This includes dishwashers, ovens, washing machines, fridges as well as personal computers [Janz et al., 2009].

Bulk densities of collected items were investigated. Figure 6 shows the average bulk densities of one specific Hungarian collector.

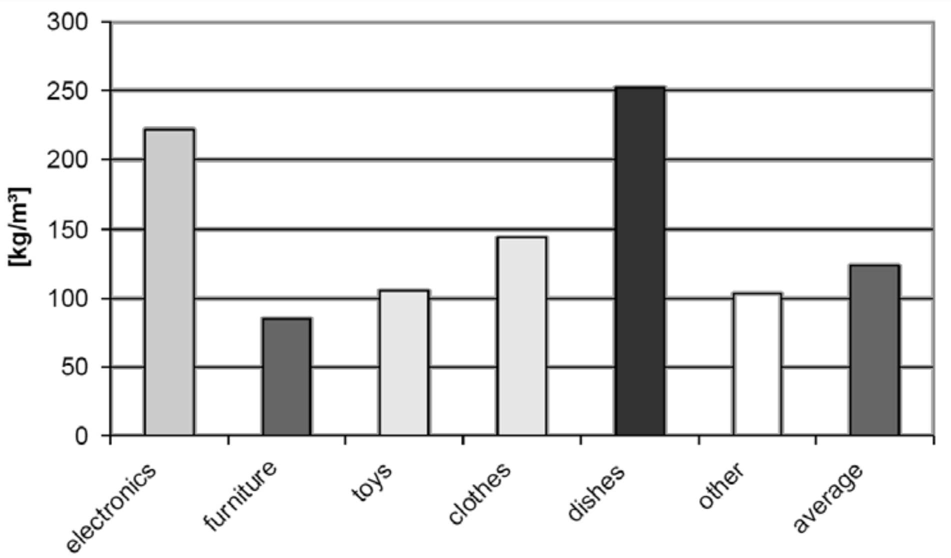


Figure 6: Bulk density of informal collected items [Obersteiner et al., 2011]

The average bulk density amounts to 125 kilograms per cubic metre. WEEE and dishes are found to be major items of the total collected fractions. Moreover, a specialisation on furniture, toys and clothing was found [Obersteiner et al., 2011].

2.3 Economic and environmental impacts of the informal sector

The environmental and economic effects of informal sector activities are subject to a controversial debate. Both positive effects and negative impacts are encountered in literature.

2.3.1 Environmental impacts of informal sector activities

In general, negative and positive environmental impacts can be classified into inadequate treatment of wastes and into conservation of natural resources caused by extraction, recycling and reuse processes. The transition between positive influences and negative impacts is highly dependent on boundary conditions.

2.3.1.1 Positive environmental impacts

Informal sector activities provide secondary raw materials. This leads to a reduction in demand for primary raw materials, of energy consumption of production processes and the associated use of water as well as the production of greenhouse gases [Coad, 2010]. Other ecological advantages arising include waste avoidance [Bilitewski et al., 2000].

Informal sector activities prolong the lifetime of WEEE appliances, when, for instance, the resale of items at flea markets in eastern European countries is taken into account. One of the largest informal reuse-markets is located in Devecser, Hungary. Informal actors offer items for resale, which have been collected in Western European countries. After a prolonged usage phase, items end up in the formal waste management and pass through the prevalent waste management system [Kozák, 2012].

[Scherhaufer et al., 2011] has investigated the environmental impacts of activities of Eastern European collectors. It is stated, for example, that informal reuse of a personal computer (PC) and monitor can be beneficial from an environmental point of view. The production of a new PC and the corresponding monitor causes 20% of the total life time emissions. This leads to environmental advantages as the reuse produces less emissions than the manufacture of a new appliance.

[Pertl et al., 2010] has detected environmental credits regarding the global warming potential (GWP) of the reuse of a washing machine. The same results are achieved by [Rüdenauer et al., 2005]. It has been verified that the substitution of an old washing machine (year of construction 1995 - 2000) does not amortise within 10 years as regards emerging production emissions. An exception to this is shown by the reuse of refigerators. High energy consumptions as well as compartments such as CFC's of old appliances lead to higher emissions in comparison to the production and use of new products [Pertl et al., 2010,].

2.3.1.2 Negative environmental impacts

Inadequate treatment techniques cause harmful emissions to the environment. Processes such as dismantling transfer hazardous substances directly to protective goods. Local pollution is often caused by informal activities and endangers the welfare of human beings and the environment in the vicinity [Gonzenbach, 2007].

WEEE consists of components such as ferrous metals, non-ferrous metals, precious metals and rare earths that should be returned to production cycles. Metals such as iron and steel are processed up to 75% in electric and electronic appliances. Plastics and non-ferrous metals, however, also constitute major parts (Table 5).

Table 5: Composition of WEEE collection groups [VDI 2343, 2011]

Components in Mass - %	CG 1	CG 2	CG 3/ no displays	CG 3/ only displays	CG 4	CG 5
Iron and steel	60 - 75 %	60 - 70 %	30 - 40 %	5 - 15 %	1%	25 - 40 %
Non-ferrous metals and compounds	10 - 15 %	3 - 5 %	10 - 15 %	2 - 5 %	1%	5 - 10 %
Plastics	8 - 12 %	15 - 20 %	30 - 50 %	20 - 30%	1 - 5 %	30 - 65 %
Circuit boards incl. precious metals	< 1 %	< 1 %	3 - 8 %	1 - 5 %	-	< 5%
Hazardous substances	< 1 %	< 2 %	< 1 %	< 1 %	< 1 %	< 1 %
Glass	5 - 10 %	< 1 %	< 2 %	60%	> 90 %	< 2 %
Others (inerts, etc.)	1 - 10 %	< 5 %	10 - 20 %	5%	-	1 - 4 %

CG = Collection groups

Informal collections reduce the amounts available for recycling, thus negatively influencing resource recovery. A resources strategy implemented by the German Federal Government highlights the necessity of recycling and raw material processing as Germany is poor in natural resources. It aims to decelerate resource consumption and support a policy of non-dependency on resource imports [BMWi, 2010]. Conversely, WEEE and used electrical and electronic products are transhipped out of Germany to Eastern European countries, where landfilling is still one of the major used disposal methods. Taking Poland as an example, 78% of collected waste is landfilled [Rózanska/Sobczyk, 2010]. It implies a lost potential of secondary raw materials, which cannot be returned to production cycles. Moreover, this represents a source of hazardous substances, which can be transferred to subjects of protection [Dimitrakakis et al., 2009]. A study revealed that 1% of WEEE contained in residual waste causes a pollutant load of 14 up to 57% of residual waste analysed [Janz/Bilitewski, 2009b].

A polluting potential is caused by substances such as

- Polychlorinated biphenyls (PCB's) (e.g. in condensers and transformers)
- Polybrominated diphenyl ethers (PBDE's) (e.g. as flame retardants in PC bodies, circuit boards or wires)
- Mercury (e.g. in fluorescent tubes, batteries and background lighting of LCD's)
- Lead and cadmium (e.g. in accumulators, panel glass or partially in plastics)
- CFC's/HCFC's (e.g. as cooling agents or as propellants in PUR foam). [Martens, 2011]

These are basic WEEE components and represent a high source of risk when inadequate treatment is considered [Bilitewski/Grundmann, 2012]. For instance, WEEE littering at unsuitable places fosters the entry of hazardous substances into protective goods such as water and soil. Experiences show that informal collectors of Eastern European countries dismantle WEEE for the purpose of extracting valuable materials thereby leaving no usable components behind [Janz et al., 2009].

2.3.2 Economic impacts of informal sector activities

Informal reuse of items prolongs the lifetime of products. The product itself can gain an added value. This leads to the discussion at what point an economic good is waste and vice versa. From an economic point of view, a material without positive value is defined as macroeconomic waste [Weiland, 2000]. However, individuals have different evaluation standards. Whereas a disposing person connects a negative value to a good, a receiving person can evaluate it positively, if a reasonable usage is provided. Hence, it can be expressed economically and can be defined as economic good [Weiland, 2000]. A transition point between waste and product is dependent on economical, technical and legal aspects. Reuse is advisable provided that limiting values are met [Brüning, 2012].

2.3.2.1 Positive economic impacts

Cost reduction can be achieved in several ways. Quantity reduction of waste leads to lower amounts and less financial expenditures on collection and transport. Consequently, more space is available at landfills. This constitutes an extension of the lifetime of capital investments. Thereby economic benefits are gained at no direct costs to tax payers [Ali/Ahmed, 2004]. Moreover, a risk reduction can be achieved by transferring marginal activities, unpredictable costs or unreliable revenues to the informal sector [Scheinberg et al., 2010].

2.3.2.2 Negative economic impacts

Official actors, who bear WEEE collection and treatment responsibility, criticise informal collection activities (especially in Germany), since extracted appliances connote a financial loss [Janz et al., 2009]. Therefore the importance of availability of valuable materials is not only connected to secondary raw material processing. Increasing prices of secondary raw materials display rising profitability of recycling processes taking into account a growing global economy and a corresponding demand for valuable materials [Dornack/Bilitewski, 2006]. A decreasing supply combined with a growing demand of precious metals (within the production of electrical and electronic products) reinforces WEEE appreciation. Although electrical and electronic appliances contain less than 1 % of precious metals such as gold, palladium and silver, they nevertheless have a higher economic relevance in comparison to major processed materials such as iron, steel and non-ferrous metals (Table 6) [Chancerel, 2010; Huismann, 2004]. No correlation can be derived between mass portion and economic value, which is exemplarily shown for selected appliances in Table 6 [Friege, 2012; Hagelüken, 2008].

Table 6: Comparison of mass and value percentage of electrical and electronic products [Friege, 2012; Hagelüken, 2008]

Mass percentage	Fe	Al	Cu	Ag	Au	Pd
Circuit board (PC)	7%	5%	20%	0,1%	0,025%	0,011%
Mobile telephone	6%	2%	13%	0,35%	0,034%	0,015%
DVD player	62%	2%	5%	0,115%	0,015%	0,004%
Value percentage						
Circuit board (PC)	0%	1%	17%	5%	62%	14%
Mobile telephone	0%	0%	8%	13%	64%	15%
DVD player	17%	5%	36%	5%	33%	5%

The enhancement in value of WEEE is reflected in gate fees at recycling facilities. Market reports on WEEE processing facilities indicate rising profitability of WEEE collection and treatment. Figure 7 exemplarily illustrates gate fees of collection group 5. Trends of gate fees of collection groups 1 to 3b can be seen in Appendix A2.

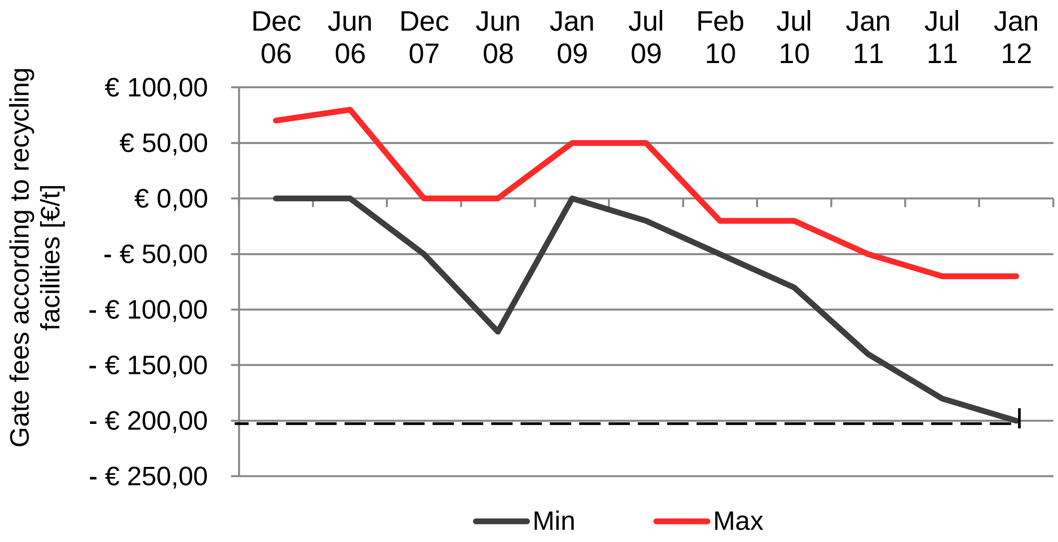


Figure 7: Gate fees of collection group 5 at recycling facilities (€/t) [EUWID, 2007-2012]

The curve progressions presented display minimum and maximum gate fees at German recycling facilities between 2006 and 2012. Thereby, values illustrate gate fees, deliverer of WEEE pay (‘+’, delivery costs) or receive (‘-‘, delivery revenues). A subsequent market stabilisation results in revenues for delivering actors despite a price depression in 2009 due to the economic crisis. In January 2012, one ton of collection group 5 generated delivery revenues of up to €200 [EUWID, 2012].

The EAR foundation documents waste management associations taking responsibility for WEEE collection and treatment in accordance with § 9 (6), ElektroG. Figure 8 exemplarily demonstrates the development of adopted treatment responsibilities of waste management associations for collection group 5.

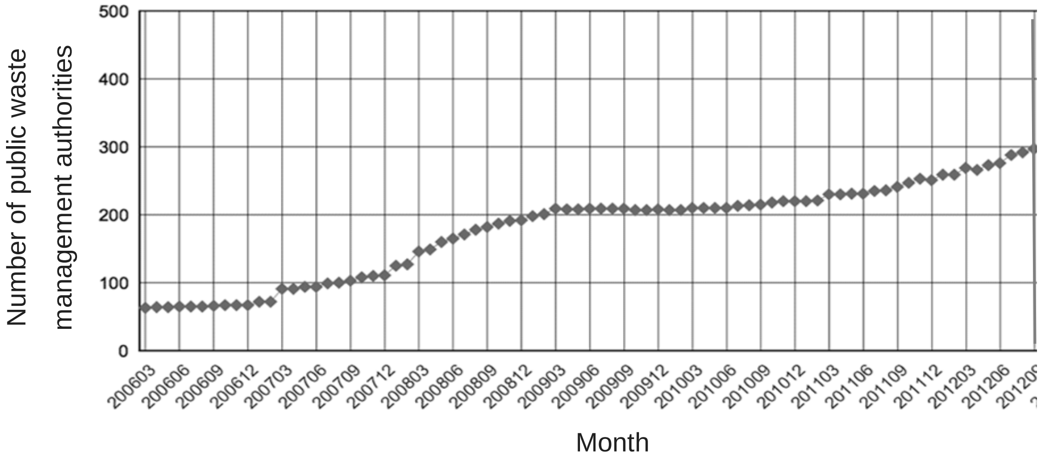


Figure 8: Number of WMAs adopting treatment responsibility for collection group 5 [EAR, 2012]

Comparing Figures 7 and 8, the number of waste management associations bearing treatment responsibility for collection group 5 and decreasing gate fees at recycling facilities are negatively correlated. Thus an interest in enforcing countermeasures on the part of waste management associations may be assumed in order to avoid informal collection and transboundary shipments of WEEE.

2.3.2.3 Economic drivers and incentives

In general, economic activities are characterised by two main factors: comparison and self-interest. The comparison is characterised by correlated alternatives. Thereby the economically most efficient option is chosen. The self-interest displays the willingness of individuals to increase their own economic benefits. It constitutes a central starting point to set incentives and to influence given economic situations [Blum et al., 2003].

Different economic drivers enforce the transhipment of materials considering informal sector activities. The following indicators play a decisive role in regard to the factor 'comparison' [Fischer et al., 2008].

- Differences in waste treatment prices
- Different secondary raw material prices
- National waste taxes
- Transportation costs
- Liberalisation

A comparison of quantified values of indicators reveals the economically most efficient treatment option or country.

Besides economic drivers, differences can be found in incentives (self-interest) based on the differentiation made in Chapter 2.1.2.1. (Organised) transhipments overseas (but also including organised transhipments to Eastern Europe) result from cost differences between the origin and destination country [Jaron, 2009]. Referring to WEEE, treatment and disposal costs are normally higher in industrialised countries and/or overmatch transhipment costs to the countries of destination [Fischer et al., 2008]. Consequently, the economic incentive is determined by a cost saving with respect to profit maximization of involved actors.

Conversely, individuals from Eastern European countries pursue informal collection to maintain their livelihood. The economic incentive is defined as satisfaction of elementary needs (Figure 9).

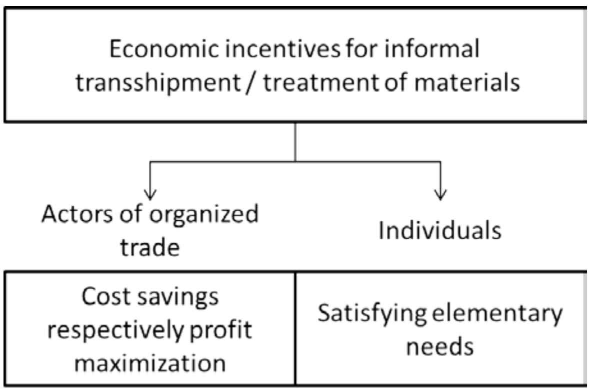


Figure 9: Economic incentives of informal collections and transhipments

An exclusion from waste business is accompanied by blocking access to an income for individuals from Eastern European countries who conduct informal collection to satisfy their basic needs.

2.3.3 Evaluation of informal sector activities

There exist various theories and methodologies for evaluating the circumstances from an economic perspective. This chapter presents the background and the application of life cycle costing (LCC) and sheds a light on the concept of eco-efficiency.

2.3.3.1 Life cycle costing (LCC)

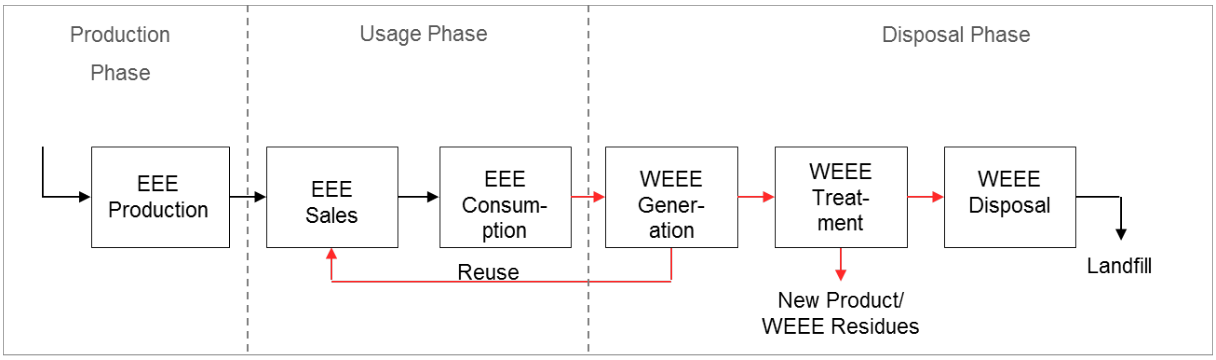
In general, LCC was not developed in an environmental context [Gluch/Baumann 2004]. The traditional life cycle costing was used to survey all the costs associated with an industrial product. In this context, however, the life cycle costing model is a decision supporting tool for the purpose of comparing alternatives during the design/acquisition phase in order to achieve the most cost-effective option for further proceedings [NSW, 2004].

LCC is a classical accounting tool that takes into account all pecuniary costs of the whole economic life cycle. It is vaguely defined as "*a technique, which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial costs and future operational costs*"[3] within ISO 15686. [NSW, 2004] determines the LCC as "*the total costs throughout* (the) *life* (of a product) *including planning, design, acquisition and support costs and any other costs directly attributable to owning or using* (this product)"[4].

The aim of applying LCC is to compare either equipment or future projects in relation to total appearing costs [Barringer et al., 1996]. Total costs include acquisition, installation, operation, maintenance, refurbishment, and discarding and disposal costs [AS / NZS 4536:1999, 1999]. Total costs refer to the total life cycle of a product, which is exemplarily illustrated for electrical and electronic products and WEEE (Figure 10).

[3] International Organization for Standardization, Buildings and Constructed Assets – service life planning (ISO 15686:2011), 2011

[4] New-South Wales Treasury, Total Asset Management-Life Cycle Costing Guideline TAM 04-10, 2004, p.1



EEE = electric and electronic equipment

Figure 10: Conceptual life cycle of EEE/ WEEE [UNEP, 2011]

In general, a life cycle model consists of three basic stages, the acquisition phase, the utilization phase and the recycling phase, whereas costs are compounded by:

- costs to the manufacturer, and/or
- costs to the user, and/or
- costs to the society [Asiedu/Gu, 1998]

A further development into more detailed life stages is reported in literature [EASEWASTE, 2010; NSW, 2004]. This can include the design phase, the manufacture phase or the distribution phase.

Cost items of each life stage differ according to the objective to be analysed. Corresponding values have to be determined while considering data originating from literature, industry, municipalities, etc. in order to reach an accurate result. Exemplarily, cost items of the disposal phase are:

- Recycling costs
- Remanufacturing costs
- Reuse costs
- Disposal costs
- Disassembly costs [Asiedu/Gu, 1998].

Costs models are used to quantify determined cost items. With respect to vague cost estimations, sensitivity analyses reveal ranges that lead to recommendations regarding the choice of different evaluated circumstances.

2.3.3.2 LCC regarding evaluation of reuse and informal sector activities

[Rüdenauer et al., 2005] calculated life cycle costs of washing machines with respect to the perspective of private households. Acquisition costs, energy costs, costs for fresh water supply as well as costs for waste water treatment were included. The analysis revealed that reuse of washing machines only leads to cost savings if old appliances with high energy and water demand are substituted (Figure 11).

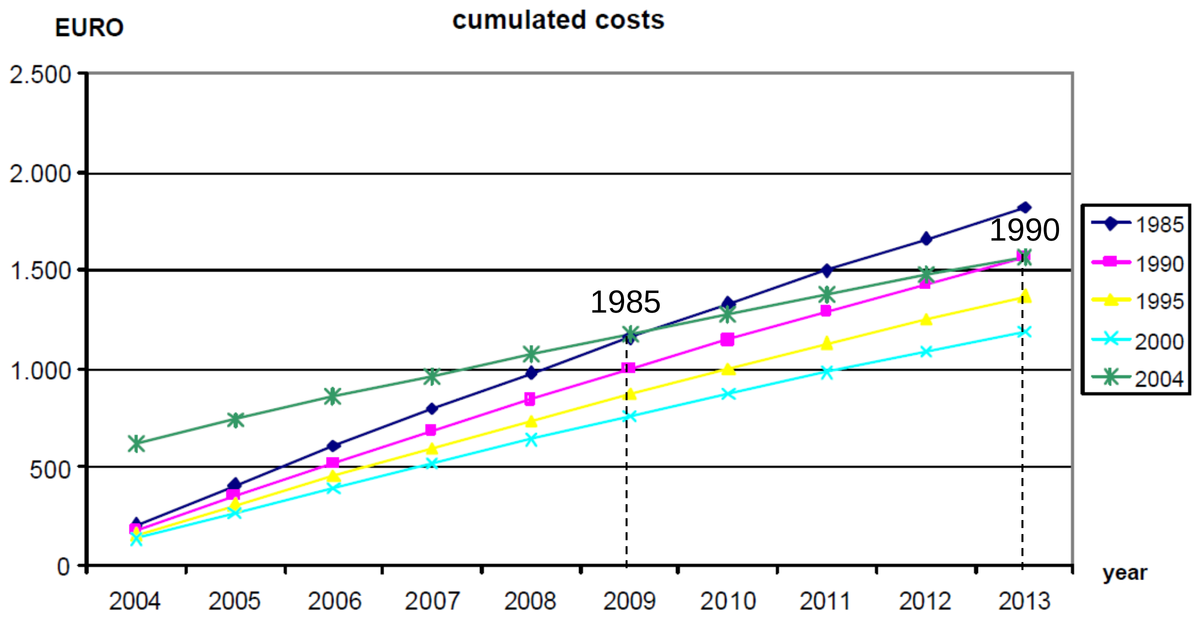


Figure 11: Life cycle costs of washing machines [Rüdenauer et al., 2005]

Old washing machines refer to the construction years 1985 and 1990, which are amortised in 2009 and 2013 by the acquisition of a new washing machine (constructed in 2004).

[Pertl et al., 2010] analysed life cycle costs of washing machines while comparing formal waste treatment in accordance with given regulations in Austria ('I_formEoL'), an informal collection and dismantling of a washing machine to sell valuable parts ('II_CollEoL') and a reuse of a washing machine collected by Hungarian informal collectors ('III_Reuse') (Figure 12).

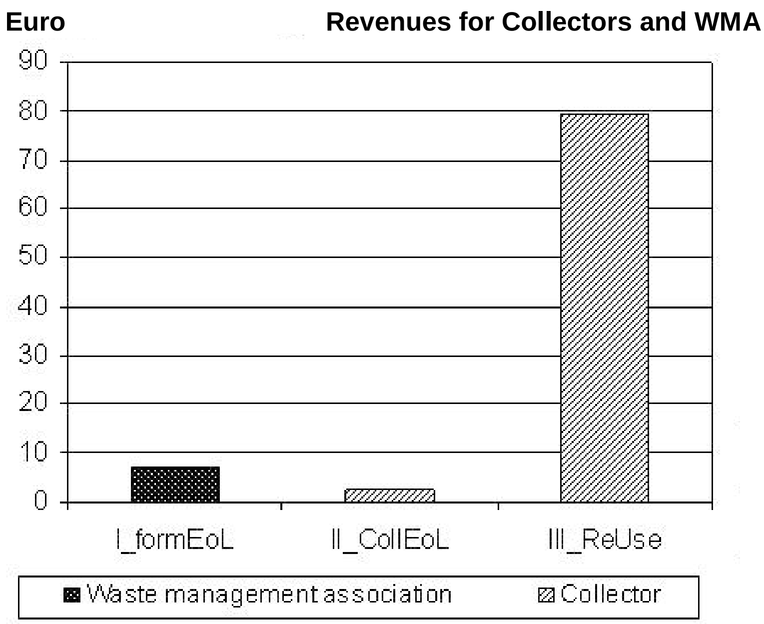


Figure 12: Economic assessment of informal sector activities in Austria [Pertl et al., 2010]

Highest revenues result for informal collectors reselling washing machines for reuse at informal flea markets ('III_Reuse'). This is based on higher sales prices than income gained by the sale of parts of a washing machine ('II_CollEoL' and 'I_formEoL') [Pertl et al., 2010].

2.3.3.3 Eco-efficiency

In times of a higher sensitivity regarding environmental issues, the attempt is undertaken to compare resulting costs with resulting environmental performances of the systems or objects considered. The aim is to evaluate alternatives that consider needs from both an environmental and an economic perspective [Rüdenauer et al., 2007]. As a requirement for this purpose, the same system boundaries and scopes for both evaluation methods are necessary.

Eco-efficiency (EE) is a possibility of combining economic and ecological issues. Although a generally accepted definition of eco-efficiency is still lacking, a general consensus exists that eco-efficiency represents an indicator that expresses the ratio between environmental and economic variables. In this case, it is feasible to reach functional units that combine both methods and give a value judgement. According to [Jeswani et al., 2010], the expressions below can be used as a functional unit:

$$\frac{Environmental\ Improvment}{Unit\ of\ Costs} \quad [2.2]$$

or

$$\frac{Costs}{Unit\ of\ Environmental\ Improvement} \quad [2.3]$$

The Organisation for Economic Co-operation and Development (OECD) defines the presented relation as an output, expressed by a certain value of considered products or services, divided by an input that displays the environmental consequences of activities conducted to achieve the output [OECD, 1998 in WBCSD, 2000].

3 METHODOLOGY OF INVESTIGATIONS

Four different investigations are conducted to reveal precise knowledge concerning informal sector activities in Germany. They include:

Approach I:	A survey of German waste management associations to characterise informal sector activities
Approach II:	Determination of informal transhipped amounts of WEEE into Eastern European countries along the entire eastern border of Germany
Approach III:	Determination of economic and ecological impacts of informal sector activities of Eastern European collectors with regard to four different perspectives: producers (§ 10 (1), ElektroG), waste management associations (WMA) (§ 9 (6) and § 9 (3), ElektroG), private households and informal collectors originating from Poland
Approach IV:	Determination of the eco-efficiency of informal sector activities

The following chapters point out the methodology used for each object of investigation. It includes the presentation of applied questionnaires, derivation of transhipped amounts of WEEE, associated economic and environmental effects of considered perspectives and a comparison of life cycle costs and life cycle CO_2 emissions.

3.1 Approach I - Survey of affected stakeholders

A survey was conducted to obtain a picture of informal sector activities of collectors originating from Eastern Europe. A total of 356 competent waste management associations from administrative districts and urban municipalities across Germany were contacted in the form of a multiple-choice questionnaire sent by email. 61 questionnaires were completed and sent back, resulting in a response quota of 17 %. If a third party was commissioned in accordance with § 22, KrWG, the participation request was in some cases forwarded.

Table 7 presents a list of the survey questions and corresponding responses. Multiple answers were allowed in questions a, d, i and j.

Table 7: Multiple-choice questionnaire and received answers

Questions		Possible answers	Answers from 61 completed questionnaires
a)	What means of collection are provided for bulky waste and WEEE for citizens in the administrative district?	• Street collection • WCC • Collection on request	14 55 41
b)	Do informal collectors appear?	• Yes • No	49 11
c)	How often do informal collectors appear?	• Daily • 2-3 times a week • Every two weeks • Once a month • Once every 6 month	15 17 3 5 6
d)	What nationality are the informal collectors?	• Hungarian • Czech • Polish • Romanian • Slovakian • Latvian • German • Not known • Other	9 14 27 15 8 3 2 15 8
e)	How much material do informal collectors collect?	• < 50 kg • 50 – 250 kg • 250 – 500 kg • 500 – 1,000 kg • 1,000 – 1,500 kg • > 1,500 kg • Not known	0 3 2 2 0 2 40
f)	Which items are preferably collected?	• Only WEEE • Only bulky waste (furniture, …) • Everything • Not known	32 6 11 4
g)	Do informal collectors cause littering?	• Yes • No	28 19

Continuation of table 7

Multiple – choice questions		Possible answers	Answers from 61 completed questionnaires
h)	Do informal collections cause additional costs or savings?	• Additional costs • Savings • Additional costs and saving • Neither costs nor savings • Not known	16 3 10 7 10
i)	Does the waste organization conduct measures to integrate informal collectors?	• Sale of reusable items at small prices • No measures • Other	4 38 6
j)	Does the waste organization conduct measures to prevent informal collections?	• Parking ban in front of WCC • Sensitisation of population • Measures by the police • No measures • Other	0 11 9 16 17

Regarding response quotas, a difference is evident between eastern and central German states (Bavaria, Brandenburg, Mecklenburg Western Pomerania, Saxony, Saxony Anhalt, Schleswig Holstein and Thuringia) and western German states (Baden Württemberg, Lower Saxony, Hessen, North Rhine-Westphalia and Rhineland-Palatinate). On average, response quotas of eastern and central German states add up to 27 %, whereas only 9 % of western German states replied.

Figure 13 displays response quotas of each federal state. Grey shaded columns refer to eastern and central German states. Red shaded columns denote western German states.

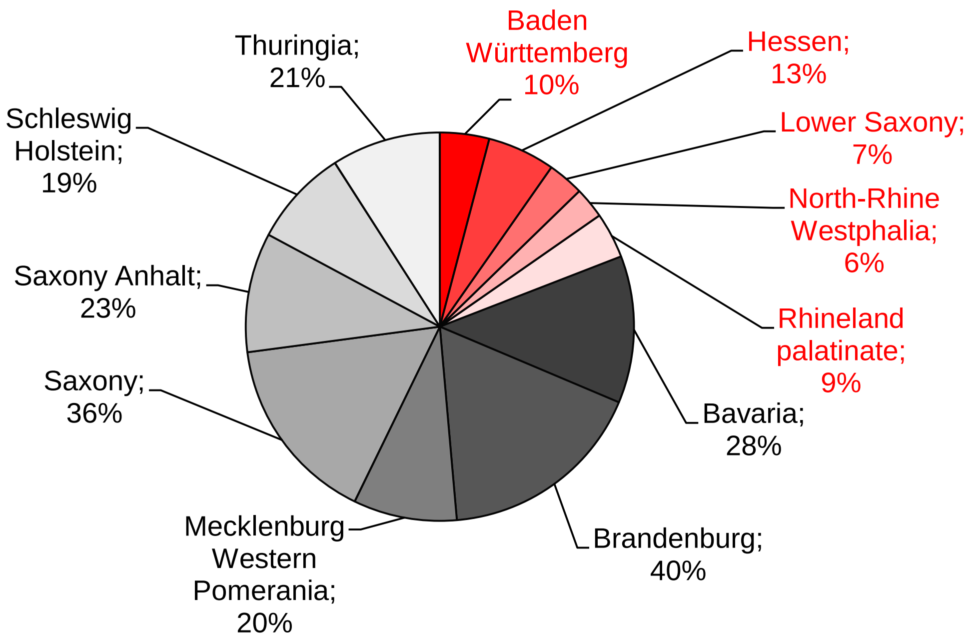


Figure 13: Classification of response quotas by German federal state

The state of Saarland is an exception and is not included in displayed response percentages. One commissioned waste organisation is responsible for all six administrative districts of Saarland due to the relatively small area of the state. Here the response quota is 100 %.

The classification of response quotas lead to a first assumption that eastern and central German states are more affected by informal collection of wastes and materials.

3.2 Approach II - Investigation of informally transhipped WEEE

The method applied here is based on the methodology of investigating transhipped amounts of [Linzner et al., 2011]. This approach uses traffic counting of vehicles transporting informally collected materials. Previously conducted countings at Germany's eastern borders form the basis of these investigations [Lange et al., 2011].

3.2.1 Background of Investigations

A total of 26 border countings took place at six different German-Polish border crossing points between 2010 and 2012. Observations revealed the amount informally transhipped to the region of Lower Silesia in Poland. The border crossing points in question were Görlitz / Ludwigsdorf (A4 motorway), Görlitz / Stadtbrücke (state road 125), Hagenwerder (state road 128), Forst / Lausitz (A15 motorway) and Podrosche (state road 8140). The distance between the northernmost (Forst/Lausitz) and southernmost border crossing point (Hagenwerder) is some 100 kilometres [Lange et al., 2011b].

Different vehicle types (passenger cars, small vans, large vans, flatbed trucks) with small and large trailers as well as those without trailers were counted. Each vehicle counted was assigned to one of three different probability levels: 1) the '> 90%' level, definite transportation of informally collected materials; 2) the '10% - 90%', if transhipment was not obvious; 3) the '< 10%' level, for vehicles with no informal background.

Controls of crossing cars revealed a proportion of vehicles transporting informally collected items in the total number of controlled cars (Appendix A3). The resulting percentage (probability factor) was applied to the total number of counted cars within level '10% - 90%', which reveals the actual number of vehicles transhipping informally collected items across the border.

The documentation of vehicles crossing was conducted on an hourly basis. The transhipped hourly volume was derived taking into account the loading volume of observed vehicle types and trailers, a determined loading factor and the proportion of vehicles that were actually transporting informally collected items. The transhipped volumes were found to range from 1 to 65 cubic metres per hour (Appendix A4).

To extrapolate transhipped volumes from an hourly to an annual basis, daily, weekly and seasonal correction factors are determined (Appendix A5). The daily correction factor (DCF) displays the proportional transhipped amount per day based on a fluctuating hourly amount on a given day. Similarly, the weekly and seasonal correction factors (WCF, SCF) represent the extrapolation from weekday to week and from month to year [Linzner et al., 2011].

3.2.2 Transhipped WEEE amounts across the eastern border of Germany

Scenarios of loading factors are defined and a classification of border crossings is conducted to determine annual transhipped amounts across the entire eastern border of Germany.

3.2.2.1 Scenarios of loading factor

The loading factor represents the proportion of transported volume in relation to the overall loading capacity per vehicle. Three different scenarios of loading factors are defined. Scenario one (LF 1) describes overloading, as informal transports with an overuse of load volume capacities are observed during border countings (105%). Scenario two (LF 2) displays a utilization of just under the total load volume (95%) and scenario three (LF 3) considers a loading factor of 75% (Table 8). Lower unused load volume capacities are not considered, as an informal transport is assumed to be inefficient for collectors.

Table 8: Scenarios of different loading factors of vehicles

Scenarios	Loading factor in percentage
Scenario loading factor 1 (LF1)	105%
Scenario loading factor 2 (LF2)	95%
Scenario loading factor 3 (LF3)	75%

3.2.2.2 Classification of border crossings

A classification of border crossings ensues by motorway (Forst/Lausitz; Görlitz/Ludwigsdorf), federal highway (Görlitz/Stadtbrücke; Bad Muskau) and state road (Podrosche, Hagenwerder). The basis of the classification builds the average transhipped volumes per hour and border crossing (Appendix A6). Transhipped volumes are displayed in Table 9 for each loading factor.

Table 9: Classification of border crossings according to transhipped volumes

Type of road	Transhipped volume per hour and border crossing		
	LF1 = 105%	LF2 = 95%	LF3 = 75%
Görlitz/Ludwigsdorf	140 m³/hr	126 m³/hr	93 m³/hr
Forst/Lausitz	62 m³/hr	56 m³/hr	41 m³/hr
Average highway	**101 m³/hr**	**91 m³/hr**	**67 m³/hr**
Görlitz/Stadtbrücke	12 m³/hr	11 m³/hr	8 m³/hr
Bad Muskau	10 m³/hr	9 m³/hr	6 m³/hr
Average federal highway	**11 m³/hr**	**10 m³/hr**	**7 m³/hr**
Podrosche	0 m³/hr	0 m³/hr	0 m³/hr
Hagenwerder	2 m³/hr	2 m³/hr	1 m³/hr
Average state road	**1 m³/hr**	**1 m³/hr**	**1 m³/hr**

The eastern border of Germany has a length of 1,253 kilometres with Poland and Czech Republic as neighbouring states. 76 border crossings are located along the border, divided into 48 state roads, 22 federal highways and 6 motorways (Appendix A6).

3.2.2.3 Calculation of total transhipped amounts

Each type of border crossing is associated with the corresponding transhipped hourly volume presented in Table 9. The extrapolation to an annual transhipped amount is conducted by using Equation 3.1 [modified according to Linzer et al., 2011]. Results are obtained for each loading factor (75% - 105%) and for different densities ($þ_x$) of transhipped materials, which are estimated between 100 and 200 kilogram per cubic metre [Lange et al., 2011].

$$Q_{LF_x} \left[\frac{t}{a}\right] = \left(\sum_{V_{hr*BC}} * DCF * 4 * WCF * SCF \right) * \frac{þ_x}{1000} \qquad [3.1]$$

Q_{LFx}	=	transhipped quantity per year and loading rate scenario
V_{hr*BC}	=	transhipped volume per hour and border crossing (BC)
DCF	=	daily correction factor
WCF	=	weekly correction factor
SCF	=	seasonal correction factor
$þ_x$	=	Density of 100 m³/kg (min), 150 m³/kg (average) and 200 m³/kg (max)

Applying equation 3.1 results in minimum, average and maximum total transhipped amounts. The range is based on different loading factors and densities. Table 10 summarises the methodology.

Table 10: Summary of methodology of investigating total transhipped amounts

ρ_x / m³/(hr*BC)	100 m³/kg	150 m³/kg	200 m³/kg
LF 1 (75%)	$MINIMUM_{total\ amount}$	-	-
LF 2 (95%)	-	$AVERAGE_{total\ amount}$	-
LF 3 (105%)	-	-	$MAXIMUM_{total\ amount}$
Total transhipped amount	$MINIMUM_{total\ amount}$	$AVERAGE_{total\ amount}$	$MAXIMUM_{total\ amount}$

3.2.2.4 Determination of proportion of WEEE

Transhipped amounts include all types of collected materials (bulky waste, WEEE, metals, etc.). The results of the survey are used to determine the WEEE proportion (refer to Chapter 3.1). Question f) regarding specialisations of informal collectors on specific fractions forms the basis of the applied WEEE proportion, which is consequently subject to a sensitivity analysis. A positive and negative deviation of 10% is considered.

From the considerations, a minimum, average and maximum amount of WEEE result in informal transhipments to eastern European countries. Table 11 summarises the methodology.

Table 11: Summary of methodology of investigating transhipped WEEE amounts

Total transhipped amounts	MINIMUM	AVERAGE	MAXIMUM
Proportion of WEEE (-10%)	$MINIMUM_{WEEE}$	-	-
Proportion of WEEE	-	$AVERAGE_{WEEE}$	-
Proportion of WEEE (+ 10%)	-	-	$MAXIMUM_{WEEE}$
Total transhipped WEEE amounts	$MINIMUM_{WEEE}$	$AVERAGE_{WEEE}$	$MAXIMUM_{WEEE}$

The prognosis of actual amounts of the launched products presented in Figure 5, Chapter 2.2.1 is compared to average values of informal transhipped WEEE.

3.2.2.5 Modelling of informal collection scenarios

It is not possible to derive a classification of informally collected types of WEEE from the investigations presented in Chapter 3.1. Therefore a modelling is conducted of five different scenarios regarding different compositions of types of WEEE (Table 12).

In accordance with § 9 (4), ElektroG, a classification is made into collection groups as presented in Table 1, Chapter 2.1.1.2. Collection group 3 is continuatively divided into 'IT telecommunication and consumer equipment without displays' (CG 3a) and 'Only displays' (CG 3b) [Euwid, 2007 - 2012]. Collection group 4 is not considered, as the informal collection is assumed to be negligible.

Table 12: Modelled scenarios regarding different distributions of informal collected WEEE

Modelling of scenarios	CG1	CG2	CG3a	CG3b	CG5
Scenario Equal Composition **(Equal_Comp)**	20%	20%	20%	20%	20%
Scenario EAR **(EAR)**	4%	29%	29%	29%	10%
Scenario High Ferrous metals **(high_Fe)**	45%	40%	5%	5%	5%
Scenario High Plastic scenario **(high_Pl)**	5%	5%	40%	10%	40%
Scenario High Precious metals **(high_PM)**	5%	5%	40%	30%	20%

The 'Equal_Comp' scenario considers an equal distribution of informal collected collection groups. The classification of the 'EAR' scenario is derived from formally collected amounts per collection group of pick-up requests commissioned by the EAR foundation (Appendix A9). It is based on the assumption that informally collected amounts correlate with formally collected amounts. The remaining scenarios are modelled according to components of WEEE (refer to Chapter 2.3.1.2, Table 5) [VDI 2343, 2011]. The 'high_Fe' scenario considers a high proportion of ferrous metals, which are found in collection groups 1 and 2. The 'high_Pl' scenario includes high proportions of plastics that are allocated to collection groups 3a and 5. The last scenario 'high_PM' considers a high proportion of precious metals, which are mostly found in collection groups 3a and 3b.

The composition of the collection groups of each modelled scenario is applied to transhipped WEEE amounts. Taking the 'Equal_Comp' scenario as an example, informally transhipped amounts are equally distributed to collection groups.

3.2.2.6 Determination of transhipped material fractions

Resulting transhipped amounts per collection group and modelled scenario are divided into typical material compositions of collection groups according to Table 5, Chapter 2.3.1.2 [VDI 2343, 2011].

Considered materials are

- Iron and steel
- Non-ferrous metals
- Circuit boards/ precious metals
- Hazardous substances
- Glass
- Other (inerts, etc.)

The results present the percentage composition of materials of each modelled scenario. The minimum and maximum percentages of each material fraction (ferrous, non-ferrous metals etc.) are applied to informal transhipped amounts. A range of informally transhipped material fractions results from a continuative perspective.

3.3 Approach III – Economic and environmental effects

This chapter presents the methodology of investigating economic and environmental impacts of informal sector activities.

The evaluation of economic impacts is divided into the analysis of costs and revenues of producers considering defined treatment amounts and the analysis of costs and revenues of private household, waste management associations and informal collectors by considering the handling of a television and a washing machine.

A CO_2 accounting is applied to the same system boundaries set for the economic analysis in order to evaluate the environmental impacts considering private household, waste management association and the informal collector perspective. No CO_2 accounting is conducted for the producer perspective as no reliable data is available for the production and distribution of products.

3.3.1 Analysis of costs and revenues from the producer perspective

Five different case studies are established to display informal sector influences on producers. Each collection group (CG 1 to CG 5) is allocated to a producer (Producer A = CG 1 to Producer E = CG 5).

For each producer equal basic parameters are defined. Parameters are chosen on the basis of [Führ et al., 2008].

- Responsibility for one type of appliance per collection group
- Updating of guarantee at EAR: 3 times per year
- Updating of amount data at EAR: 1 time per year
- Internal administration effort: 6 hours per month
- treatment amount of WEEE: 1,500 t/a

The analysis of costs and revenues focuses on the disposal phase. The following flow chart (Figure 14) includes considered cost and revenue flows, which are marked with a numbered, red rhombus. In general, rose shaded arrows illustrate cost flows and green shaded arrows revenue flows.

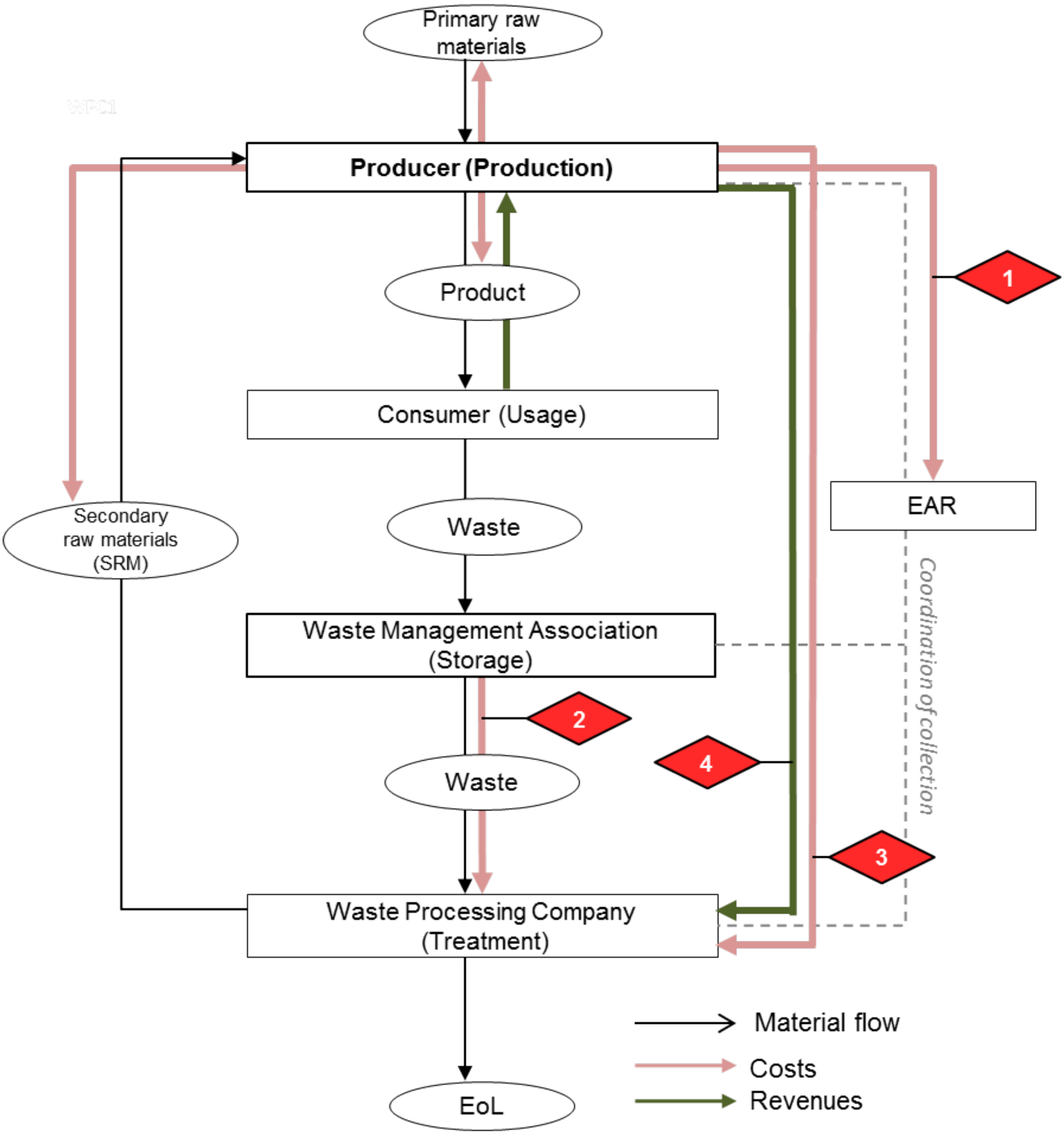


Figure 14: Cost and revenue flows of the system of WEEE management (producer perspective)

Considered cost and revenue flows (1 - 4, Figure 14) are divided into different cost (variable and fix) and revenue items. Table 13 presents applied specific cost and revenue items originating from literature and company information.

Table 13: Quantification of cost and revenue items

Cost and revenue flow (figure 14)	Corresponding cost and revenue items	Type of costs	Quantification (specific costs and revenues)	Source
1	1a) Fees for updating guarantee amount	fixed	€43 / update	EAR, 2011
	1b) Fees for updating amount data	fixed	€83 / update	EAR, 2011
	1c) Internal administration	fixed	€26.04 / hour	Führ et al., 2008
	1d) Guarantee	fixed	See equation 2.1	§ 6 (3), ElektroG
	1e) Collection requests	variable	€25 / request	EAR, 2011
	1f) Pick-up requests	variable	€20 / request	EAR, 2011
2	2a) Transport to recycling facility	variable	€23.08 / ton	Based on Fuhrmann, 2003
3	3a) Delivery costs at recycling facility (negative gate fees = producer pays recycling facility for delivery)	variable	CG1: €0 / ton CG2: -€50 / ton CG3a: -€50 / ton CG3b: -€50 / ton CG5: €0 / ton	Average EUWID WEEE market report, 2012
4	4a) Delivery revenues at recycling facility (positive gate fees = producer is paid by recycling facility for delivery)	variable	CG1: €149 / ton CG2: €30 / ton CG3a: €35 / ton CG3b: €140/ ton CG5: €135 / ton	Average EUWID WEEE market report, 2012

Specific cost and/or revenues of each producer are calculated on the basis of the amounts for treatment. The defined treatment amount of 1,500 tons per year and producer refer to the base case, which considers informal WEEE collection.

The treatment amount of the base case is increased by informally collected amounts of WEEE, which result from investigations presented in Chapter 3.2.2.

Nevertheless, total informally collected amounts of WEEE cannot be allocated only to producers in accordance with § 10 (1) and § 9 (6), ElektroG. Producers collect 62.43% of total formal WEEE amounts (§ 10 (1), ElektroG) while waste management associations collect 37.57% (§ 9 (6), ElektroG). This information is based on official EAR foundation statistics (Appendix A9).

The proportion of 62.43 % is applied to the average informally transhipped amount of WEEE. It represents the proportion continuatively distributed to producers. The amount for treatment of each producer in the base case is determined at 1,500 tons and forms a share of the total formally collected WEEE (Table 14).

Table 14: Share of treatment amount per producer to total formally collected amount

(1) CG	(2) Formal collected WEEE per collection group [EAR, 2012]	(3) Treatment amount per producer	(4) Share on total formal collected amount [%]
CG1	13,731	Producer A, CG1 1,500 t/a	11%
CG2	111,121	Producer B, CG2 1,500 t/a	1%
CG3a	112,622	Producer C, CG3a 1,500 t/a	1%
CG3b	112,622	Producer D, CG3b 1,500 t/a	1%
CG5	36,815	Producer E, CG5 1,500 t/a	4%
Total	**386,912**		

§ 14 (5), ElektroG defines the obligatory treatment amount per producer as a percentage of the total quantity of products placed on the market in the previous calendar year, which refers to column 4 (Table 14). Hence, the presented share is applied to the sum of the total formally and informally collected amounts per modelled scenario. It presents actual WEEE for treatment per producer (Table15). Detailed calculations can be seen in Appendix A9.

Table 15: Additional treatment amounts per producer and modelled scenario

Treatment amount per scenario	Producer A (CG1)	Producer B (CG2)	Producer C (CG3b)	Producer D (CG3a)	Producer E (CG5)
Base case (t/a)	**1,500**	**1,500**	**1,500**	**1,500**	**1,500**
Equal_Comp (t/a)	2,550	1,630	1,628	1,628	1,892
EAR (t/a)	1,686	1,686	1,686	1,686	1,686
High_Fe (t/a)	3,863	1,760	1,532	1,532	1,598
High_Pl (t/a)	1,763	1,532	1,756	1,564	2,284
high_PM (t/a)	1,763	1,532	1,756	1,692	1,892

Each amount for treatment is related to the corresponding cost and revenue items. The results are compared to the base case for the purpose of evaluating the economic influence of informal sector activities.

3.3.2 Analysis from a household, WMA and informal collector perspective

The economic analysis considers a reuse of informally transhipped appliances related to [Pertl et al., 2010]. It is assumed that Polish informal actors collect old electronic appliances in Germany, transport them to Poland and sell them at flea markets. A Polish household then buys the offered appliances and reuses them.

Different scenarios are established to compare the reuse via informal collection with the recycling of an old appliance and acquisition of a new appliance from different perspectives (Figure 15):

- German private household:
  - acquisition of new appliance *(pHH ‘new appl’)*
  - further use of old appliance *(pHH ‘further use’)*
- Polish private household:
  - acquisition of new appliance, *(pHH ‘new appl’)*
  - further use of old appliance, *(pHH ‘further use’)*
  - reuse of appliance purchased at flea market *(pHH ‘reuse’)*
- WMA
  - Collection of WEEE at household level and storage (§ 9 (3), ElektroG) *(WMA)*
  - Collection of WEEE at household level, storage and further transportation to recycling facility considering either delivery revenues or costs (§ 9(6), ElektroG) *(WMA)*
- Informal collector: Collection of appliance and transport to flea market *(IC ’reuse’)*

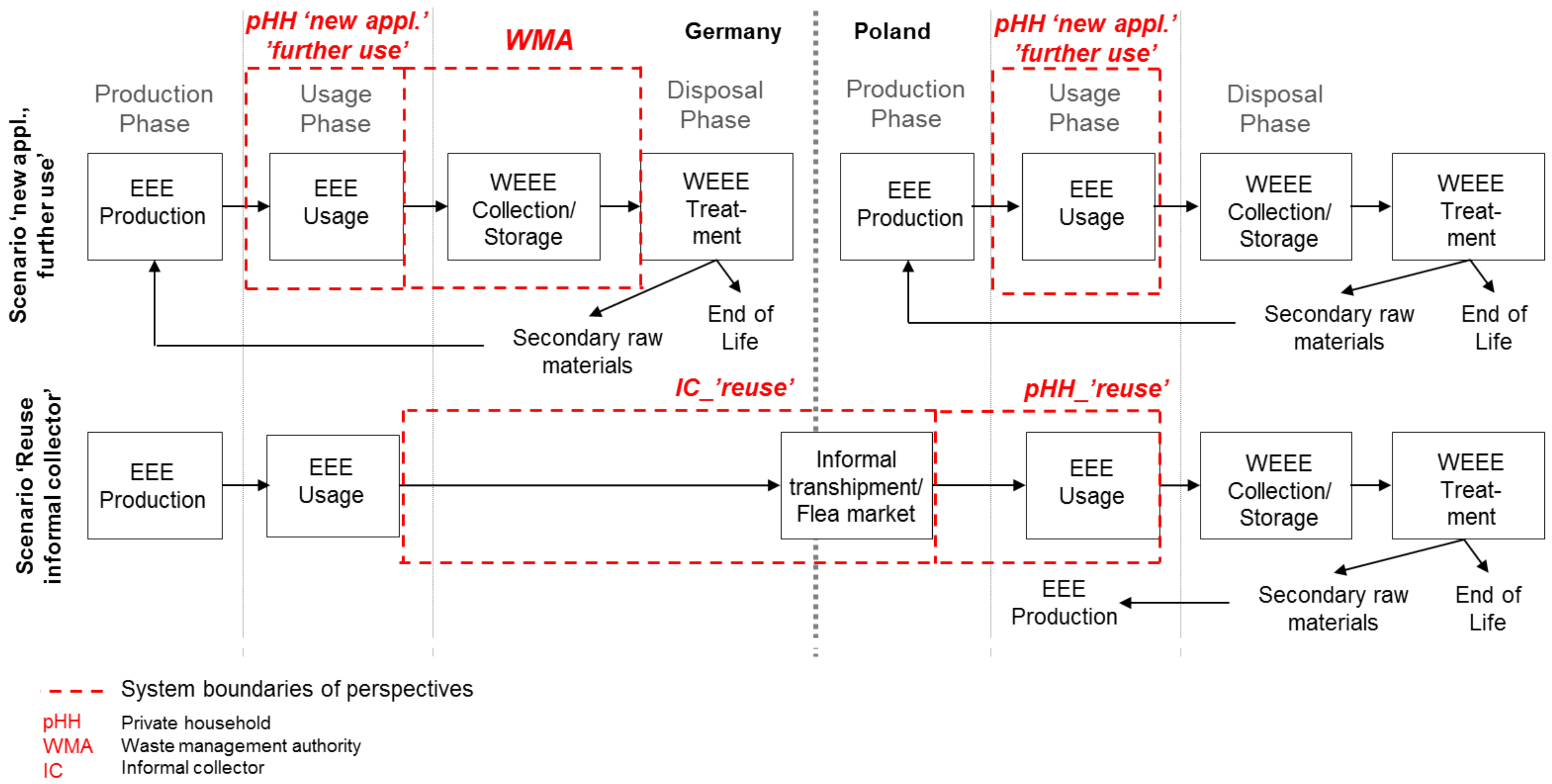


Figure 15: System boundaries of perspectives [modified according to Pertl et al., 2010]

The following two electrical and electronic appliances are investigated within the presented system boundaries:

- Washing machine
- Television

The washing machine was selected, since the replacement of an old appliance only has environmental and economic advantages after a period of more than 10 years has elapsed [Rüdenauer et al., 2005; Pertl et al., 2010]. No direct contrasting is available of economic and environmental performance (refer to Chapter 2.3.3.3, Equations 2.2 and 2.3). The television is selected as it is likely to be collected by informal collectors based on a high lifetime and selling quota.

An average life time of 20 years of each appliance is assumed for the analysis. The first utilisation period is conducted in Germany (10 years) and the second reuse phase takes place in Poland (10 years) [Scherhaufer et al., 2011]. Data of old appliances originate from 2002. The appliances considered are constructed in 2011 and purchased at the beginning of 2012 within the 'new acquisition' scenario.

With regard to the washing machine, an average utilisation of 200 washes at 60°C (cotton programme) per year is determined. The loading capacity is 7 kilograms, which is fully exploited at each wash. The televisions considered are characterised by a 27 inch (diagonal) screen size. Old appliances work on the cathode ray tube (CRT) display technology. New appliances are equipped with liquid crystal displays (LCD). The running time per day is determined at 4 hours with no standby [AGF, 2012]. Moreover, no repairs are foreseen within the reuse scenario and a discount rate of 5% is defined to evaluate the actual cash flow. Table 16 summarises the characteristics of presented appliances.

Table 16: Characteristics of washing machine and television

Appliance	Characteristics
Washing machine ➢ Loading capacity: 7 kg ➢ 200 washes per year ➢ Washing program: 60°C cotton programme ➢ Volume: 0.29 m³ ➢ Weight: 71.38 kg	<u>Old appliance</u> ➢ Sales price: *€114.80 / item* ➢ Energy demand: *0.19 kWh / kg* [Rüdenauer, 2005] ➢ Water demand: *9.7 l/kg*
	<u>New appliance</u> ➢ Sales price: *€ 441.00 /item* ➢ Energy demand: *0.14 kWh/kg* *[average of new appl.]* ➢ Water demand: *6.4 l/kg*
Television ➢ CRT(old)/ LCD (new) technology ➢ 27 inch ➢ CRT volume: 0.23 m³ ➢ CRT weight: 53 kg ➢ LCD volume: 0.06 m³ ➢ LCD weight: 6.9 kg	<u>Old appliance</u> ➢ Sales price: *€ 25 / item* ➢ Energy demand *(run): 95 W (4h/d per 350days)*
	<u>New appliance</u> ➢ Sales price: *€ 389 / item* ➢ Energy demand *(run): 37 W (4h/d per 350days)*

Economic outcomes and corresponding CO_2 emissions are presented for each scenario. Emission factors of electricity consumption of Germany and Poland are used, which amount to 0.624 kg $CO_{2,\ eq}$, and 1.19 kg $CO_{2,\ eq}$ per kilowatt hour, respectively [EC, 2010]. Both values originate from the technical annex of the Sustainable Energy Action Plan Guidebook (SEAP) [EC, 2010]. Nevertheless, emission factors can fluctuate. According to [UBA, 2012a], the German emission factor of electricity consumption amounts to 0.559 kg $CO_{2,\ eq}$ per kilowatt hour in 2011. A sensitivity analysis considers presented deviations.

3.4 Approach IV - Eco-efficiency of informal sector activities

A contrast of economic and environmental performances reveals the eco-efficiency according to Equation 2.2. The aggregation of presented perspectives allows a holistic consideration of the appliances' lifecycle. Three different scenarios are evaluated and compared to each other [Pertl et al, 2010]:

- Production, acquisition, usage and recycling of washing machine and television in Germany
- Production, acquisition, usage and recycling of washing machine and television in Poland
- Production, acquisition, usage in Germany, transhipment of washing machine and television via informal collector, reuse and recycling in Poland

The system boundaries explained are illustrated in Figure 16. Assumptions have been made due to missing data of specific production and treatment phase costs of the appliances considered. The washing machine and television production costs are assumed to amount to 60% of the purchase price. Treatment costs are determined at 40% of the delivery costs. Possible fluctuations are considered by the application of a sensitivity analysis. Emerging CO_2 emissions of production, distribution and treatment phase are adopted from [Rüdenauer et al., 2005].

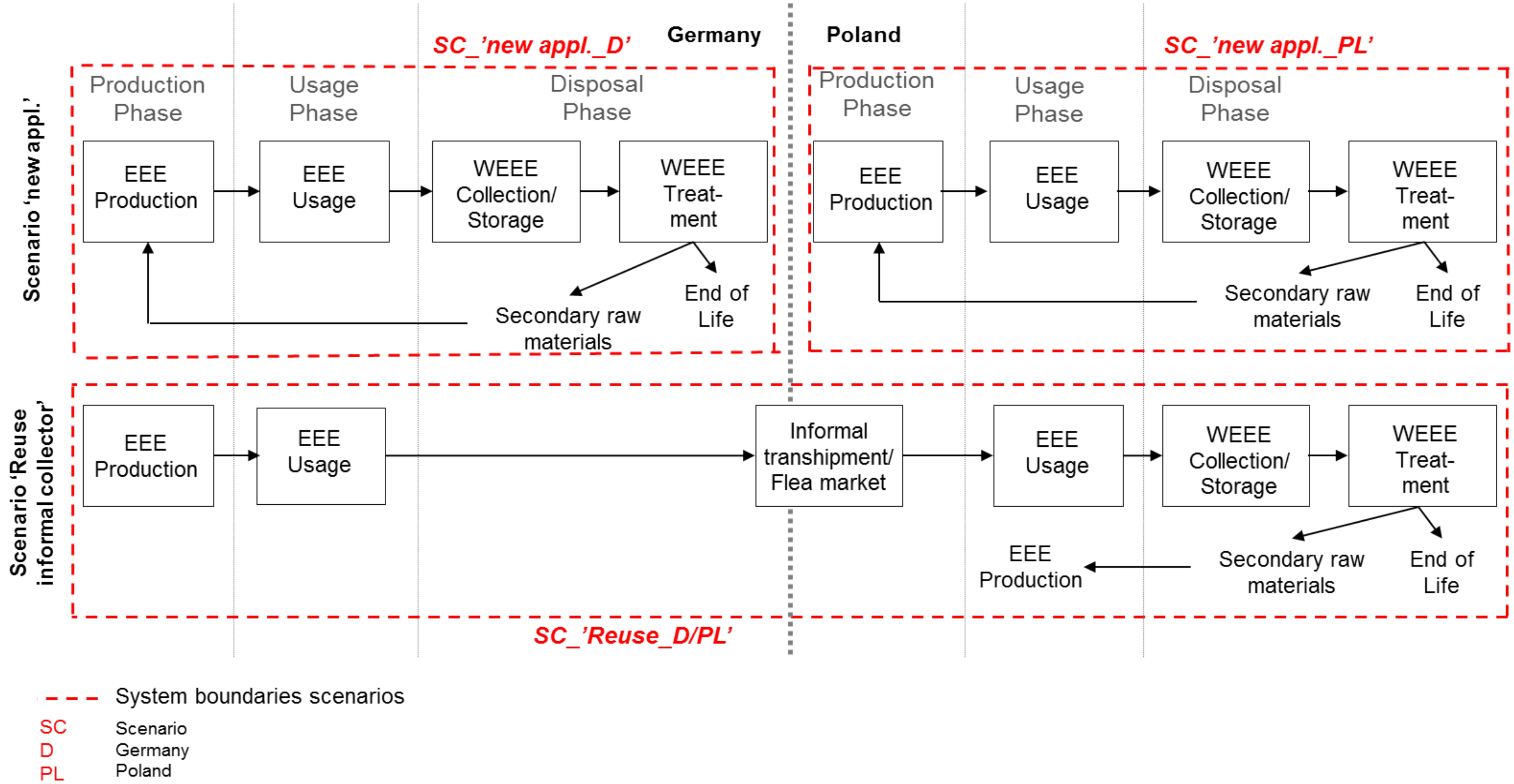


Figure 16: System boundaries of appliances [modified according to Pertl et al., 2010]

4 RESULTS OF INVESTIGATIONS

The following chapter presents the results of the investigations. It is divided into four approaches according to the methodology. The first part contains the results of interviews with waste management authorities. The second part displays WEEE amounts and transhipped fractions to Eastern Europe countries. The third and fourth parts present the results of economic and environmental impacts and the aggregation of both these performances.

4.1 Approach I - Results of the survey

The next chapter outlines the results with regard to the official type of collection of waste management associations, appearance of informal collectors, nationalities and transhipped amounts, specialisation on fractions, economic influences of informal collection and measurements to integrate or avoid informal collection activities.

4.1.1 Official collection system

Results regarding the applied type of bulky waste collection reveal a clear preference for the use of collection on request and waste collection centres. 60 responses are included in the evaluation.

Small numbers of waste management associations only conduct street collection and collection on request (3% and 5%). 58 % of waste management associations operate waste collection centres in connection with waste collection on request (Figure 17). Two persons interviewed reported a planned restructuring from street collection to collection on request as a method to avoid informal collection activities. A similar picture arises when interviewing other waste management associations. For example, informal collection activities were observed during official street collections in the past in Dresden. A subsequent orientation towards collection on request then took place [PC, 2009].

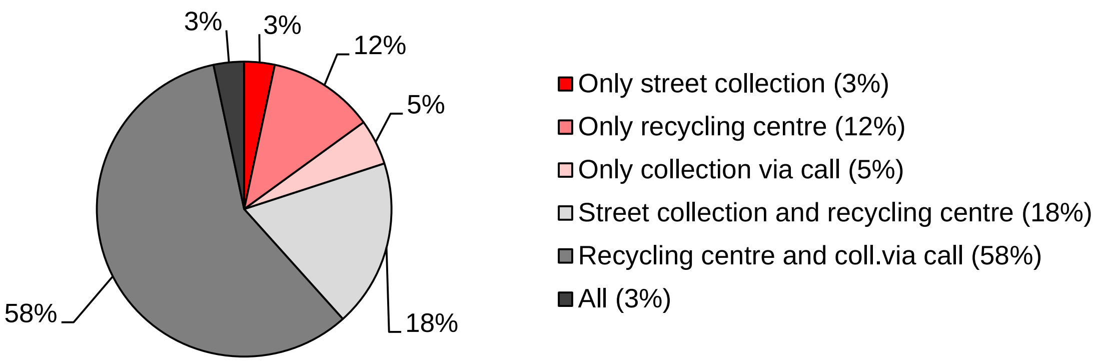


Figure 17: Type of bulky waste collection of interviewed WMAs (n=60)

Another waste management association reports on the implementation of waste collection on request in the middle of 2010. Similarly, the aim is to avoid informal sector collections (so-called ‘cherry picking’) during street collection [PC, 2009]. Implementation of collection on request is explained by significant amounts, which are extracted out of the official waste stream. The change-over towards collection on request will antagonise informal collections in the future. Nevertheless, tendencies of interview partners are recognized that consider the importance of more tolerance of individual informal collectors [PC, 2009].

4.1.2 Appearance of informal collectors

German waste management associations report of informal collections in front of waste collection centres (Figure 18) and at household level during street collections.

Figure 18: Informal collector in front of waste collection centre on Hammerweg (Dresden City Cleaning Department)

Moreover, an informal collection is conducted via the distribution of flyers advertising the collection of old and defect household items (Figure 19).

ALTHAUSHALTSGERÄTESAMMLUNG

22 -04- 2010

AM:

SAMMELN WIR KOSTENLOS/ AUCH DEFEKT/:

Radio-und Fernsehapparate plastic, HI-FI und Videogeräte, Computer, CD-Rekorder, Drucker, Bürogeräte/Kopierer, Faxgeräte, Telefonapparate/, Elektrowerkzeug/ Bohr-, Schleifmaschinen/, Mikrowellen, Staubsauger, Musikinstrumente, Alu-felgen, Sportgeräte, Reifen, Fotoartikel, Waschmaschinen, Kühlschränke, Ski, Gaskocher, Gasöfen, Fahrräder, Rasenmäher und anderes, Motorsage, Kompresor, Betonmischer, Plastefenster, Mopet, Teppichboden, Heizkörper, Autoteile, Angelnzubehör, alte defekte Uhren, Kupfer- und Aluminiumkabels, Buntmetalle, Metallschrott, Kleidungen, Kinderartikels.

Legen Sie bitte ihre Spenden gut sichtbar bis **10.00** Uhr an den Strassenrand.

Figure 19: Informal information flyer promoting the collection of old items in Dresden

The flyer illustrated includes the announcement of collection of defect appliances (“auch defekt”). Defect items are covered by § 3, KrWG as outlined in Chapter 2.2.1. Continuatively, the collection of appliances connected to this flyer imply a violation of this paragraph and is punishable by law if no notification process is proven by the informal collector.

In general, 49 waste management associations (82%) reported the appearance of informal collectors. Informal activities are recognized in each federal state. This information verifies that informal collection activities appear throughout Germany (Table 17).

Table 17: Appearance of informal sector activities in the federal states of Germany (n=61)

	Informal collection recognized	No informal collection recognized
Baden-Württemberg	4	0
Bavaria	18	3
Brandenburg	5	0
Hessen	2	1
Lower Saxony	2	1
Mecklenburg Western Pomerania	2	1
North - Rhine Westphalia	2	1
Rhineland-Palatinate	2	1
Saarland	1	0
Saxony	4	0
Saxony-Anhalt	1	2
Schleswig Holstein	3	0
Thuringia	3	1
Total (n=60)	49	11
Total percentage	82%	18%

No clear conclusion can be drawn regarding higher or fewer informal collection activities in eastern, central or western Germany based on responses (completed questionnaires) per federal state. Moreover, waste management associations that recognise informal collections tend to respond to transmitted questionnaires in contrast to waste management associations without recognised informal activities, which do not.

As a next step, the frequency of appearance was investigated. Interviewed persons reported a daily informal collection in 33% out of 46 responses. An appearance was recognized several times a week in 37% and every two weeks in 7%. A proportion of 11% of interview partners reported an appearance once a month and 13% of interview partners recognised informal collection every six months. The results correspond with the results of [Janz et al., 2009], which mostly indicated an 'often' collection activity (refer to Chapter 2.2.1, Table 4).

4.1.3 Nationalities of informal collectors

The evaluation includes 101 responses in 61 completed questionnaires regarding the nationalities of informal collectors (Table 18).

Table 18: Nationalities of informal collectors (n=101)

Nationalities of informal collectors	Percentage of appearance
Czech Republic	14 %
Poland	27 %
Hungary	9 %
Slovakia	8 %
Romania	15 %
Germany	2 %
Lithuania (LT)	0 %
Ukraine	0 %
Latvia (LV)	3 %
Others	8 %
Not known	15 %

The majority of informal collectors are found to be from the Czech Republic, Poland, Romania, and Hungary. A location close to the German border plays an important role. The category “Others” is composed of Russian, Bulgarian, Estonian but also French informal collectors. A proportion of 15% of interviewed persons could not give information concerning the nationalities of informal collectors.

4.1.4 Specialisation on fractions and collected amounts

No reliable data resulted regarding informally collected amounts. A total of 49 waste management associations (82%) noted that a quantification of extracted amounts is not possible. Only 3 participants estimated informal collected amounts at 50 - 250 kilograms per day, 2 at 250 – 500 kilograms per day and 2 at 500 - 1,000 kilograms per day. One participant indicated an extracted amount higher than one ton per day. An informal collected amount is estimated at 1,000 tons per year in Dresden. It refers to a collected amount of 2.7 tons per day [Schönekerl, 2009].

Specialisations of informal collectors on different fractions play a decisive role in conveying transhipped amounts of fractions. The evaluation of informal collector specialisation includes 53 responses (Figure 20).

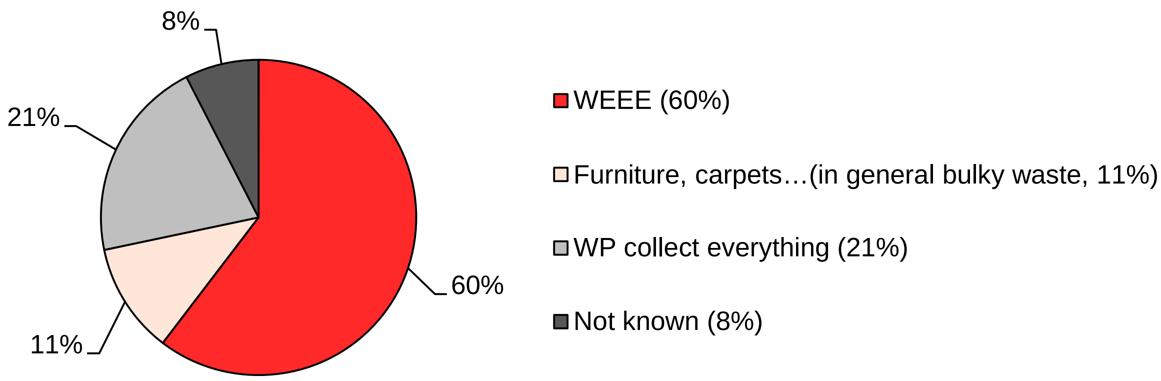


Figure 20: Specialisation on fractions of informal collectors (n=53)

A specialisation on WEEE is indicated in 60% of given responses. Bulky waste such as furniture, carpets and kitchen utensils takes up 11%. Some 21% of participants reported informal collectors without specialisation on fractions.

The high percentage of informal collectors focusing on WEEE is based on the resale of appliances at flea markets. Interviewed waste management associations reported collection activities that have become more professional in recent years. Informal collectors use emergency power generators to control the functional capability of electrical and electronic devices on-site. This indicates a high prioritisation of reusing appliances.

Moreover, dismantling is conducted on site to sell contained valuable materials (metals, semi-conductor wafers, etc.). Thereby a littering is recognised of non-usable items such as plastic PC casings.

4.1.5 Littering and economic impacts

Waste management association representatives questioned provided information on littering. Out of 47 responses, a proportion of 60% mentioned waste left by informal collectors. The remaining share of the participants did not recognise littered waste. As an example, Figure 21 shows a popular position of informal collectors next to a waste collection centre in Dresden (Altonaer Straße 15). The littering is obvious and can be allocated to informal actors.

Figure 21: Littered waste of informal collectors at a popular collection position in Dresden

Observed littering as well as the extraction of valuable materials is indicated to cause additional costs for waste management associations. Conversely, other interviewed public waste management authorities recognised savings that arise due to decreasing amounts of waste for transportation and treatment. Figure 22 shows the classification of the ‘additional costs’, ‘savings’, ‘saving and costs’, ‘neither costs nor savings’ and ‘not known’ responses regarding the economic influences of informal collections. The sample size consists of 42 responses.

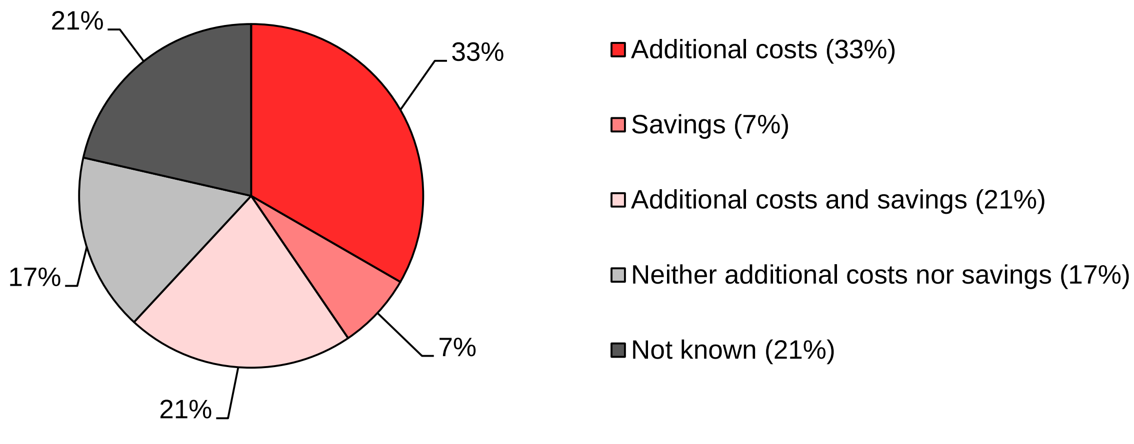


Figure 22: Costs and/or savings caused by informal collection (n=42)

A proportion of 33% of questioned participants reported additional costs caused by informal collectors, whereas 7% affirmed savings. The identical response quota of 21% resulted for the categories ‘costs and savings’ and ‘neither costs nor savings’.

Thus, no general conclusion can be drawn regarding costs and/or savings caused by informal sector activities. Chapter 4.3 investigates the presented influences in detail.

4.1.6 Integration and countermeasures

A clear distinction can be made regarding measures undertaken to integrate or avoid informal sector activities. Only 20% out of 48 participants reported integration concepts, of which 7% mentioned the possibility to buy used electrical and electronic devices at a low price. 13% provided information on other strategies. This corresponds to 6 waste management associations, five of which offer a flea market. These second-hand markets are usable by both the public and informal collectors. One public waste disposal authority mentioned tolerance of informal collection activities as an integration concept.

Measures to avoid informal collections are more likely to be applied than integration measures. One third of the 53 answers did not implement countermeasures. The remaining two-thirds use different strategies to prevent informal collection. A sensitisation of the population is conducted in 21% with respect to informal sector activities. Citizens are informed to put out waste for street waste collection and collection on request only one night before the official collection takes place. Moreover, information is given that a transfer of materials to informal collectors, intended to be provided at waste collection centres, constitutes an illegal act in accordance with § 17, KrWG.

Continuatively, police actions are used to reduce informal collection in front of waste collection centres (17% of 53 answers). A proportion of 32% of participants reported other measures to avoid informal collections, including:

- Employee training and video controls at waste collection centres,
- Implementation of waste collection on request instead of street collection,
- Limitation of the opening hours at second-hand markets,
- Informing of informal collectors regarding a collection prohibition,
- Information to local authorities to prevent informal collection, and
- Constructive limitation of parking spaces in front of recycling centres.

4.2 Approach II - Results of transhipped amounts of WEEE

This chapter outlines the results regarding informal transhipped amounts along the entire eastern border of Germany and transhipped material fractions.

4.2.1 Total transhipped amounts per year

Transhipped amounts per year are calculated according to Equation 3.1 (refer to Chapter 3.2.2.3). Table 19 displays the annual informally transhipped tonnage across the entire eastern border of Germany. This results in a minimum amount of 63,000 tons per year regarding the minimum loading factor and minimum density of materials and a maximum amount of 189,000 tons per year result regarding an overloading and maximum density of materials. Presented amounts include all collected fractions, inter alia bulky waste, WEEE, textiles and scrap metals.

Table 19: Transhipped amounts per year considering different loading factors and densities [t/a]

$ϸ_x$ / m³/a	100 m³/kg	150 m³/kg	200 m³/kg
LF 1 (75 %) 630,479.22 m³/a	**63,047.92 t/a**	94,571.88 t/a	126,095.84 t/a
LF 2 (95 %) 855,650.37 m³/a	85,565.04 t/a	**128,347.55 t/a**	171,130.07 t/a
LF 3 (105%) 945,718.82 m³/a	94,571.88 t/a	141,857.82 t/a	**189,143.76 t/a**
Total transhipped amounts	63,047.92 t/a	**128,347.55 t/a**	189,143.76 t/a

Resulting amounts per year are subject to wide fluctuations on account of the informal background of transhipments. Nevertheless, it is assumed that no consequent overloading and no consequent non-utilization of loading capacities appear. It is likely that average values display actually transhipped amounts. The considered scenario results in an average transhipped amount of 128,300 tons per year (including all fractions).

4.2.2 Transhipped amounts of WEEE per year

A proportion of 60% of informal collectors is determined, who specialise in WEEE collection (refer to Chapter 4.1.4, Figure 20). In addition, 21% of interview partners recognised a collection of both, bulky waste and WEEE. Therefore sensitivity is considered of higher WEEE amounts and fewer WEEE amounts of 10 %. The results are displayed in Table 20. Given data refers to the investigation period 2010 - 2012 and depicts an annual average (refer to Chapter 3.2.1).

Table 20: Informal transhipped amounts of WEEE into eastern European countries per year

Transhipped amount / WEEE proportion	MINIMUM	AVERAGE	MAXIMUM
50% WEEE	**31,523.96 t/a**	47,285.94 t/a	63,047.92 t/a
60% WEEE	51,339.02 t/a	**77,008.53 t/a**	102,678.04 t/a
70% WEEE	66,200.32 t/a	99,300.48 t/a	**132,400.64 t/a**
Total transhipped WEEE	**31,532.96 t/a**	**77,008.53 t/a**	**132,400.64 t/a**

Transhipped amounts of WEEE vary between 31,500 tons and 132,000 tons per year. [Janz et al., 2009] revealed an amount of transhipped WEEE ranging between 36,000 tons and 122,000 tons per year in 2009. Figure 23 contrasts these results (red column) and results of present investigations (grey shaded columns).

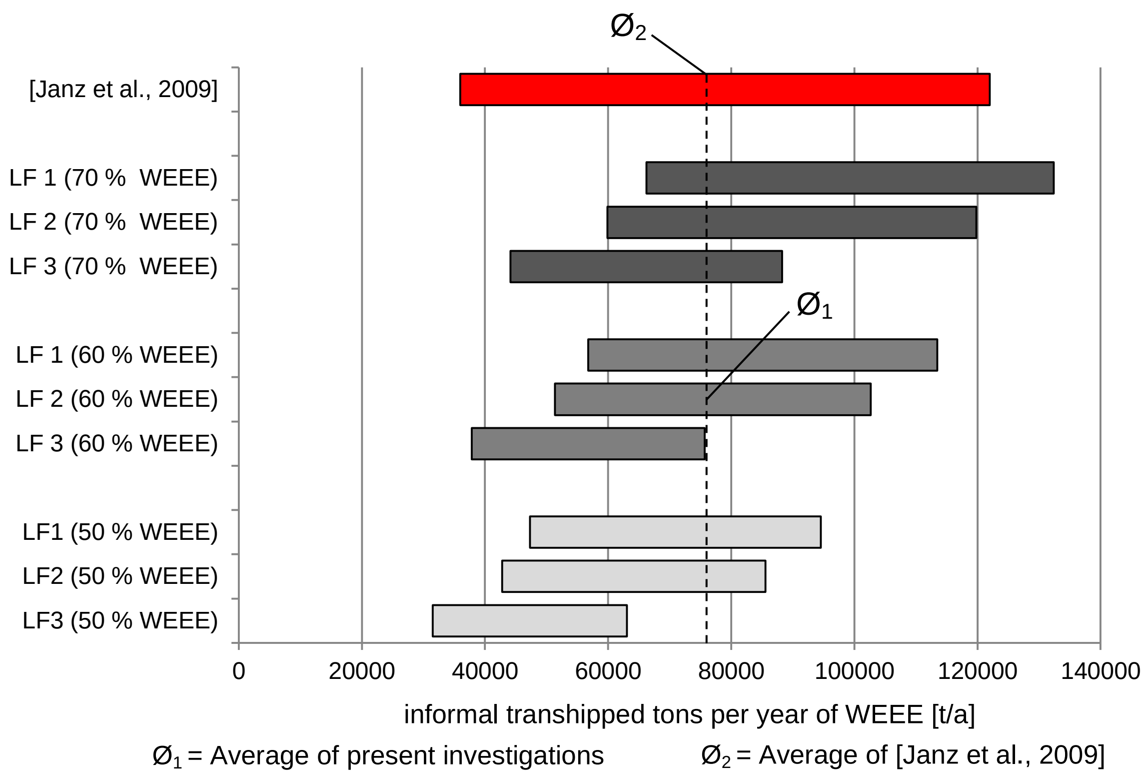


Figure 23: Comparison of informal transhipped amounts of WEEE into Eastern Europe

Minimum amounts of WEEE (50% WEEE) add up to 31,000 tons per year considering a loading factor of 75% and a density of 100 m³/kg of transhipped material. Maximum amounts of WEEE (70% of WEEE) add up to 132,000 tons considering a loading factor of 105% and a density of 200 m³/kg of transhipped material. Average transhipped amounts of WEEE are found to be in the same range as results of [Janz et al., 2009], which amount to 77,000 tons per year. The total average of the present investigations amounts to 77,008.53 tons per year of transhipped WEEE (Table 20).

4.2.3 Quotas of transhipped amounts of WEEE

In the next step, the share of 77,008.53 tons per year on total electrical and electronic devices put on the market is presented. This represents the basis for Figure 5, which outlines a prognosis of actual electronic products put on the market considering a usage phase of 7.5 years. Exemplarily, the data originates from 2010. Table 21 displays officially collected WEEE amounts, predicted amounts of launched products considering a usage phase of 7.5 years and investigated flows of WEEE, which do not go into the official return system.

Table 21: Aggregation of different sources of official, transhipped, stored and incorrectly sorted WEEE

Official launched products and collected WEEE		Quantity (t/a)	Source
a)	Predicted amount of products put on the market (2010)	1,338,000	[EAR, 2012; Consumer Research Association (GfK), 2012; Figure 5]
b)	Collected amount of WEEE (2010)	586,000	[DESTATIS, 2012]
1)	Difference of a) and b) = missing amounts of WEEE	752,000	
	Informal transhipped, stored and incorrect sorted WEEE	unofficial flows of WEEE (t/a)	Source
c)	1% of WEEE ending up in residual waste (14,358,000 tons of residual waste in 2010)	143,580	[Janz, Bilitewski 2009] [DESTATIS, 2012]
d)	WEEE transhipped via Hamburg harbour	155,000	[Sander, 2010]
e)	WEEE transhipped to Dutch and Belgium harbours	50,000	[Sander, 2010 in Friege, 2012]
f)	WEEE transhipped to Eastern Europe	77,008	own investigations
2)	Total of c) to f) = flows of missing amounts of WEEE	425,588	

An amount of some 326,000 tons per year remain comparing flows of missing amounts of WEEE (2) and the difference between collected and launched items (1). Proportions are determined for each quantified destination of WEEE on total amounts of launched products. The results are presented in Figure 24.

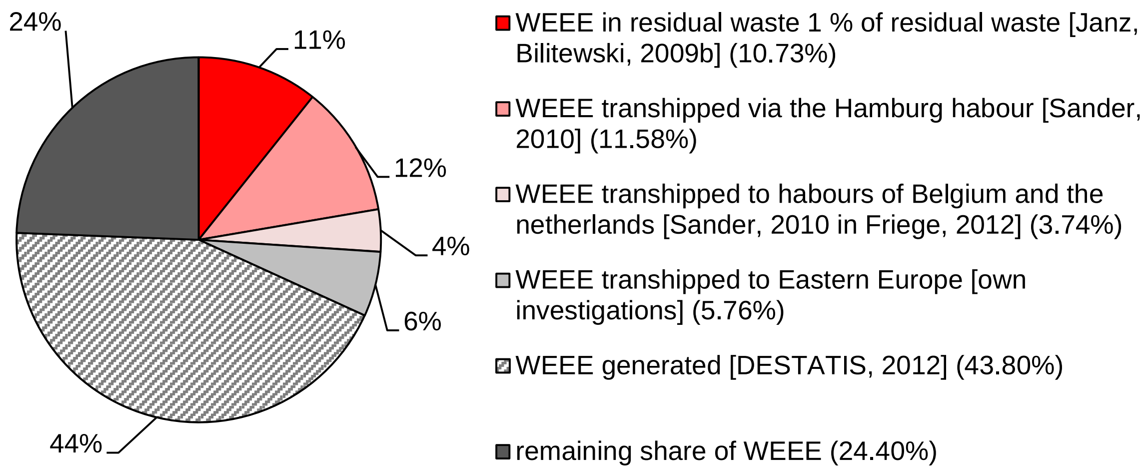


Figure 24: Share of informal collected amounts on actual available amounts of WEEE

A proportion of 5.8% of actual launched products is transhipped to Eastern European countries. Twice that amount is illegally transported via Hamburg harbour and 3.7% via Dutch and Belgium harbours. In total, some 21% of launched products based on informal collections and transhipments do not end up in the official return system. A proportion of 11% ends up in the residual waste stream and a proportion of 24 % could not be allocated to presented flows. A study analysed the amount of WEEE, which is stored in German households and not directly transferred to waste collection centres. This temporary storage amounts to 350,000 on an annual basis [Janz, Bilitewski 2009a], which could explain the remaining share of 24% of WEEE that cannot be allocated. Finally, a share of 44% is officially collected and treated.

Quantified mass flows of WEEE (outside the official return system) are distributed to total missing WEEE amounts as depicted in Figure 5. The distribution is displayed in Figure 25.

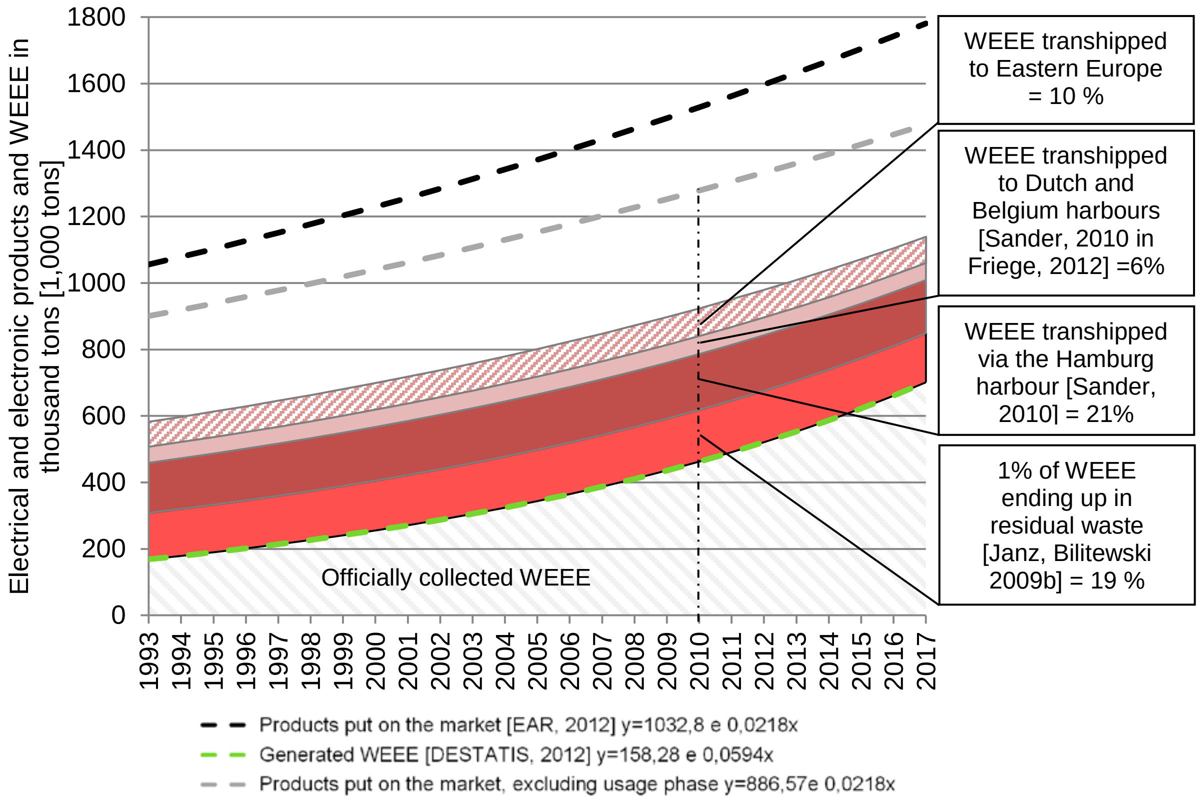


Figure 25: Share of unofficial flows of WEEE on total missing amounts of WEEE

A proportion of 19% of WEEE end up in the residual waste stream. A mostly small WEEE amount is included in this share. In total, 37% of WEEE is informally collected and transhipped out of Germany. This consists of 21% of WEEE transhipped via Hamburg harbour, 10% of WEEE transported into countries of Eastern Europe and 6 % of WEEE brought to Dutch and Belgian harbours. A total amount of 350,000 tons of WEEE was estimated to be temporarily stored at households per year [Janz/Bilitewski, 2009a]. Using 2010 as reference year, it complies with a percentage of 47% of total missing WEEE amounts. Consequently, no unclear whereabouts of WEEE follow.

4.2.4 Transhipped material fractions of WEEE

The percentage composition of collection groups of modelled scenarios ‘Equal_Comp’, ‘EAR’, ‘high-Fe’, ‘high_Pl’ ‘high-PM’ (refer to Chapter 3.2.2.5, Table 12) is applied on the average transhipped amount of WEEE of 77,008.53 tons per year, which is informally transhipped to Eastern European countries (Table 22).

Table 22: Percentage composition of collection groups of total transhipped WEEE amount

		CG1	CG2	CG3a	CG3b	CG5
Total informal collected amount (t/a)		**77,008.53 t/a**				
1a	Scenario Equal Composition **(Equal_Comp)** *(Table 12)*	20%	20%	20%	20%	20%
2a	Scenario EAR **(EAR)** *(Table 12)*	4%	29%	29%	29%	10%
3a	Scenario High Ferrous metals **(high_Fe)** *(Table 12)*	45%	40%	5%	5%	5%
4a	Scenario High Plastic **(high_Pl)** *(Table 12)*	5%	5%	40%	10%	40%
5a	Scenario High Precious metals **(high_PM)** *(Table 12)*	5%	5%	40%	30%	20%
1b	Scenario Equal Composition **(Equal_Comp)** (t/a)	15.402	15.402	15.402	15.402	15.402
2b	**Scenario EAR (EAR) (t/a)**	2.733	22.117	22.416	22.416	7.327
3b	Scenario High Ferrous metals **(high_Fe)** (t/a)	34.654	30.803	3.850	3.850	3.850
4b	Scenario High Plastic scenario **(high_Pl)** (t/a)	3.850	3.850	30.803	7.701	30.803
5b	Scenario High Precious metals **(high_PM)** (t/a)	3.850	3.850	30.803	23.103	15.402

The distribution of material fractions (refer to Chapter 2.3.1.2, Table 5) of each collection group is applied to resulting amounts per collection group and scenario as presented in Table 22 (rows 1b - 5b). Exemplarily, the results are shown for the 'EAR' scenario. Amounts of material fractions per collection group according to Table 5 are applied to transhipped amounts per collection group as displayed in Table 22 (row 2b). The sum of each material fraction of all collection groups gives the total transhipped fraction of the 'EAR' scenario. The percentage distribution of material fractions of the 'EAR' scenario is presented in Figure 26.

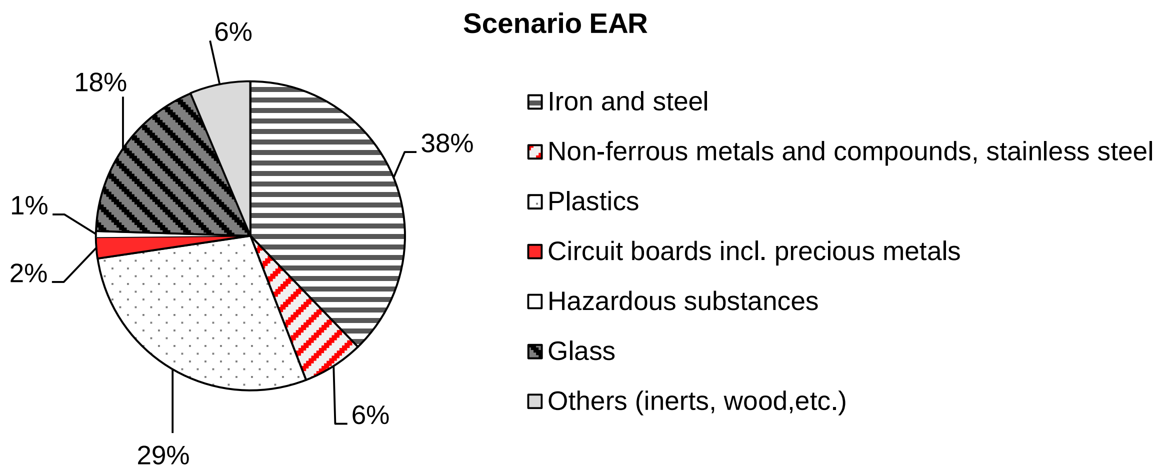


Figure 26: Material composition of scenario 'EAR'

The composition of material fractions is characterised by major amounts of ferrous metals, glass and plastics. High amounts of iron and steel are allocated to collection groups 2 and 3a. High glass amounts refer to collection group 3b and plastics to all three collection groups.

The remaining scenarios (‘Equal_Comp’, ‘high-Fe’, ‘high-Pl’, ‘high-PM’) are analysed accordingly. The composition of material fractions can be seen in Appendix A8. The resulting minimum and maximum percentages per fraction of all scenarios are applied to minimum and maximum transhipped amounts of WEEE and reveal the amounts of transhipped fractions per year (Figure 27).

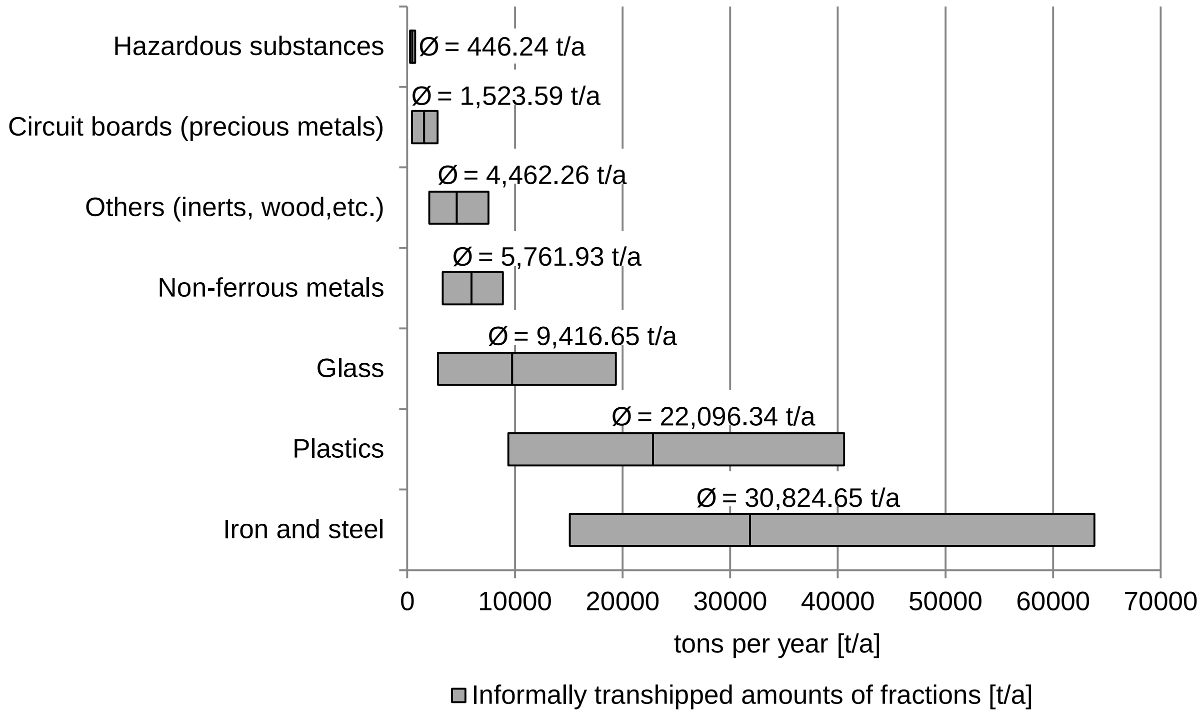


Figure 27: Informally transhipped material fractions per year

The ‘iron and steel’ fraction is characterised by a transhipped amount ranging from 15,100 tons to 63,000 tons per year. It is based on the high processing within electrical and electronic appliances. Plastics, mostly bodies of WEEE, are also transhipped to a high degree (from 9,400 tons to 40,500 tons per year). The lowest transhipped amounts are hazardous substances with from 270 tons up to 719 tons per year. Transhipped amounts of circuit boards range from 420 tons to 2,800 tons per year, whereas informally exported amounts of glass are found to lie between 2,800 and 19,400 tons per year. This is based on high processing rates within collection group 3b, which is likely to be collected by informal collectors based on a high reuse quota. The transhipped amount of non-ferrous metals ranges between 3,300 and 8,900 tons per year.

4.3 Approach III - Results of economic and environmental impacts

This chapter presents the results of the economic and environmental analysis regarding informal sector activities. Four different perspectives are considered: producers, households, waste management associations and informal collectors. The producer perspective is evaluated on the basis of transhipped amounts, while the other perspectives are environmentally and economically evaluated with regard to two different products: a washing machine and television.

4.3.1 Producer perspective

The base case scenario (collected amounts of 1,500 tons per year) and the base case scenario plus informal collected WEEE amounts are contrasted to highlight the economic impacts of informal sector activities.

4.3.1.1 Base case

The base case displays the current situation. Hereby informally collected amounts are not available for treatment. Figure 28 displays the specific variable and fixed costs of all producers A (CG1) to E (CG5).

The specific variable costs of one ton of treated WEEE per collection group range between €30 (producer C (CG3a), producer D (CG 3b)) to €39 (producer B (CG2)) (Figure 28). This includes transportation costs plus costs allocated to the EAR (pick-up requests and provision orders, refer to Chapter 3.3.1, Table 13). Delivery costs and delivery revenues at recycling facilities are excluded.

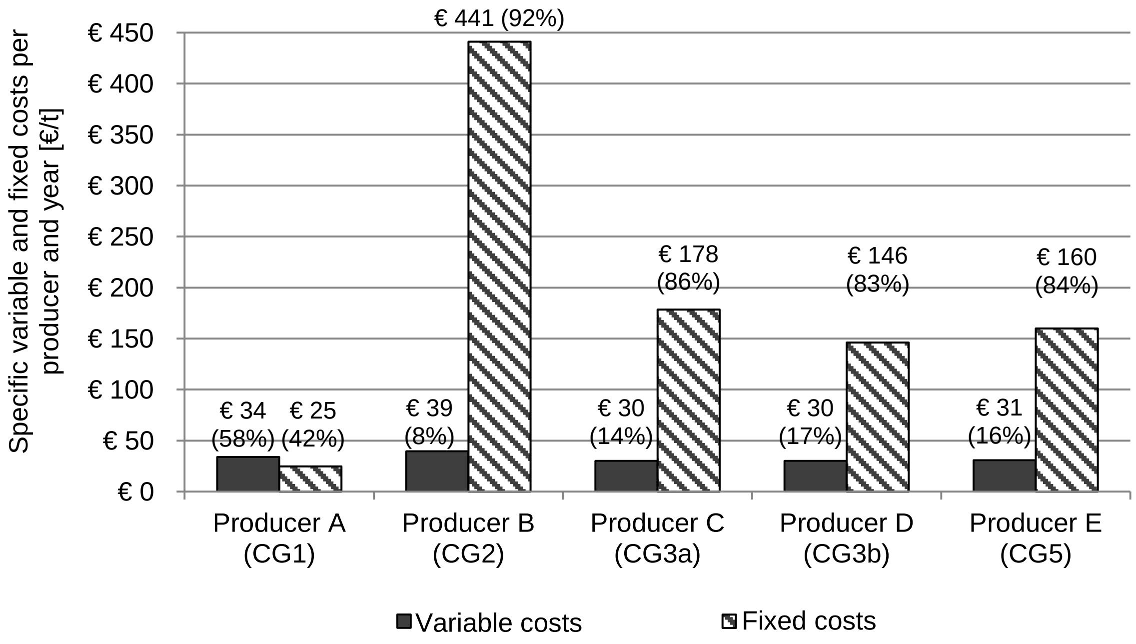


Figure 28: Specific variable and fixed costs per ton for producers of WEEE (base case)

The highest specific variable costs of €39 per ton are allocated to producer B (CG 2). The difference of up to €9 per ton of variable costs is based on different numbers of pick up requests and corresponding provision orders and thus different costs in comparison to producer A (CG1) C (CG3a), D (CG3b) and E (CG5).

The different numbers of pick-up requests are explained by different bulk densities of collection groups, which lead to different tonnage per transported container. Table 23 presents average tons per collected container and collection group. The data is based on the quotient of official collected amounts and corresponding pick-up requests per year and collection group. The calculations can be seen in Appendix A7.

Table 23: Average tons per container per collection group [EAR, 2012]

Collection group	CG1	CG2	CG3a	CG3b	CG5
Tons per pick up request [t/container]	4.1	2.7	6.3	6.3	5.9

Exemplarily, the average transported weight per pick-up request and container amounts to 2.7 tons for CG 2 [EAR, 2012]. Conversely, 6.3 tons result for CG 3a and 3b per collected container. Accordingly, a higher number of pick-up requests and thus higher costs arise for producer B (CG 2) to cover the treatment responsibility for the same envisaged amount of WEEE of producer A (CG1) and C (CG3a) to E (CG

5). Similarly, higher specific variable costs of €34 of producer A (CG1) are explained in comparison to Producer C (CG3a) to producer E (CG5). The proportion of costs of pick-up requests on total variable costs of all producers (CGs) ranges between 13% and 23%. The remaining share is caused by transportation costs (59% - 76%) and provision orders (11% - 18%) (Appendix A10).

The specific fixed costs vary between €25 (producer A (CG1)) and €441 (producer B (CG2)) per treated ton of WEEE. The specific fixed costs consist to a high degree of guarantees (Appendix A10). Equation 2.1 explains the basis of the calculation of guarantees per producer (refer to Chapter 2.1.1.2). It includes average treatment costs and return rates defined within [Regulation 02_003, 2012]. Exemplarily, collection group 2 accounts for €176 per ton treatment costs and a return rate of 75% (Appendix A1). This explains the high fixed costs of producer B (CG 2) of €441 per treated ton of waste (Figure 29). Only minor proportions of less than one per cent are allocated to updating fees and internal administration (Appendix A10).

Total specific costs (variable plus fixed) are significantly influenced if either delivery costs (negative gate fees) or delivery revenues (positive gate fees) are included (refer to Chapter 3.3.1, Table 13). Figure 29 shows the final balance of total specific costs (green column) adding either delivery costs per ton (striped columns) or delivery revenues per ton (grey columns).

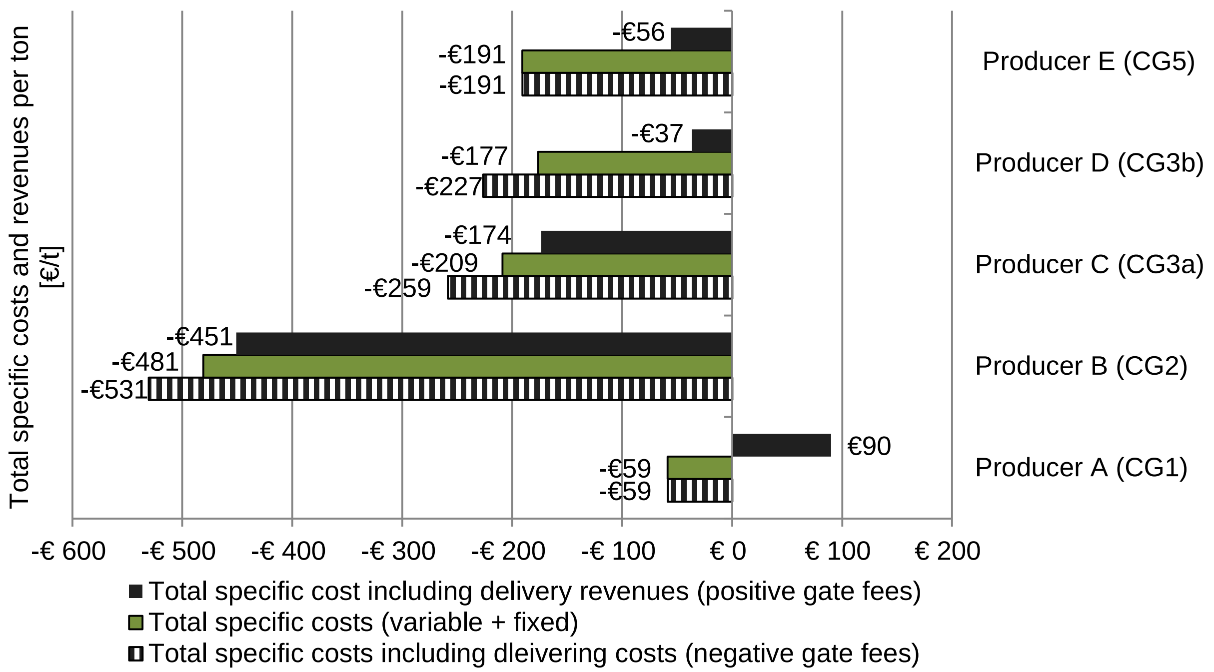


Figure 29: Comparison of specific costs including delivery costs or revenues of each producer

In the case of producer A (CG1), WEEE treatment is economically efficient if the producer receives delivery revenues (positive gate fees) at recycling facilities. Delivery revenues amount to €149 per ton on average in January 2012 and can cover costs such as presented fixed and variable costs. This is not true for producers B (CG2) to E (CG5). Received delivery revenues (positive gate fees) cannot cover costs for guarantees, transportation etc. Increasing market prices and, hence, higher delivery revenues might have an impact on producers D (CG3b) and E (CG5). A positive balance is achieved if delivery revenues (positive gate fees) rise by 20%, and 30%, respectively.

Delivery costs are documented for CG 2, 3a and 3b [EUWID, 2012] (refer to Chapter 3.3.1, Table 13). This increases the costs of producer B (CG2) to producer D (CG3b) by some 9% to 23%.

4.3.1.2 Impacts of informal sector activities according to modelled scenarios

The base case costs of each producer are contrasted to costs of each modelled scenario per producer (‘Equal_Comp, ‘EAR’, ‘High_Fe’, ‘High_Pl’, ‘High_PM’) (Appendix A14).

Exemplarily, total costs, total fixed costs and specific fixed costs are shown for producer A (CG1) excluding delivery costs (negative gate fees) and delivery revenues (positive gate fees) at recycling facilities (Figure 30).

Informal sector activities show a positive influence only when considering variable costs. Total variable costs are shown in Figure 30 and refer to the distance between total fixed costs and total costs; specific variable costs refer to the distance between specific total and specific fixed costs.

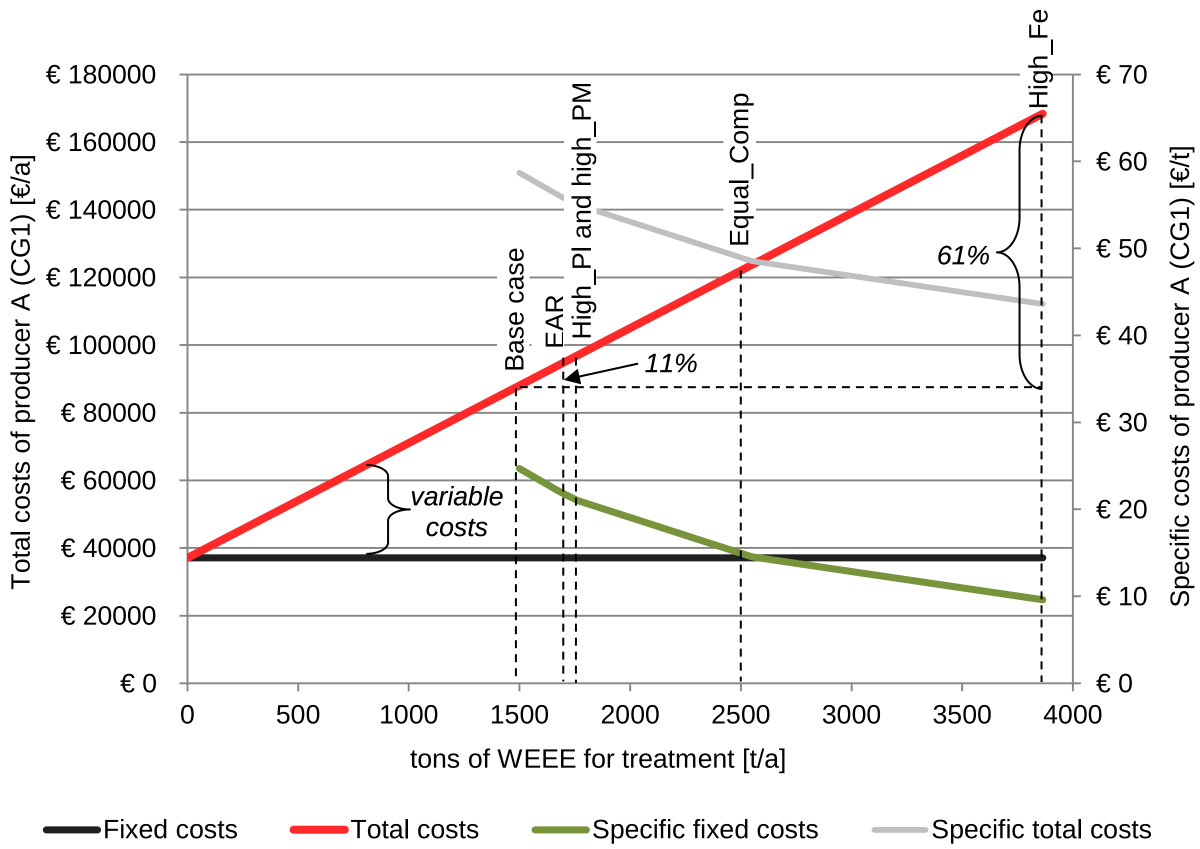


Figure 30: Fixed, total, specific fixed and specific total costs of producer A (CG1)

The base case includes the lowest total variable costs of €51,001 per year in comparison to all modelled scenarios. A higher amount for treatment implies higher variable costs for treatment. Therefore an informal collection reduces variable costs of producer A (CG1) by some 11% (‘EAR’ scenario) to 61% (‘High_Fe’ scenario). Detailed data is presented in Appendix A12.

The total costs increase from €88,045 (base case) to €168,404 (‘High-Fe’) per year based on additional amounts for treatment. The highest costs arise considering the ‘high_Fe’ scenario with a share of 45% of collection group 1 on total informally collected amounts. Conversely, the total fixed costs of €37,044 per year remain constant considering increasing treatment amounts. The specific fixed costs therefore decrease with additional amounts for treatment from €24.70 (base case) to €9.60 per ton (‘High_Fe’ scenario). Subsequently, the same curve progression is recognisable for the total specific costs, which is increased by specific variable costs of €34 per ton.

The presented costs per ton of collection group 1 can be covered by receiving delivery revenues at recycling facilities. The base case results in specific total costs of €58.70 per ton. Delivery revenues of the same amount would lead to a net total resulting in neither revenues nor costs for producer A (CG1). The total specific costs decrease down to €43.59 per ton (‘High_Fe’ scenario) considering no informal collection, which refers to 26%. Hence, producer A (CG1) would already reach a break-even point at the lower delivery revenues of 26%.

However, the delivery revenues (positive gate fees) of collection group 1 add up to €149 per ton in January 2012. The base case would result in a net total of €89.97 per ton as the total specific costs of €58.70 per ton are covered. An additional available amount for treatment would cause an increase in the net total of up to €105.08 per ton (‘High_Fe’ scenario). The results are displayed in Figure 31.

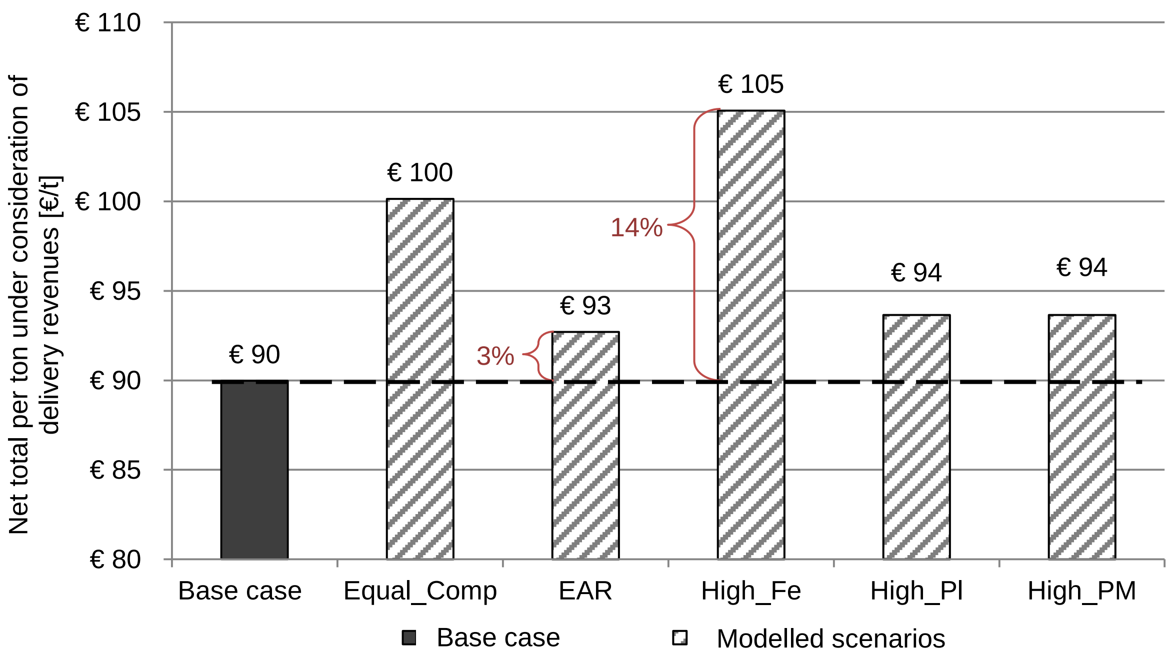


Figure 31: Comparison of base case and scenarios considering delivery revenues (prod. A (CG1))

The net total increases about 14% considering the ‘High_Fe’ scenario. The lowest growth is allocated to the ‘EAR’ scenario of 3%, which refers to €92.87 per ton. Informal sector activities therefore have a negative influence on the net total of producer A considering the collection and treatment of collection group 1 at current delivery revenues (positive gate fees) at recycling facilities.

4.3.1.3 Assessment of the modelled scenarios of all producers

The specific total costs are presented in Figure 32 for all producers A (CG1) to E (CG5) and all modelled scenarios. The specific total costs decrease with higher amounts for treatment. The highest additional amounts of 2,363 tons per year are allocated to producer A (CG1) within the 'high_Fe' scenario, which is explained by a high treatment proportion of 11% based on § 14 (5), ElektroG. Similarly, the high amounts of 734 tons per year of producer E(CG5) within the 'High_Pl' scenario are based on a treatment proportion of 4% (refer to Chapter 3.3.1, Table 14).

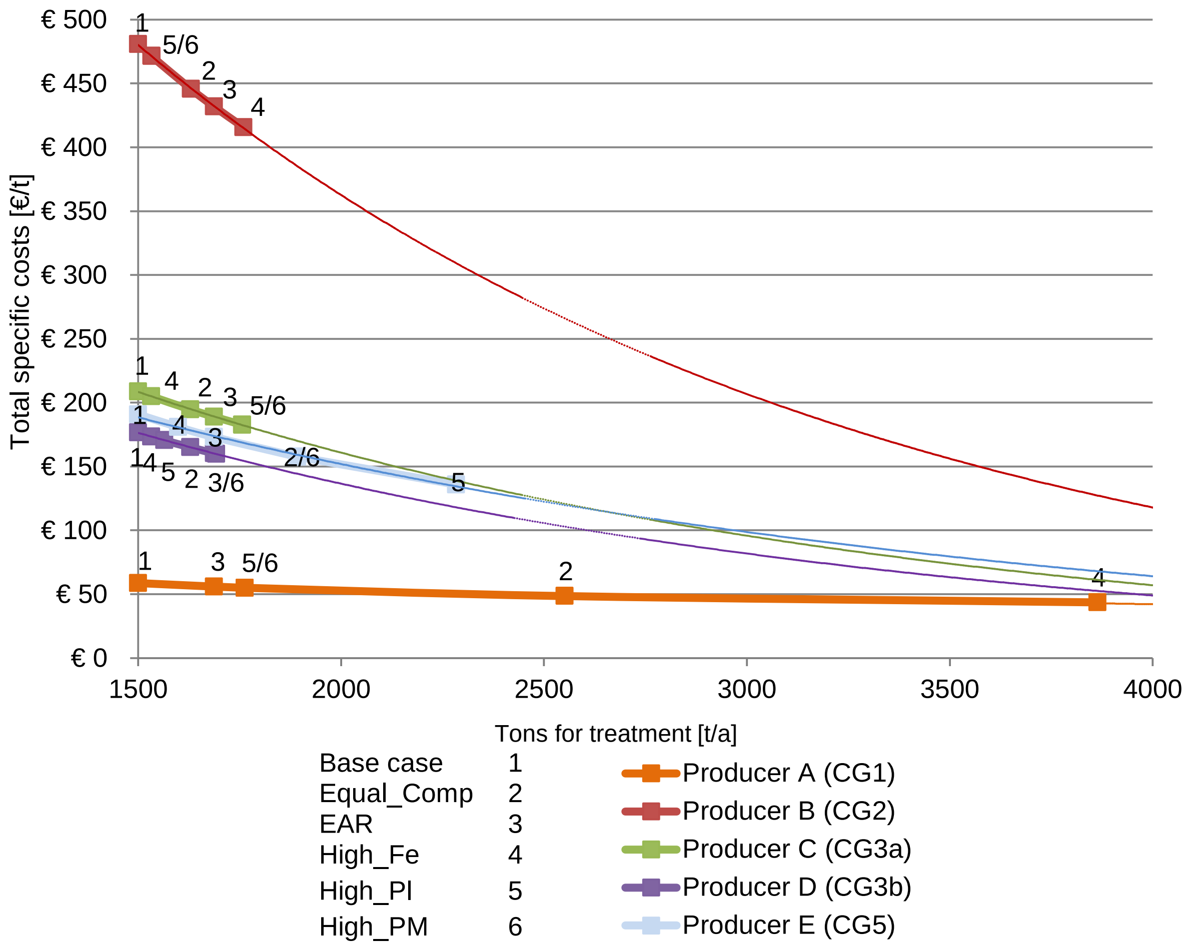


Figure 32: Assessment of modelled scenarios of all producers (CG) considering specific total costs

The highest specific total costs of €481 per ton are allocated to producer B (CG2) within the base case. The highest amounts for treatment appear within the 'High_Fe' scenario. Consequently, the lowest specific total costs of €416 per ton arise within the same scenario. This complies with a reduction of specific total costs of 14% in comparison to the base case. Considering revenues, producer B would already reach a break-even point if the lower revenues of 14% can be achieved at recycling facilities. Similarly, the specific total costs of producer C (CG 3a) decrease about 12%, the specific total costs of producer D (CG3b) decrease about 9% and the specific total costs of producer E (CG5) decrease about 29%. The highest decrease of specific total costs of producer E (CG5) is explained by higher amounts for treatment in comparison to producer B (CG2), C (CG3a) and D (CG3b) and a higher share of specific fixed costs of 84% in comparison to producer A (CG1).

Therefore the received delivery revenues (positive gate fees) at recycling facilities, which cannot cover costs in the base case, might be able to generate a break-even point considering lower specific total costs based on missing informal collection. Figure 33 clarifies this situation, whereby the base case (100%) is put into relation to the modelled scenarios. The zero point implies neither resulting costs nor revenues (break-even point). The delivery revenues (positive gate fees) are displayed in Table 13, Chapter 3.3.1, ranging between €30 (CG2) and €149 (CG1) [EAR, 2012].

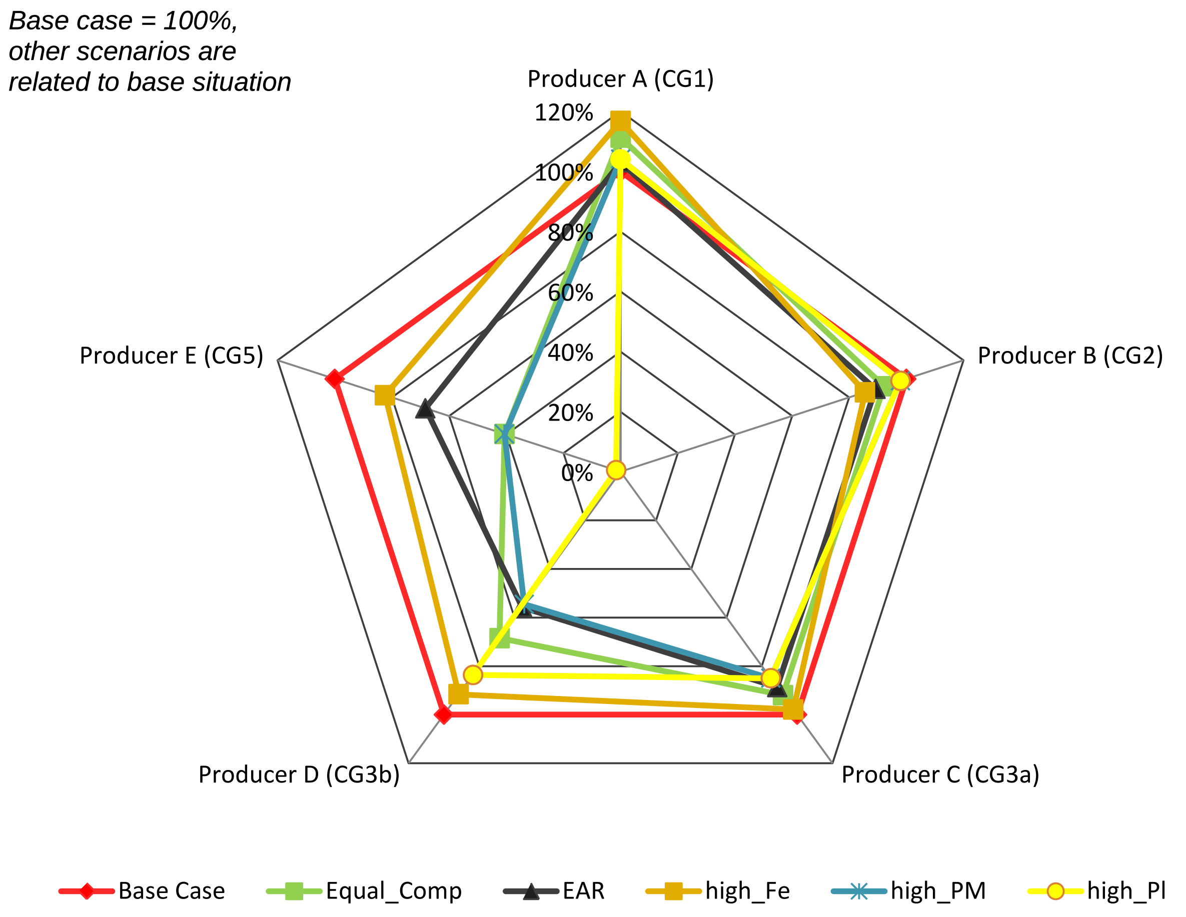


Figure 33: Assessment of all modelled scenarios of all producers considering delivery revenues

As outlined in the previous chapter, informal collection causes losses up to 14% considering producer A (CG1). Hardly any effects are recognisable considering producer B (CG2) and producer C (CG3a) in comparison to producer D (CG3b) and E (CG5). Delivery revenues amount to €30 per ton for CG2. Consequently, the specific total costs of producer B (CG2) decrease to €451 per ton. This implies an economic advantage if the items are informally collected as variable costs drop. The same applies to producer C (CG3a). The delivery revenues amount to €35 per ton for collection group 3a. Here the specific total costs decrease to €173.73 per ton, whereby no cost covering can be achieved. Similarly, informal activities would imply savings of variable costs of €30 per ton of informally collected WEEE (Figure 28).

Conversely, producer E (CG5) has the lowest specific total costs of €136 per ton within the 'High_Pl' scenario. The delivery revenues amount to €135 per ton for collection group 5, whereas a break-even point is nearly achieved. Taking into account continuous price increases of valuable materials, informal collections can cause losses for producer E (CG5) in the future. The same relation can be transferred to producer D (CG3b). The lowest total specific costs of €160 per ton and delivery revenues of €140 per ton reveal a negative net total of €20. Nevertheless, an increase of delivery revenues of over 12.5% results in a positive net total for producer D (CG3b). Informal collection can therefore cause losses for producer D (CG3b) considering rising market prices.

In summary, the dependency of informal sector activities, and missing amounts for treatment on the net total of producers, respectively, can be described as follows:

$$TC_{Producer_x} > TR_{Producer_x} \qquad positive\ economic\ influence\ of\ informal\ sector \qquad [4.1]$$

$$TC_{Producer_x} = TR_{Producer_x} \qquad no\ econmic\ influence\ of\ informal\ sector \qquad [4.2]$$

$$TC_{Producer_x} < TR_{Producer_x} \qquad negative\ economic\ influence\ of\ informal\ sector \qquad [4.3]$$

$whereby$

$$TC_{Producer_x} = total\ costs\ of\ producer \qquad [4.4]$$

$$TR_{Producer_x} = total\ revenues\ of\ producer \qquad [4.5]$$

Thereby the quantity of economic influences of informal sector activities equals either the positive net total (Equation 4.3) or saved cost per untreated ton of WEEE (Equation 4.1). No influence will be recognisable if the total costs equal total revenues (Equation 4.2).

4.3.2 *Private household perspective*

Economic and environmental impacts of informal sector activities are presented for Polish and German private households while considering a washing machine and television.

4.3.2.1 German private household

Washing machine

The comparison of emerging costs of using a washing machine is based either on new acquisition (183 kWh per year) or the further use of an old washing machine (266 kWh and 240 kWh per year) (Figure 34). Different energy consumptions of old washing machines will highlight a sensitivity with regard to parameters such as emission factor or price of electricity of different observed scenarios. Furthermore, a price increase is included of 1% per year of used energy costs at €0.24 per kilowatt hour.

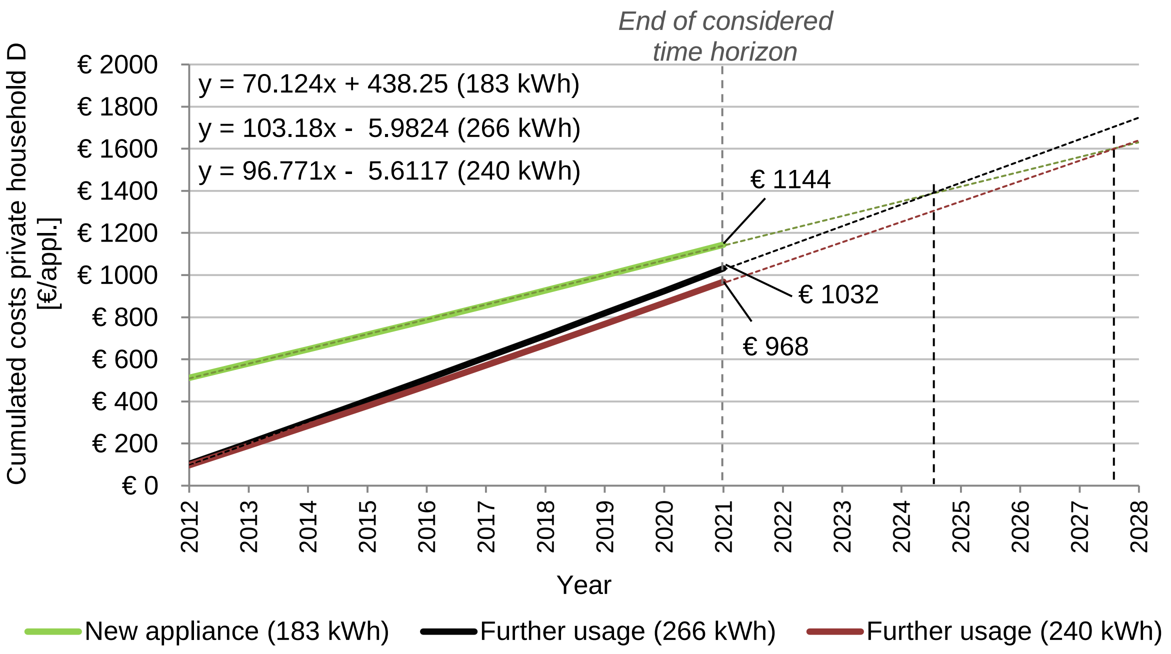


Figure 34: Cumulated costs of German household, washing machine

Total costs amount to €1,144 for 10 years in the case of purchasing a new washing machine (183 kWh) and to €1,032 for the further utilisation of an old washing machine with an annual energy demand of 266 kWh. The amortisation is reached after 13.5 years – beyond the considered time period of 10 years. A lower energy demand of 26 kWh (240 kWh) per year would lead to an amortisation period of 16.5 years. It implies that the purchase price of a new washing machine cannot cover the higher energy costs of a used washing machine in a ten-year time horizon. The results are in line with observations made by [Rüdenauer et al., 2005].

A break-even point emerges at an earlier time regarding CO_2 emissions. Amortisation is reached after 7.5 years considering a replacement of an old washing machine (266 kWh) by a washing machine with an annual energy demand of 183 kWh (Figure 35).

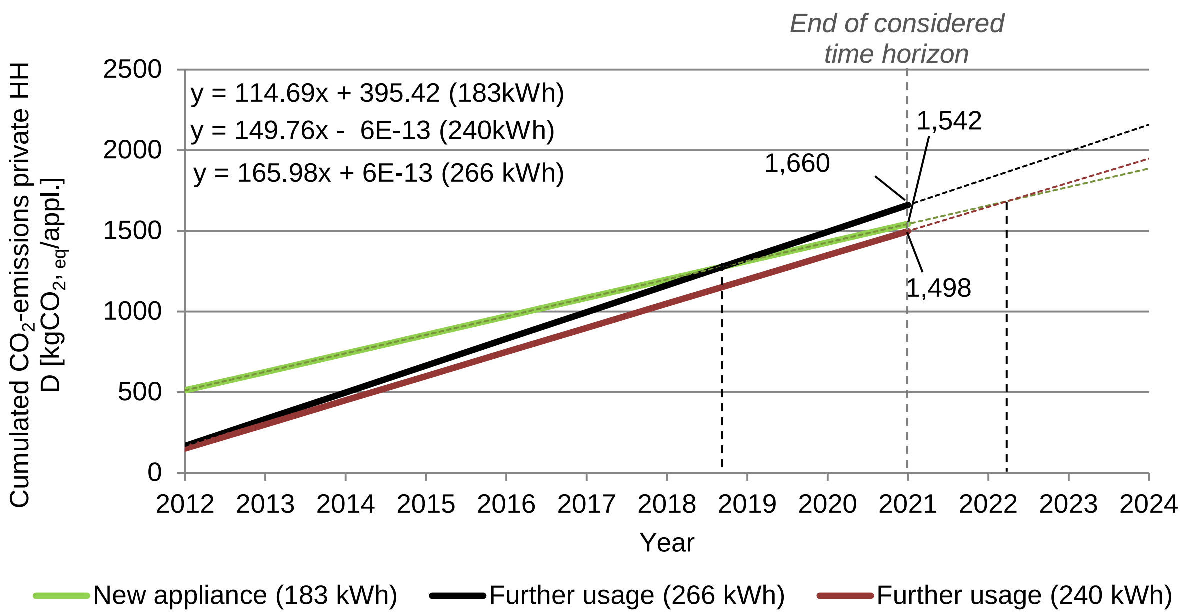


Figure 35: Cumulated CO_2 emissions of German household, washing machine

Cumulated CO_2 emissions amount to 1,542 kg $CO_{2,\,eq}$ within 10 years considering the acquisition of a new washing machine (183 kWh). This includes production and distribution emissions, transportation as well as the energy consumption of the appliances. Further use of an old appliance (266 kWh) results in CO_2 emissions of 1,660 kg $CO_{2,\,eq}$. Nevertheless, if an energy demand of used products of 240 kWh per year is considered, the amortisation time is reached after 11.5 years. This implies that CO_2 emissions resulting from the production and distribution of a new appliance cannot cover higher CO_2 emissions of an old appliance.

Amortisation of CO_2 emissions is reached after 10 years, if an annual energy demand of 230 kWh is considered. Subsequently, reuse and further use is advisable from an economic and environmental perspective if the energy demands of old appliances are lower than 230 kWh per year within the considered system.

Television

The same statements can be transferred to the analysis of a television. Cumulated costs (energy demand, sales prices) illustrate that the acquisition of a new appliance (LCD, 78 kWh) leads to higher total costs in comparison to the further use of an old appliance (CRT, 100 kWh and 140 kWh) within a ten-year time horizon (Figure 36).

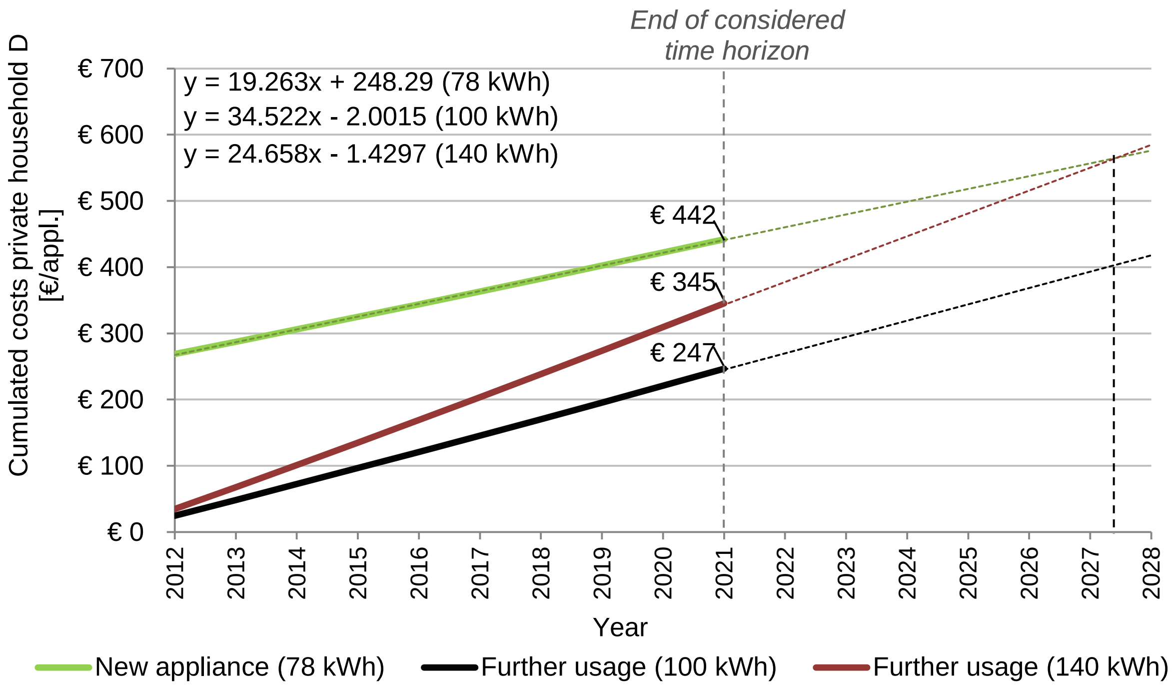


Figure 36: Cumulated costs of German household, television

The LCD television accounts for an annual energy demand of 78 kWh. Amortisation of the corresponding sales prices and lower energy costs is not reached after 20 years. Higher energy demands of old appliances, exemplarily shown for a CRT - television using 140 kWh per year, cover the costs of a new acquisition only after 16.5 years. This implies that the reuse of an old appliance can be definitely advised from an economic point of view.

The same relation can be observed considering CO_2 emissions (Figure 37). The amortisation of CO_2 emissions is reached after 10 years considering a television with CRT technology and an energy demand of 140 kWh.

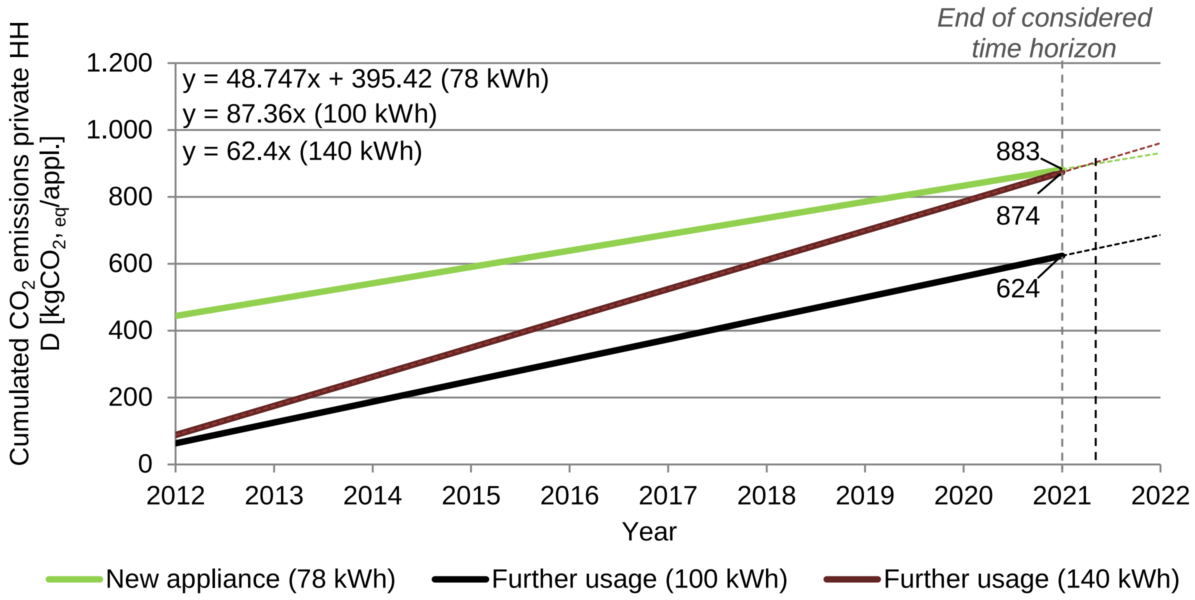


Figure 37: Cumulated CO_2 emissions for German household, television

CO_2 emissions of a LCD television amount to 883 kg $CO_{2,\ eq}$ after 10 years. Further use of a television equipped with CRT technology causes 874 kg $CO_{2,\ eq}$ (140 kWh/a) and 624 kg $CO_{2,\ eq}$ (100 kWh/a) in the same time horizon. The production and distribution of a new appliance (LCD, 78 kWh) cannot be covered through higher CO_2 emissions of old televisions based on higher energy demands. CO_2 production and distribution emissions are taken from [Rüdenauer, 2005] and can widely fluctuate due to applied production technology and processed primary raw materials. This issue will be subject to a sensitivity analysis (refer to Chapter 4.4.1.2).

On the basis of the considerations made, reuse of a television equipped with CRT technology is advisable from an environmental point of view within the considered system boundaries.

4.3.2.2 Polish private household

The emission factor for energy consumption amounts to 1.19 kg $CO_{2,\ eq}$ per kilowatt hour in Poland. This is twice higher than the German electricity emission factor of 0.624 kg $CO_{2,\ eq}$ per kilowatt hour. This fact together with lower energy costs gives different results regarding costs and CO_2 emissions.

Washing machine

Further use of an old washing machine (266 kWh) includes clear cost advantages in contrast to the acquisition of a new washing machine (183 kWh) in Poland. Current energy costs per kilowatt hour are 3.5 times lower in comparison to energy costs in Germany (€0.24 /kWh). A range of 0.17 zł (Gdansk - €0.04 /kWh) to 0.38 zł (Wroclaw - €0.09 /kWh) per kilowatt hour is recognised regarding household level electricity expenditures depending on the geographic location [GTAI, 2012]. A mean of €0.07 per kilowatt hour is used for the evaluation. Prices converted into Euros are based on exchange rates in July 2012 [OANDA, 2012].

No amortisation of costs is achieved within the considered time horizon considering an increase of prices of 3% per year [GTAI, 2012]. The results are presented in Figure 38.

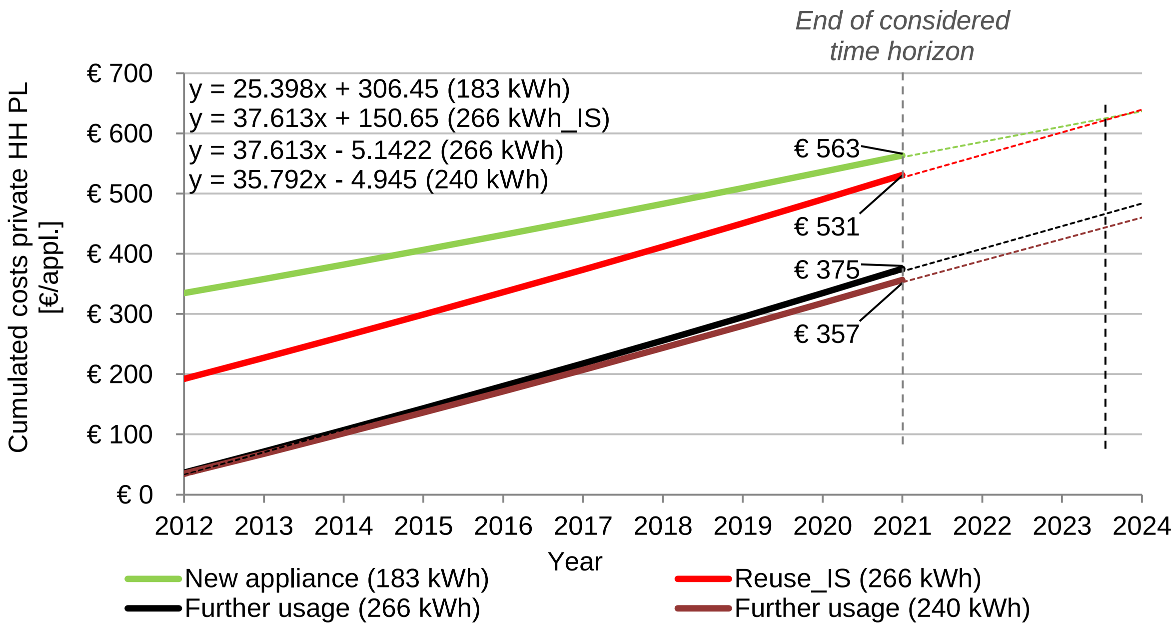


Figure 38: Cumulated costs for Polish household, washing machine

The total costs for the acquisition of a new appliance (183 kWh) after 10 years amount to €563. This is lower than half of the total costs of a German household (€1,144), which is mainly based on energy costs of €0.07 per kilowatt hour in comparison to €0.24per kilowatt hour in Germany. The practically parallel course progressions of further use of a washing machine and new acquisition of a washing machine are based on acquisition costs, which cannot be covered by cost savings based on lower energy consumption. The total costs for the further use of a washing machine using an average of 266 kWh per year amount to €375. The same applies to a washing machine purchased at an informal flea market. An amortisation of a new appliance is only reached after 12.5 years. This is based on lower acquisition costs of €114 at informal flea markets in comparison to €309 for a new washing machine. The main cost driver of the Polish scenario is the sales price. Therefore reuse or further use of an old washing machine is advisable from an economic perspective.

A different picture emerges considering CO_2 emissions. Amortisation of an old appliance (266 kWh and 240 kWh) by the acquisition of a new appliance (183 kWh) is already reached after 4 years, and 6.5 years, respectively (Figure 39). Despite the energy industry currently undergoing a modernisation process, the electricity mix in Poland is still dominated by utilisation of fossil fuels. A future diversification of the electricity mix is expected away from reliance on coal towards clean energy sources [Polish Chamber, 2010]. Continuatively, an annual increase of 1% of the Polish emission factor is assumed within the CO_2 accounting. The results are presented in Figure 39.

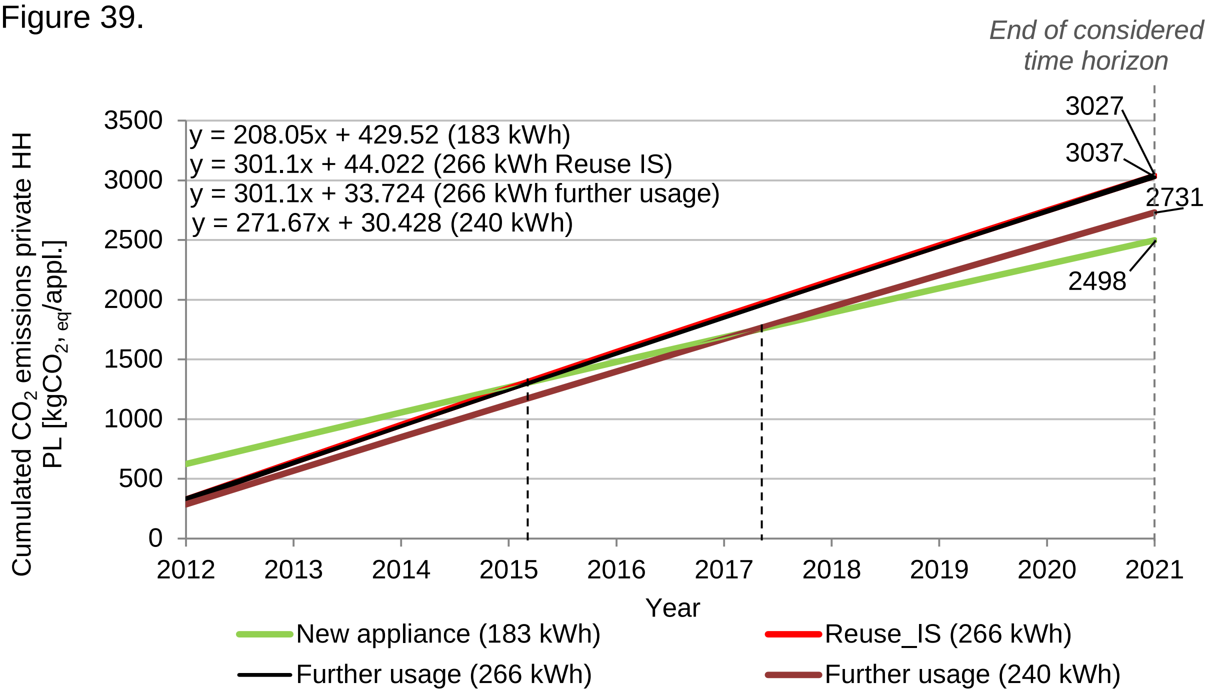


Figure 39: Cumulated CO_2 emissions for Polish household, washing machine

Further use and reuse (informally collected) of a washing machine of 266 kWh would lead to higher CO_2 emissions of 529 kg $CO_{2,\ eq}$ and 539 kg $CO_{2,\ eq}$ within 10 years. The difference of 10 $kgCO_{2,\ eq}$ is caused by additional transport distances covered by the informal collector. Amortisation is reached after 4 years within the further use scenario. Lower energy consumption of 26 kWh would lead to amortisation after 6.5 years, this corresponds to an additional 2.5 years (240 kWh).

This shows that a higher emission factor causes a higher sensitivity regarding energy demands, as a difference of 26 kWh per appliance caused a later amortisation of 4.5 years in Germany (refer to Figure 35). Therefore a reuse or further use of appliances in Poland is significantly dependent on the energy demand of the considered items and cannot be recommended within the presented system boundaries.

Television

The low impact of energy costs is recognisable with regard to costs for reused, further used (CRT) and new televisions (LCD). Hardly any influence is recognisable regarding higher energy efficiency of new appliances and corresponding cost savings. Only the acquisition price of appliances has an influence on total households costs (Figure 40).

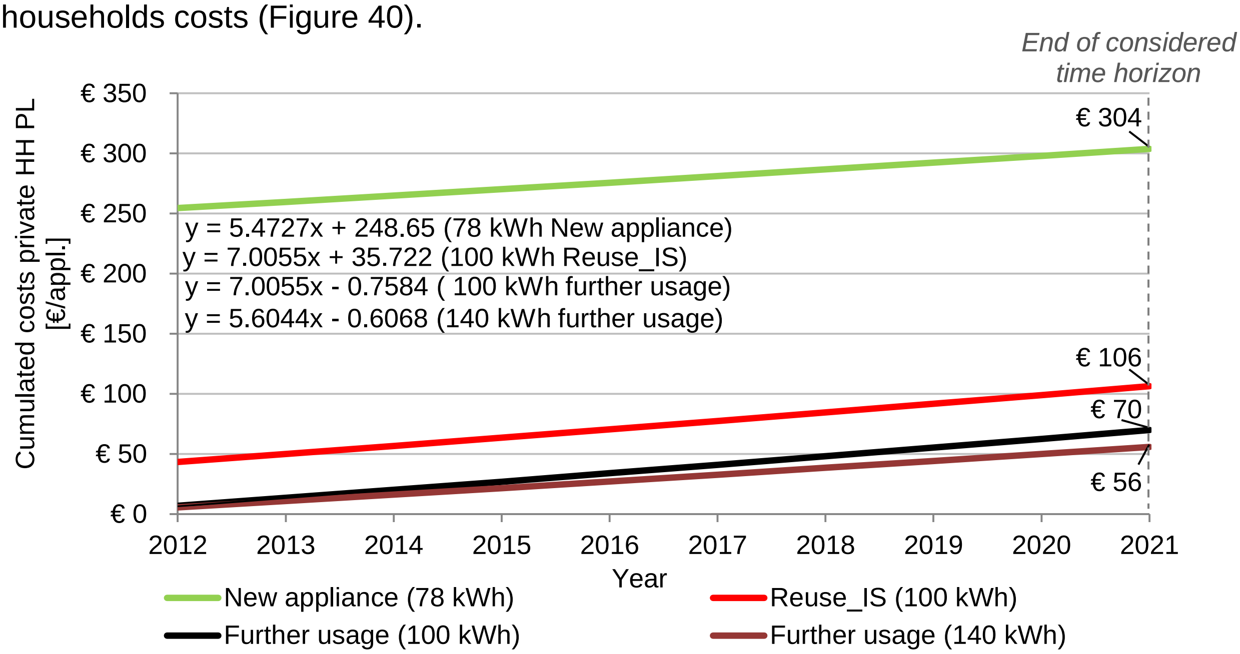


Figure 40: Cumulated costs for Polish household, television

A cost difference of €248 emerges when comparing further use of a television equipped with CRT technology (140 kWh) and a LCD television (78 kWh) after ten years. The informal reuse of a CRT television (100 kWh) results in costs of €106 for a Polish household in the same time horizon. The savings amount to €197 per household in comparison to the new acquisition of a LCD television. Therefore the further use and reuse of a CRT television is recommended from an economic perspective.

CO_2 emissions amortise after 9.5 years comparing a new LCD television (78 kWh) and further use of a CRT television (140 kWh). Amortisation is reached after 16 years considering the reuse and further use of a CRT television with an energy demand of 100 kWh (Figure 41).

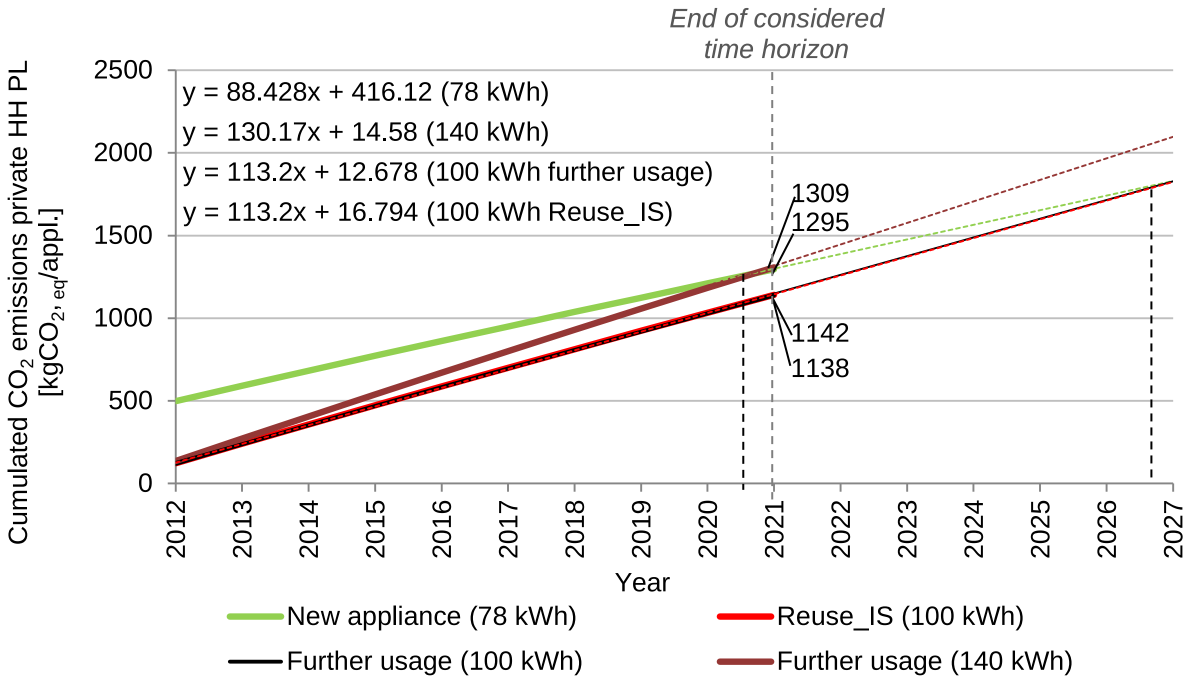


Figure 41: Cumulated CO_2 emissions for Polish household, television

The acquisition of a new television leads to an emission of 1,295 $kgCO_{2,\ eq}$ after ten years. This implies a lower emission of 13 kg $CO_{2,\ eq}$ in comparison to the further usage of a CRT television with 140 kWh (1,308.53 kg $CO_{2,\ eq}$). Further use and reuse (informally collected) of a television with an energy demand of 100 kWh per year lead to an emission of 1,142 kg $CO_{2,\ eq}$, and 1,138 kg $CO_{2,\ eq}$, respectively. The difference is marginal and is based on additional emissions from transportation of informally collected goods from Germany to Poland and emissions of household-undertaken transport that amount to 4.12 kg $CO_{2,\ eq}$.

Therefore reuse of a CRT television is recommended from an environmental perspective considering an energy demand of 100 kWh. The higher energy consumptions of 140 kWh amortise after 8.5 years. Nevertheless, higher emissions of 13 $kgCO_{2,\ eq}$ result after 10 years. From an environmental perspective, a new acquisition would be advisable. Conversely, it is debatable whether an additional emitted amount of 13 $kgCO_2$ would compensate for emerging social disadvantages for informal collectors, if a ban on such collection activities were applied.

4.3.3 WMA perspective

Three different scenarios are evaluated regarding the WMA perspective.

A) WMA collects and stores appliances in accordance with § 9 (3), ElektroG, or
B) WMA has an option on treatment and collection in accordance with § 9 (6) including delivery revenues (DR) (positive gate fees, Table 13), or
C) WMA has an option on treatment and collection in accordance with § 9 (6) including delivery costs (DC) (negative gate fees, Table 13)

<u>Washing machine</u>

The costs per washing machine add up to €2.72 and €4.36 considering scenario A (§ 9 (3)), and scenario B (§ 9 (6)), respectively (Figure 42). This includes the costs for household collection and the storage at waste collection centres considering A, and the additional costs for transportation to recycling facilities and delivery costs considering B. No delivery costs are documented for washing machines (CG 1) in January 2012 [EAR, 2012, Table 13]. Figure 42 illustrates the costs and revenues of waste management associations.

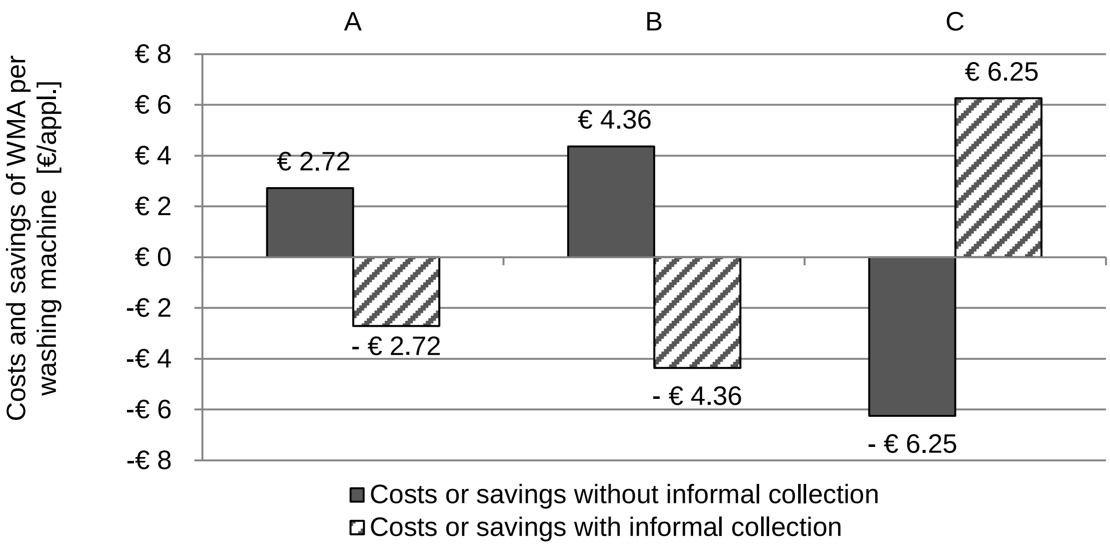


Figure 42: Costs and savings from WMA perspective, washing machine

The analysis shows that informal collection of these items leads to cost savings if the aforementioned cases occur. Only if delivery revenues are achieved (€149 /t for CG1) benefits result considering the acceptance of treatment responsibility (C).

Therefore scenario C results in revenues of €6.25 per washing machine. Conversely, a loss arises if a washing machine is informally collected.

CO_2 emissions are higher for scenarios B and C in comparison to scenario A. This is based on the transportation path to the recycling facility, which accounts for 75 km for the round journey. CO_2 emissions amount to 1.42 kg $CO_{2, eq}$ for the whole collection and transportation process of one washing machine considering cases B and C (Figure 43). This is relatively low in comparison to the usage phase of a washing machine (1,542 – 1,660 kg $CO_{2, eq}$, Figure 35).

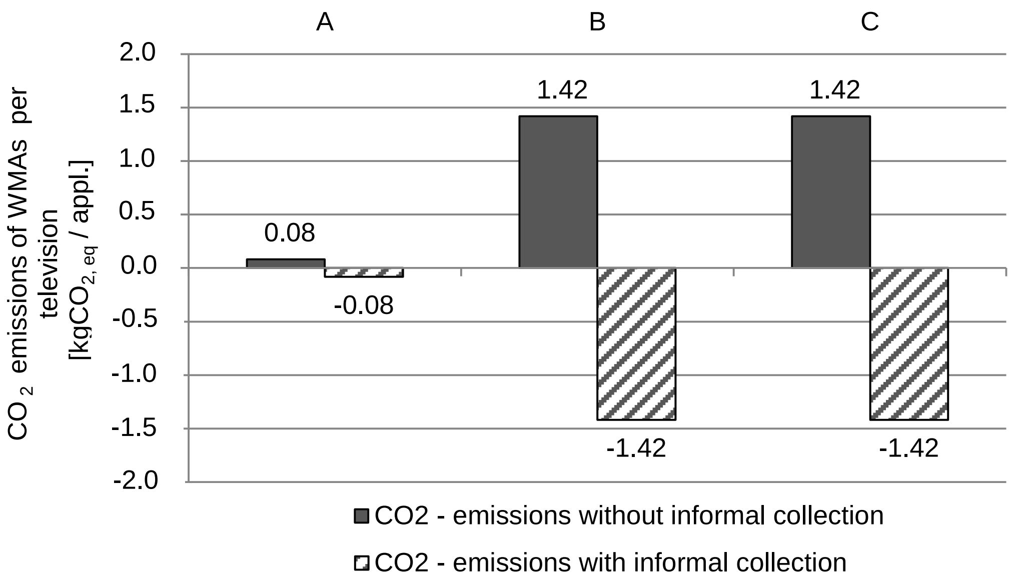


Figure 43: CO_2 emissions resulting from WMA perspective, washing machine

Waste management association save on CO_2 emissions in the same range of 0.08 to 1.42 kg $CO_{2, eq}$, if a washing machine is informally collected, whereas the savings are supplemented by emissions caused by informal transportations (refer to Chapter 4.3.4).

<u>Television</u>

Costs of €0.37 and €1.08 per television arise when considering scenario A, and B, respectively. Revenues of €0.75 per television arise if delivery revenues (positive gate fees) are received. Lower costs account for the television in comparison to the washing machine, as the proportion of the volume of items is related to the whole volume capacity of the transporting vehicle (Figure 44).

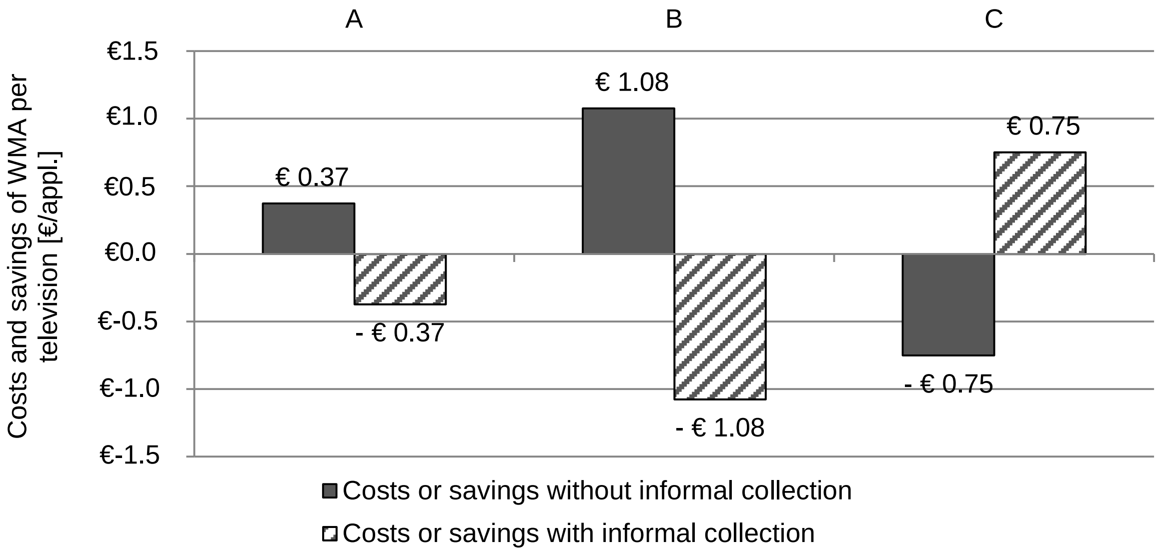


Figure 44: Costs and savings of WMA perspective, television

Current system boundaries reveal a financial loss of about €0.75 per television (C) if an informal collection appears. Conversely, cost savings of €0.37 and €1.08 per informally collected washing machine result with scenario A (§ 9 (6)), and B (§ 9 (3)), respectively. Accordingly, waste management association have economic advantages if a television is informally collected in case A or B.

CO_2 emissions for transportation amount to 0.37 kg $CO_{2,\ eq}$ per television in scenario B and C, which is negligible in comparison to the usage phase (624 – 874 kg$CO_{2,\ eq}$, Figure 45).

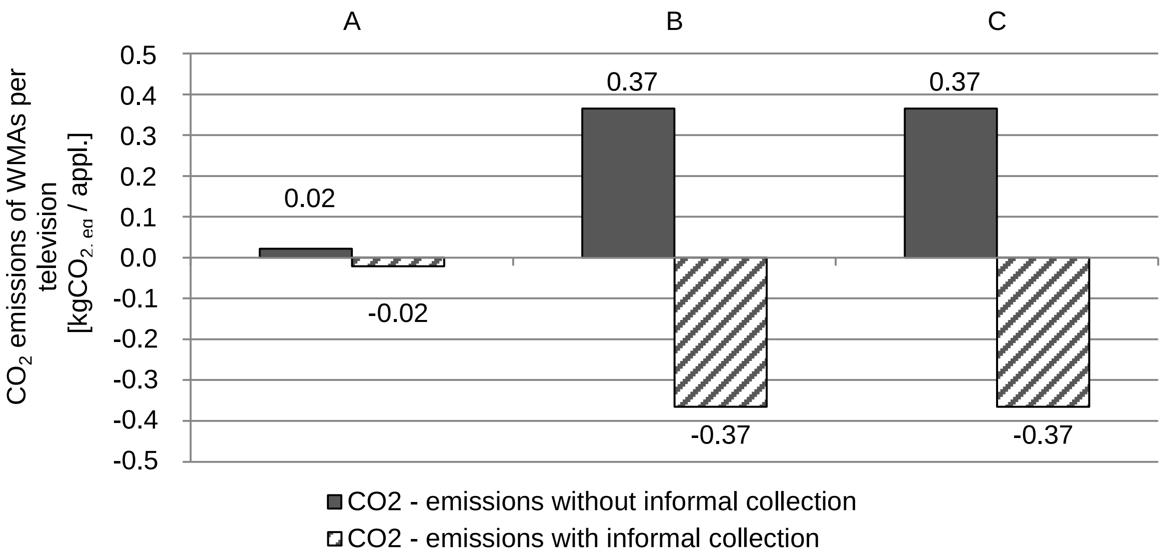


Figure 45: CO_2 emissions of WMA perspective, television

Waste management associations produce 0.02 kg $CO_{2,\ eq}$ within scenario A. Resulting emissions refer to collection and storage. An informal collection would result in CO_2 emission savings amounting to 0.02 kg $CO_{2,\ eq}$ for scenario A, and 0.37 kg $CO_{2,\ eq}$ for scenario B and C.

4.3.4 Informal collector perspective

Informal collectors cover a round journey of 800 kilometres to collect washing machines and televisions. Thus, transportation costs represent the major influence on the total costs of informal collectors. As is similarly the case with waste vehicles, the volume of transported appliances is related to the total load capacity, amounting to 8 cubic metres of considered transporters.

Washing machine

The transportation costs of one washing machine amount to €4.63. It is assumed that a collected washing machine is sold within 2 weeks after collection. Only minor volume-based costs regarding the rent of an exhibition stand at flea markets are allocated to the washing machine (€0.17). Continuatively, total costs of €4.80 arise for the collection and sale of one washing machine. The average sales price of a washing machine is €114 (refer to Chapter 3.3.2, Table 16). This implies a benefit of €109 per informal collector, subject to fluctuations based on the quality and age of the item.

The CO_2 emissions result from the distances travelled to collect items. CO_2 emissions for the considered transporter account for 0.238 kg CO_2 per kilometre. This leads to emissions of 8.33 kgCO_2 per collected and sold washing machine.

Table 24: Costs for informal collectors and CO_2 emissions caused by informal collectors, washing machine

Costs of informal collector	€ 4.80 per appliance
CO_2 emissions caused by informal collector	8.33 kg CO_2 per appliance

Television

The costs for informal collectors amount to €1.24 per television. This consists of the volume based share of storage costs (€0.05) and transportation costs (€1.19). Sales prices of used CRT televisions add up to about €25 per item. This implies an income of €23.8 per sold item (Table 25).

Lower emissions of 6.18 kg CO_2 result from the transport of a television in comparison to that of a washing machine. This is based on the lower transport volume required. Arising CO_2 emissions amount to 2.15 kg CO_2 per television.

Table 25: Costs for informal collectors and CO_2 emissions caused by informal collectors, television

Costs of informal collector	€1.24 per appliance
CO_2 emissions caused by informal collector	2.15 kg CO_2 per appliance

In summary, the waste management association and informal collector perspectives display two disposal phase alternatives with regard to the collection of a washing machine and television. Comparing both alternatives, the informal collection of a washing machine leads to higher CO_2 emissions of 6.91 kg CO_2 per item in comparison to scenario B and C. The informal collection of a television would lead to higher emissions of 1.78 kg CO_2. This is explained by higher transport distances that informal collectors have to cover. Nevertheless, resulting emissions in both perspectives are negligible in comparison to CO_2 emissions in the usage phase.

The highest income per washing machine (€109) can be obtained by informal collectors. Waste management associations only receive revenues of €6.25 per washing machine if case C applies. Considering case A and B regarding waste management associations, economic advantages would arise for both the waste management association and informal collector. The latter receives an income per washing machine of €109, whereas the waste association obtains savings due to no transportation costs.

4.4 Approach IV - Eco – efficiency of informal sector activities

Whole life cycles of both appliances are evaluated regarding their eco-efficiency with respect to energy consumption. CO_2 emissions and life cycle costs for corresponding emissions are contrasted according to the system boundaries presented in Figure 16.

4.4.1 New production, further use and reuse: Washing machine

Figure 46 illustrates the total life cycle costs of energy consumption and corresponding CO_2 emissions according to the system boundaries depicted in Figure

16, Chapter 3.4. This includes the new acquisition and further use of a washing machine in Germany (D) and Poland (PL) as well as both the sum of produced appliances in Germany and Poland and the reuse of an old appliance collected in Germany and reused in Poland (D and PL).

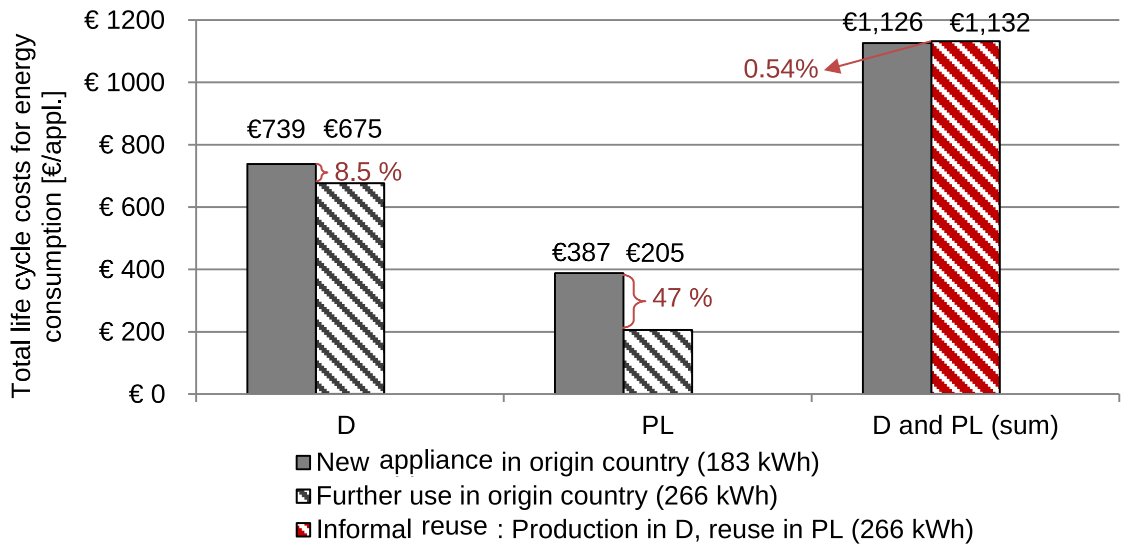


Figure 46: Total life cycle costs for energy consumption, washing machine

Further use of a washing machine is less cost-intensive than the acquisition of a new appliance both in Germany and Poland. Total life cycle costs decrease by some 8.5%, and 47%, respectively (Figure 46). The total life cycle costs of new appliances (sum of costs for Poland and Germany, D and PL) are found to be slightly lower (€6 per washing machine) than costs for reuse caused by informal sector activities. Thereby lower energy costs, Polish production costs and German treatment costs (‘new appliance’) face additional costs for collection by the informal collector and higher energy consumption costs (‘informal reuse’). Therefore a washing machine with an annual energy consumption of less than 266 kilowatt hours leads to fewer total costs within the reuse scenario.

Further use of a washing machine as well as the reuse scenario results in higher emissions in comparison to the production of new appliances in Poland and Germany (Figure 47).

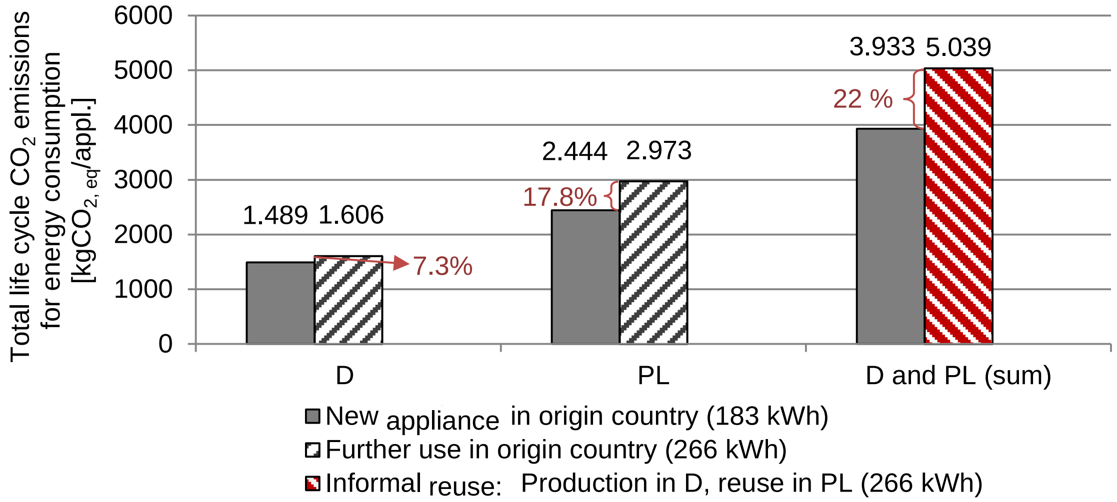


Figure 47: Total life cycle CO_2 – emissions for energy consumption, washing machine

The lowest increase of CO_2 emissions of 7.3% is allocated to the further use of a washing machine in Germany. In Poland CO_2 emissions increase about 17.8% and the reuse scenario results in an increase of 22%. The higher emissions in Poland are based on energy production, which is mainly dependent on fossil fuels. In addition, higher CO_2 emissions caused by further use of a washing machine result from higher energy demands in Germany, which are not covered due to the lack of production and distribution emissions. The same applies to the further use in Poland as well as the reuse (informally collected).

The relation between the considered scenarios results from contrasting both the economic and environmental performances (Figures 46 and 47). Exemplarily, the German comparison between further use and a new appliance is explained.

An added value is gained by overall cost savings within the further use scenario. The resource consumption displays additional associated CO_2 emissions. The relation between both is presented in Figure 48. The scale ranges from 0 to 1, where 1 expresses the highest costs (y-axis) and highest CO_2 emissions (x-axis). The 0 value implies no costs, and no CO_2 emissions, respectively.

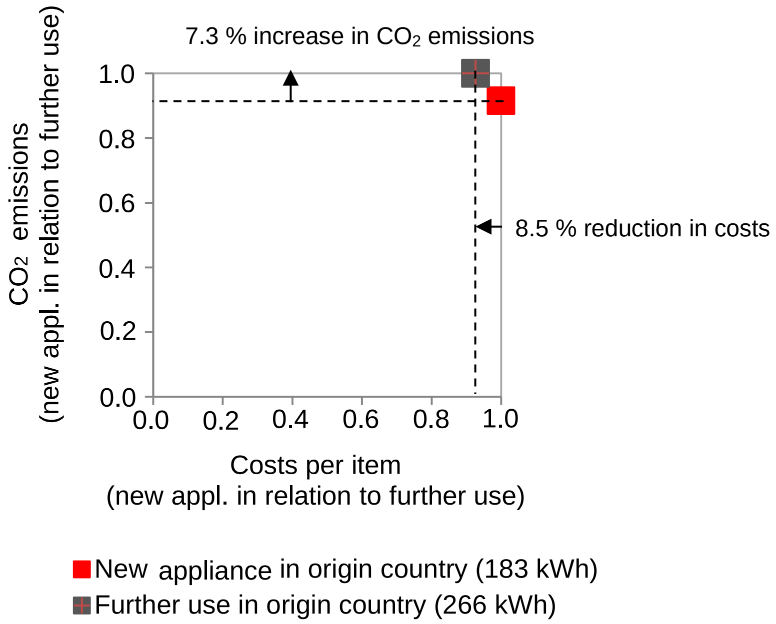


Figure 48: Relation of costs and CO_2 emissions of energy consumption, washing machine

Considering the 'further use' scenario, it is evident that higher environmental burdens simultaneously result at lower costs. This means that the reduction of costs of about 9% through further use of a washing machine results in 7% higher CO_2 emissions.

The relation between all alternatives (D, PL and D/PL) is shown in Figure 49 using Equation 2.2 (refer to Chapter 2.3.3.4).

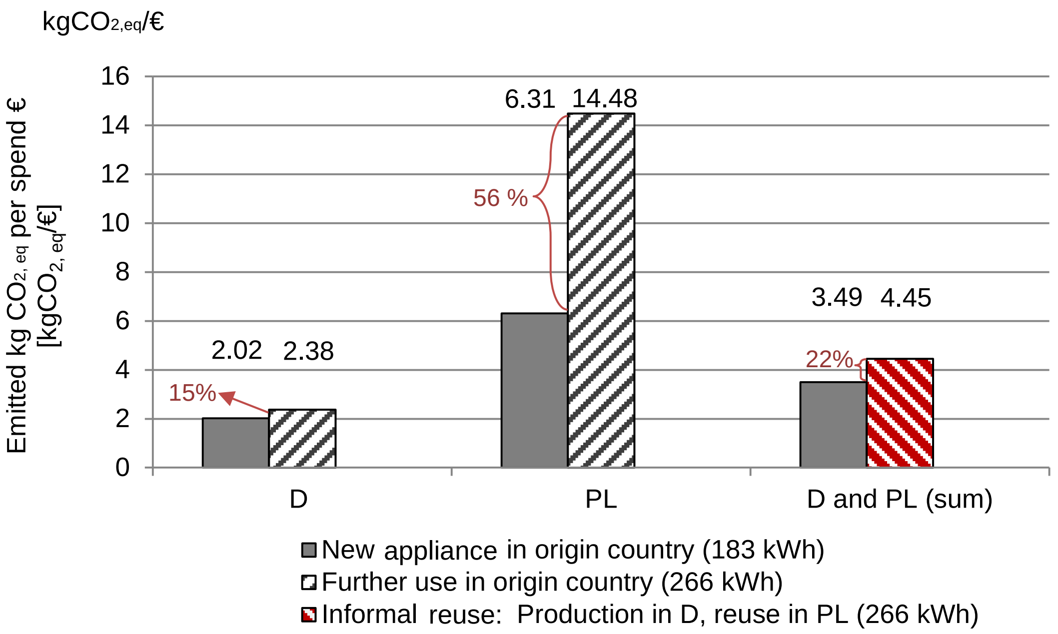


Figure 49: Emitted kg CO_2 per spend € for energy consumption, washing machine

The highest CO_2 emissions at the same spend-cost unit are produced through the further use of a washing machine in Poland. In comparison to a new production of a washing machine, 56% higher CO_2 emissions result. The further use of a washing machine causes 15% higher CO_2 emissions per spend-cost unit in Germany. Informal reuse results in higher CO_2 emissions (22%) per spend-cost unit.

As outlined in Chapter 4.3.2, higher CO_2 emissions in the Polish further use scenario are based on the high emission factor of 1.19 kg $CO_{2,\,eq}$ per kilowatt hour. The reuse (informally collected) achieves a good performance regarding the relation between spend-costs and the emitted CO_2 amount. This, moreover, implies environmental advantages in comparison to new acquisition and usage of a washing machine in Poland. No advantages therefore appear if an old German washing machine is reused in Poland as it already has a lower CO_2 accounting regarding the production and usage phase.

4.4.2 New production, further use and reuse: Television

The total life cycle costs of used televisions (100 kWh) are lower in each scenario than the total life cycle costs of new televisions (78 kWh). This is due to a difference in the energy demand of only 22 kWh per year. Figure 50 displays the total life cycle costs of the considered television considering all scenarios.

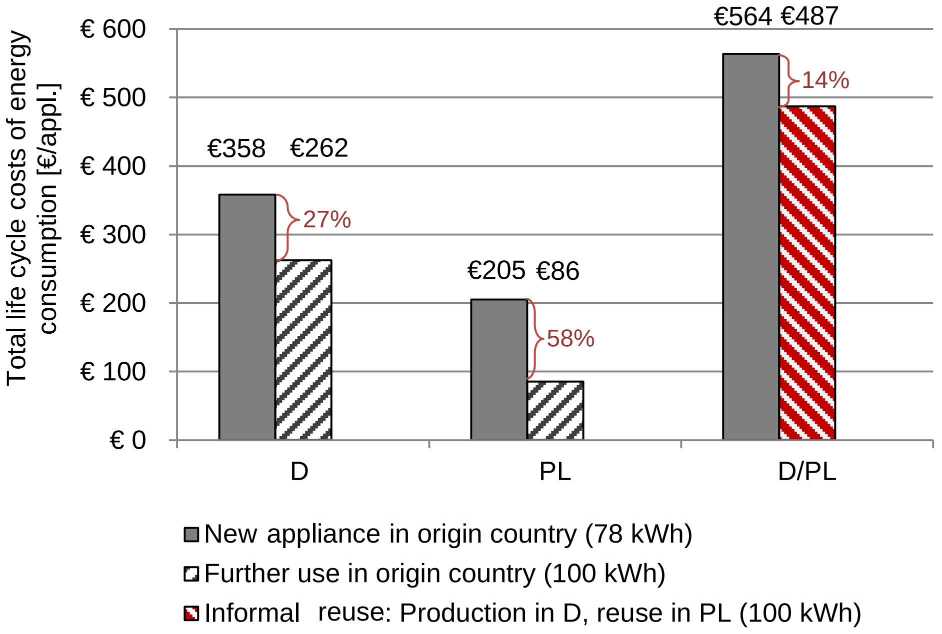


Figure 50: Total life cycle costs for energy consumption, television

The lowest total life cycle costs (€86) arise considering the further use of a television equipped with CRT technology in Poland. The difference of 58% is mainly explained by the missing production costs of the LCD television. Only a low influence is caused by the energy costs per kilowatt hour at the household level (refer to Chapter 4.3.2.) and the costs of the treatment of the appliance. The further use of a television with CRT technology results in 27% less costs in Germany, which is nearly half the cost savings of the Polish scenario. The higher energy consumption of 22 kWh of the old television has a higher influence on total costs of the usage phase based on higher energy costs per kilowatt hour at the household level of €0.24 per kWh in comparison to €0.07 per kWh in Poland. The lowest cost reduction of 14% appears within the informal reuse scenario, which is mainly based on high production costs and costs of the usage phase of €397 in Germany, representing nearly 80% of the total life cycle costs. The Polish reuse and disposal phase only accounts for 20%.

The lower CO_2 emissions of 31% and 13 % can be recognised regarding the further use of a CRT technology-based television in Germany and Poland. It is based on high CO_2 emissions during production, which are not covered by the higher energy efficiency of new products and consequently less resulting CO_2 emissions (Figure 51).

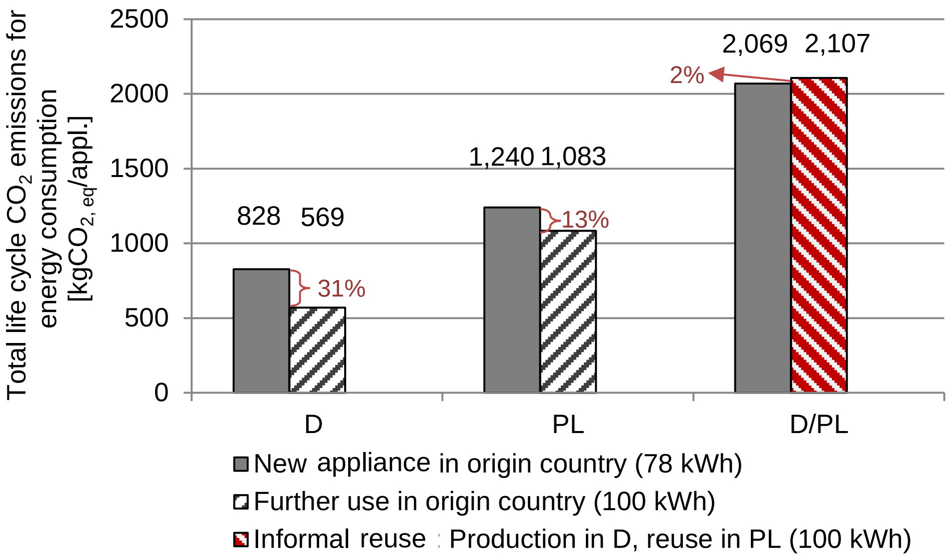


Figure 51: Total life cycle CO_2 emissions for energy consumption, television

The reuse scenario (informally collected) shows slightly higher CO_2 emissions (2%) than the production and usage of a new appliance in both countries. This is explained by emerging emissions during production and high dependency on fossil fuels in the Polish energy sector.

The ‘new appliance’ and ‘reuse’ scenario in Germany are compared regarding both economic and environmental performance (Figure 52).

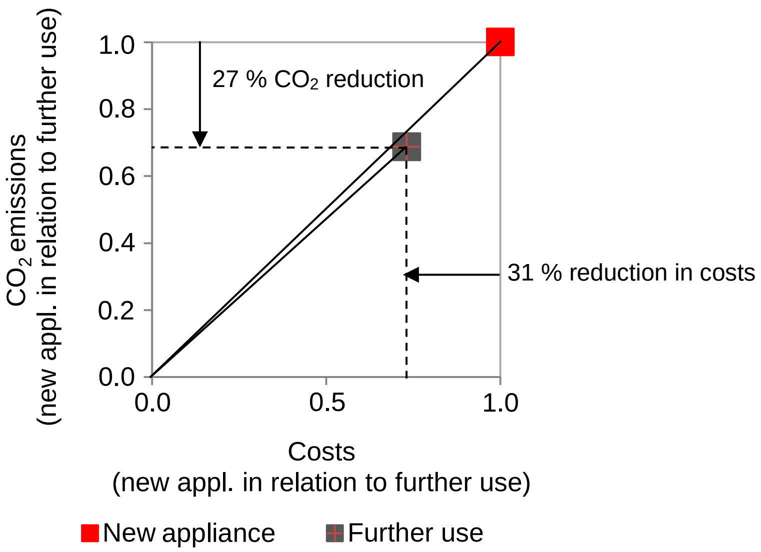


Figure 52: Relation of costs and CO_2 emissions of energy consumption, television

Figure 52 shows that the further use of a television results in 27% less total CO_2 emissions and 31% less total costs for energy supply. For a comparison of all alternatives, the costs and emissions resulting are put into relation according to Equation 2.2 (Figure 53).

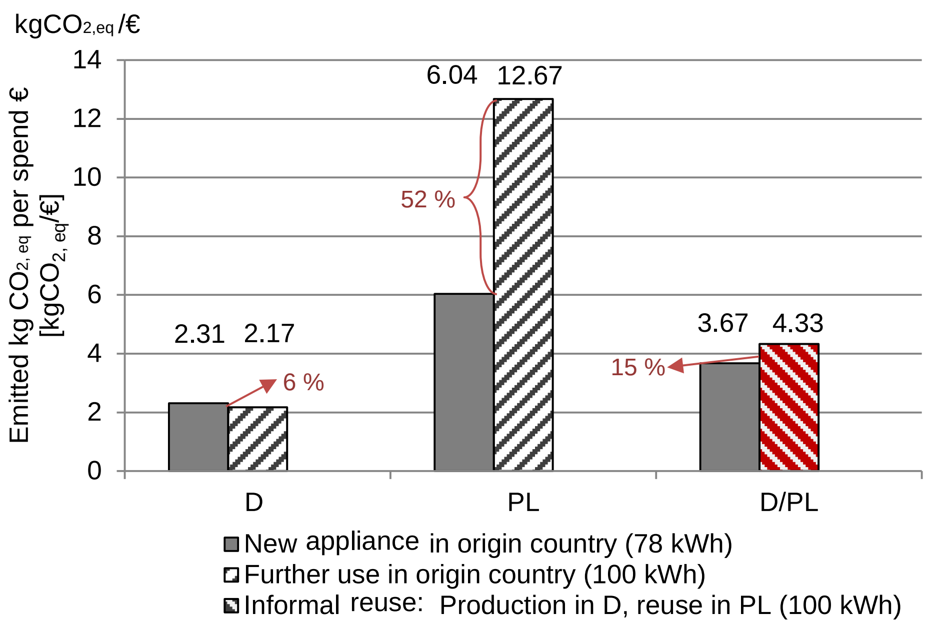


Figure 53: CO_2 emissions per spend-cost unit for energy consumption, television

The lowest CO_2 emissions per cost of 2 kg $CO_{2,\ eq}$ per spend-cost unit (€) arise regarding the further use of a television in Germany. A decrease of 6% is recognisable in comparison to new television production and usage. The highest CO_2 emissions are allocated to the further use of a television in Poland. This amounts to almost 13 kg $CO_{2,\ eq}$ per spend-cost unit (€) and is in accordance with an increase of 52% in comparison to new appliance production and usage. The same reasons as mentioned above for the washing machine also apply here (Figure 53).

The reuse scenario is characterised through a doubling in the amount of CO_2 emissions in comparison to the German further use and new production of a television. Nevertheless, it forms a suitable alternative to the Polish further use and new production of a television. Similarly to the washing machine, the dependency on fossil fuels is a decisive factor considering high CO_2 emissions in Poland.

4.4.3 Sensitivity analysis

Based on assumptions made in the beginning, most of the influencing factors such as emission factor, energy demand of product, energy demand of production, higher energy costs and higher production costs are subject to a sensitivity analysis. Consequently, a sensitivity analysis for a washing machine is conducted. The results only differ marginally regarding conclusions considering a television. The sensitivity is applied to the reuse case and the corresponding case of new production and usage in Poland and Germany. The total CO_2 emissions and life cycle costs are taken into account, with a span of minus 30% to plus 30% to account for each parameter.

<u>Amending the life cycle costs</u>

Three parameters are analysed regarding their sensitivity:

- costs for treatment (€10.50 - €19.50 per washing machine)
- energy costs PL (€0.05 - €0.09 per kWh)
- production costs D and PL
  (€185 - €344 / €168 - €310 per washing machine)

Treatment and production costs are selected as assumptions to be used for the analysis based on missing data. Energy costs in Poland are subject to an future increase as the energy industry increasingly focuses on renewable energies [Polish Chamber, 2010]. Figure 54 displays the spans for the considered parameters.

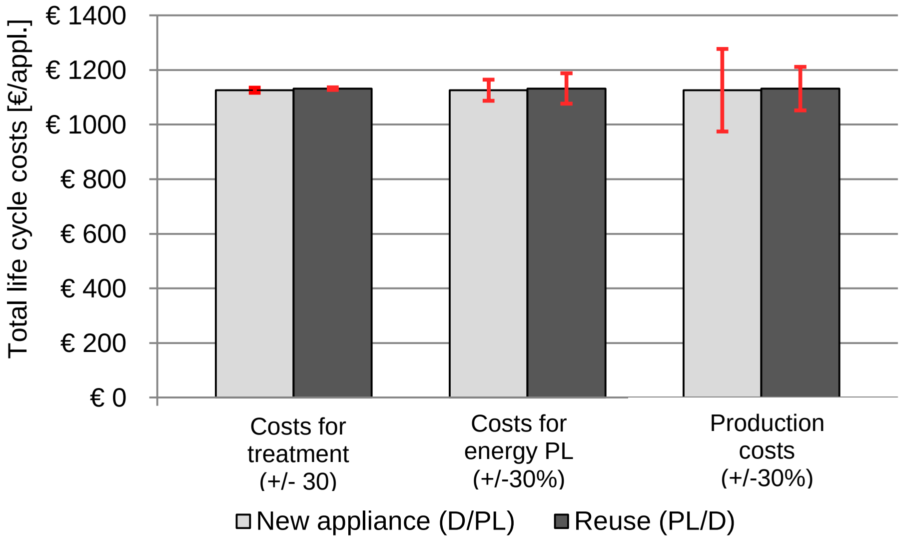


Figure 54: Sensitivity analysis of total life cycle costs

The sensitivity analysis shows that amending the treatment costs has a negligible influence on the total life cycle costs. Energy costs as well as production costs constitute major shares, whereas a fluctuation of treatment costs has no influence on the total result.

Regarding energy costs, an 2% annual increase of electricity costs at household level is already included in the analysis. As was stated in [GTAI, 2012], it is assumed that energy prices are subject to an increase based on necessary investments in high standard technologies and on participation in the emission trade starting in 2013. Higher energy prices of €0.09 per kilowatt hour have a higher influence on the reuse scenario as the used washing machine is assumed to consume more energy. It leads to an increase of €39 for the usage of a new appliance and an increase of €56 for reuse. This amount is negligible In comparison to the total life cycle costs.

The biggest influence can be expected if production costs fluctuate. Thereby higher production costs have a higher influence on the 'new appliance' scenario as production costs are doubly counted (both in Germany and in Poland). This implies that higher production costs have a positive influence on the reuse scenario as costs are saved proportionally.

Amendment of CO_2 emissions

The sensitivity analysis considers three different parameters:

- energy consumption of old appliance (180 - 340 kWh per year per washing machine)
- energy consumption of production (275 – 511 kWh per washing machine)
- Energy mix PL (0.8 - 1.5 kg $CO_{2, eq}$ / kWh)

Fluctuating energy consumptions are chosen, as the performance of washing machines is highly dependent on the type, quality and age of the considered product. The energy mix, and emission factor, respectively in Poland may decrease in the future as the energy industry is developing towards a sustainable energy supply. The energy consumption of production is subject to a sensitivity analysis as information is taken from literature and may change due to boundary conditions (type of technology, used material, etc.). Figure 55 illustrate the results of the sensitivity analysis.

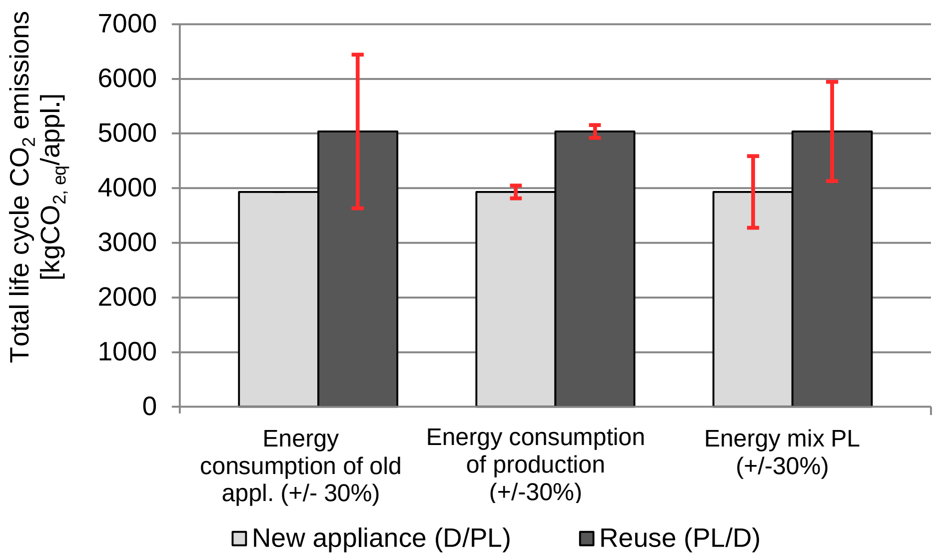


Figure 55: Sensitivity analysis of total CO_2 emissions

Significant influences are caused by amending the energy demand of old washing machines. In the considered boundary conditions, it can lead to higher efficiency in the reuse scenario. Nevertheless, it can be assumed that used washing machines have annual consumption ranges exceeding 200 kWh. In future, these demands may decrease, which will support the reuse scenario.

Only a minor effect is recognisable through the fluctuation of energy consumption during the production. Furthermore, it has no influence regarding the altering relation between both the production of a new product and reuse of a product (informal collection). Higher energy demand of production is not assumed as company data based on annual management reports is in line with the considerations made [Miele, 2004, Bosch 2011].

A significant influence on the considered system is recognised by amending the emission factors. For the current system, it is considered that the Polish emission factor decreases by some 30% (0.08 kg $CO_{2,\ eq}$ / kWh), which results in a decrease of emissions of 900 kg $CO_{2,\ eq}$ in the considered time horizon. Nevertheless, the decrease of emission factor applies to both the new appliance and reuse scenarios, whereas no influences result for the relation between them.

5 CONCLUSION AND OUTLOOK

This thesis analyses the characteristics, transhipped amounts, economic and environmental effects as well as the eco-efficiency of informal sector activities originating from eastern European countries. Informal collectors tranship electrical and electronic products as well as WEEE to destination countries, such as Poland, and resale collected items at flea markets.

A survey of waste management associations affected showed that a majority of informal collectors originate from Poland, Czech Republic, Hungary and Romania. Informal collection is recognised throughout Germany. Thereby mainly electrical and electronic appliances as well as WEEE are collected, but bulky waste, such as carpets, furniture and kitchen utensils, are also extracted.

Investigations of transhipped WEEE revealed an annual amount of 31,500 to 132,400 tons transported to Eastern European countries across the entire eastern border of Germany. It verifies estimations of [Janz et al., 2009] of 36,000 tons to 122,000 tons of transhipped WEEE per year. The annual average amounts to 77,000 tons. It complies with an informally transhipped amount of 6% of the total launched products. Transhipped fractions add up to 15,000 to 63,000 tons of ferrous metals, 10,000 to 40,000 tons of plastics and 3,000 to 9,000 tons of non-ferrous metals.

Thereby informal activities cause different economic influences. It may be stated that decrease in costs result if total costs are higher than delivery revenues received at recycling facilities considering the perspective of producers. This is true for collection groups 2, 3a, 3b and 5. Missing amounts collected by the informal sector result in decreasing costs of transportation, pick-up requests and provision orders. Strong determinants of the outcome are the amount of fixed costs, particularly guarantees and market prices of valuable materials. The increase in market prices and thus delivery revenues of more than 1% and 12.5% of collection groups 3b and 5 would have caused revenues in the considered system without informal collection. The informal collection of collection group 1 results in losses of up to 14% for the considered producer. High delivery revenues and low fixed costs per ton result in overall revenues per ton. Therefore either the positive net total of one ton of WEEE displays the loss caused by informal sector activities, or cost savings based on less

WEEE available for treatment constitutes a benefit for producers. The same applies to waste management associations considering § 9 (6), ElektroG. Conversely, informal collection results in cost savings for waste management associations if the collection and storage of WEEE is accomplished in accordance with § 9 (3), ElektroG.

Informal reuse activities lead to cost savings considering private households. The acquisition costs of new appliances (washing machine and television) cannot cover the costs of the higher energy consumptions of the old items. The amortisation point was beyond the considered time horizon of ten years, which is in line with considerations made by [Rüdenauer et al., 2005] and [Pertl et al., 2010]. Amortisation of CO_2 emissions was partially achieved in Germany and Poland considering the washing machine and television. Thereby the results are strongly dependent on the energy demands of devices and the applied emission factor, the latter fluctuating within literature information.

The ratio between economic and environmental performance regarding energy consumption revealed that informal reuse activities achieve a higher environmentally sound performance in comparison to the further usage of considered devices in Poland. Exemplarily, specific CO_2 emissions of 4.33 kg $CO_{2,\ eq}$ per spend-cost unit (€) regarding the reuse (collection in Germany, reuse in Poland) of a television contrast with 12.67 kg $CO_{2,\ eq}$ per spend-cost unit (€) of further use of same appliance in Poland. This corresponds to around 70% higher CO_2 emissions per spend-cost unit (€) for both television and washing machine. Conversely, further use in Germany results in 30% and 50% less CO_2 emissions per spend cost unit (€) regarding television and washing machine in comparison to the reuse scenario.

In summary, it can be stated that reuse conducted by informal sector activities can indeed have a positive effect. Future electrical and electronic products available for reuse already have lower energy consumptions, whereas a positive contribution to resource protection is achieved while prolonging the already short life cycles of appliances. Taking into account a dependency on collections with respect to their income, a pure ban of informal sector activities would be socially counterproductive. A structured and controlled accomplishment of informal collection would open up new opportunities to enlarge the (already existing) concept of reuse on an international level.

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APPENDIX

A1 Fees, treatment costs, probable return rate and average lifetime of appliances defined by EAR foundation

Table A1 - 1: Fees according to ElektroGKostV [Annex 1, ElektroGKostV]

Nr.	Legal fees for producers	Fee in €
1	***Registration***	
1.01	Registration (per producer, first brand as well as first type of appliance)	€64
1.02	Further registration (per producer, further brand and further type of appliance)	€35
1.03	Updating of data of amounts regarding existing registrations according to 1.01 and 1.02 (per update)	€43
1.04a	Full audit of guarantee per producer (per audit)	€129
1.04b	Full audit of guarantee based on a prior controlled producer guarantee system (per audit)	€118
1.04c	Extension of controlled guarantee to another type of appliance according to 1.04 a and 1.04b (per extension)	€37
1.04d	Change and annual update of a guarantee considering constant type of appliance (per change, update)	€83
1.04e	Change of other guarantee data (per change)	€35
1.04f	Audit of justification according to § 6 (3) sentence 2, ElektroG (per registration)	€107
1.05	Other change of data of registration (per change)	€21
1.06	Special effort for data transfer on a not digital basis (per process)	€28 – €400
1.07	Creation of certificate about obligation of registration	€28 – €7,500
2	***Provision order (per provision order)***	**€20**
3	***Pick – up request (per pick- up request)***	**€25**
4	***Sanction***	
4.01	Order of increase of guarantee	€28
4.02	Revocation of registration	Up to 75% of fee according to No. 1

Table A1 - 2: Return rates, average lifetime and average treatment costs of WEEE [Regelsetzung 02-003, 2012]

CG	Category	Type of appliance	Prob. return rate [%]	average lifetime [month]	average treatment costs [€/t]
1	Automatic Dispensers (10)	Automatic dispenser for application at private households	15%	96	€20.00
	Large Household Appliances (1)	Other large HH appliances for usage in private HH	50%	120	
2	Large Household Appliances (1)	Cooling appliances, climate appliances, oil radiator	75%	120	€220.00
3	IT and Telecommunications Equipment (3)	private data processing appl.	27%	84	€230.00
		private telecommunication appl.	27%	84	
		private printing of data and transfer of printed data	27%	84	
		cameras (photo)	27%	84	
		Mobiles	27%	84	
		Monitors	33%	96	
	Consumer Equipment (4)	TV- appliances	50%	120	
		Other appl. Of consumer equipment	50%	60	
5	Small Household appliances (2)	SHA for usage in private HH	40%	60	€170.00
	Electrical and Electronic Tools (6)	Electrical and electronic tools for usage in private HH	12%	60	
	Toys, Sports and Leisure Equipment (7)	Toys for usage in private HH	7%	120	
		Sports and leisure Equipment for usage in private HH	7%	120	
	Medical Products (8)	Medical products for usage in private HH	5%	60	
	Monitoring and Control Instruments (9)	Monitoring and Control Instruments for usage in private HH	35%	96	

HH = Household, CG = Collection group, Prob. = probable

A2 Trends of gate fees of collection groups at recycling facilities

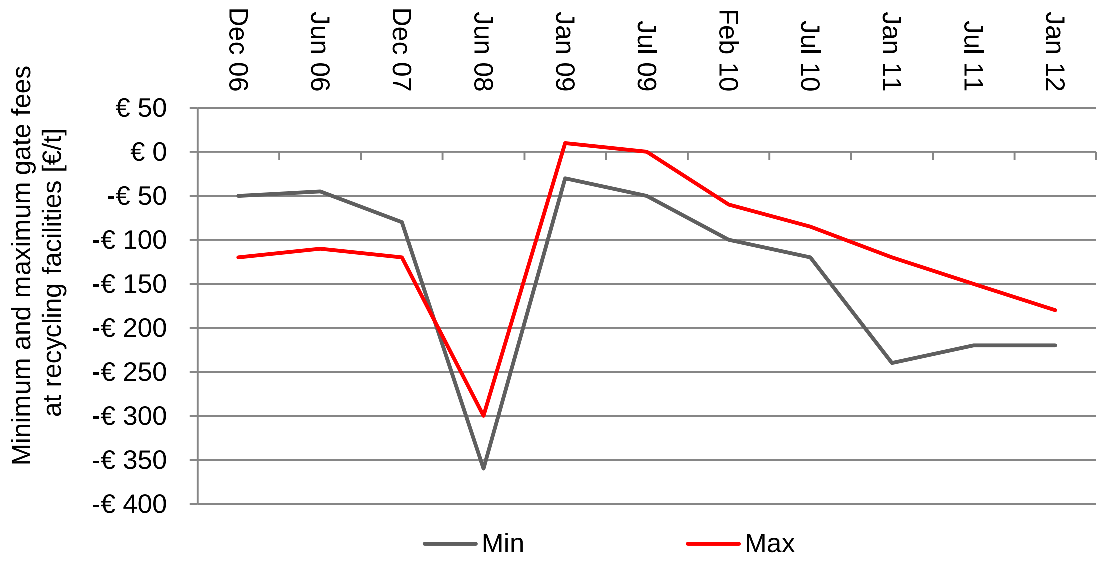

Figure A2 - 1: Trend of gate fees of WEEE collection group 1 (€/t) [EUWID, 2007-2012]

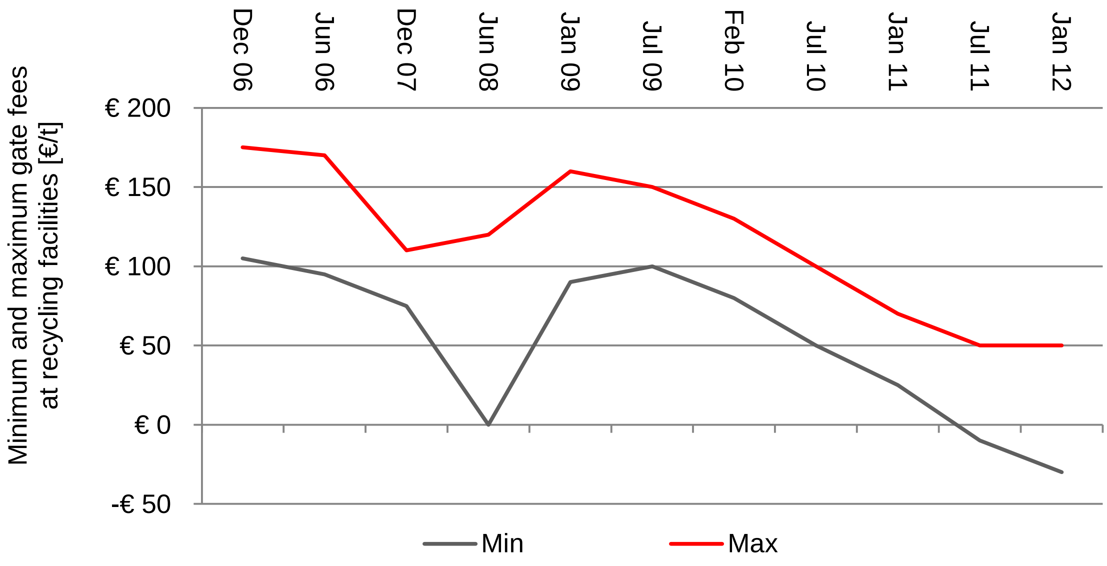

Figure A2 - 2: Trend of gate fees of WEEE collection group 2 (€/t) [EUWID, 2007-2012]

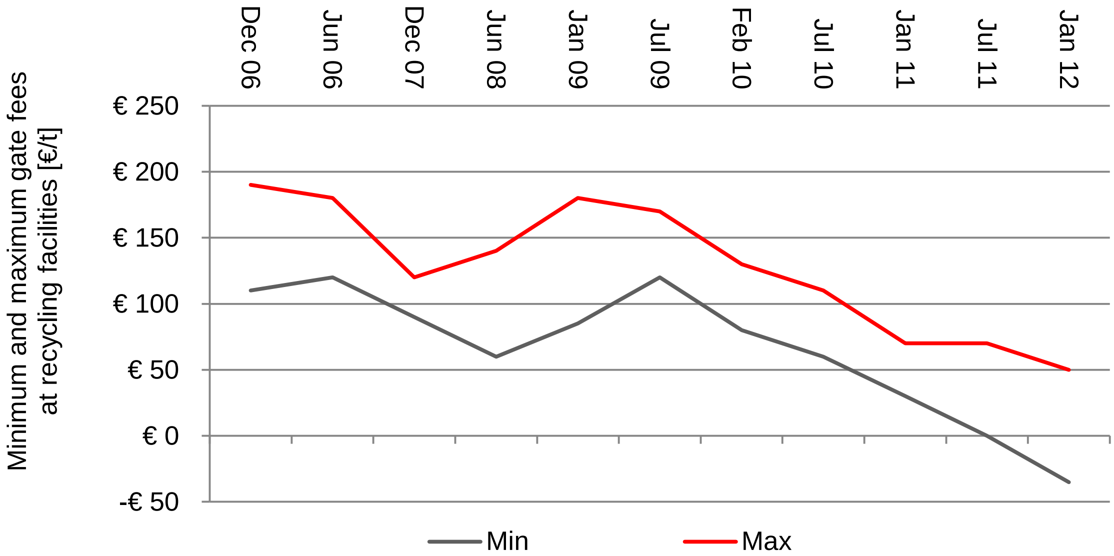

Figure A2 - 3: Trend of gate fees of WEEE collection group 3a (€/t) [EUWID, 2007-2012]

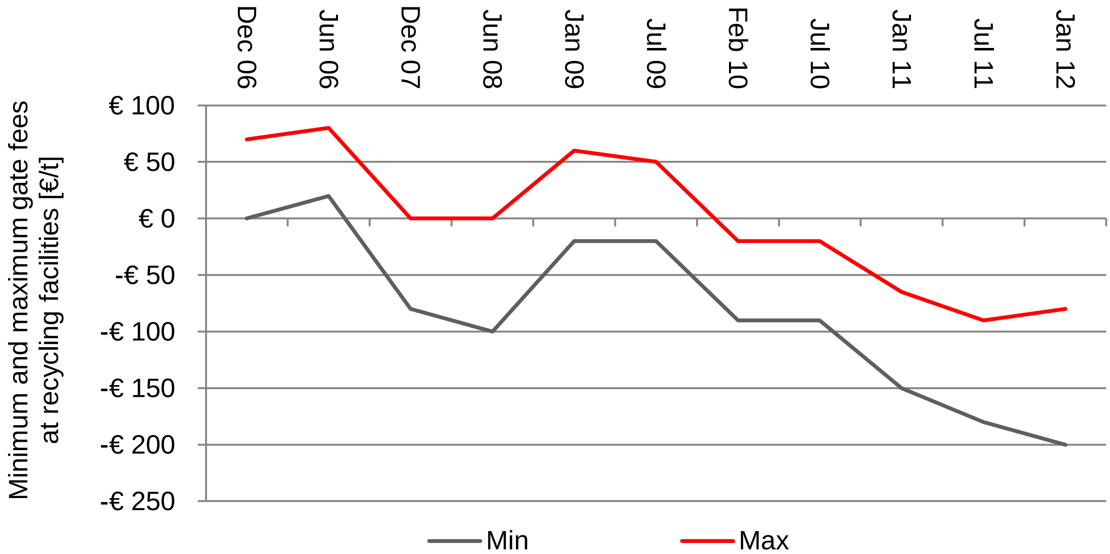

Figure A2 - 4: Trend of gate fees of WEEE collection group 3b (€/t) [EUWID, 2007-2012]

A3 Probability factors of counted vehicles

The probability factor is the quotient of controlled vehicles transporting informal collected items and total controlled vehicles [Linzner et al., 2011; Lange et al., 2011].

Table A3 - 1: Probability factors of counted vehicles [Lange et al., 2011]

Type of vehicle	Probability level	Probability factor		
		Only vehicle	Vehicle with small trailer	Vehicle with large trailer
Passenger car	> 90%	95 %	95 %	95 %
Small van	> 90%	95 %	95 %	95 %
	10 – 90%	32 %	32 %	32 %
	< 10%	0 %	0 %	0 %
Large van	> 90%	95 %	95 %	95 %
	10 – 90%	30 %	30 %	30 %
	< 10%	0 %	0 %	0 %
Flatbed truck (covered or uncovered)	> 90%	95 %	95 %	95 %
	10 – 90%	3 %	3 %	3 %
	< 10%	0 %	0 %	0 %

A4 Transhipped volumes per hour and border crossing

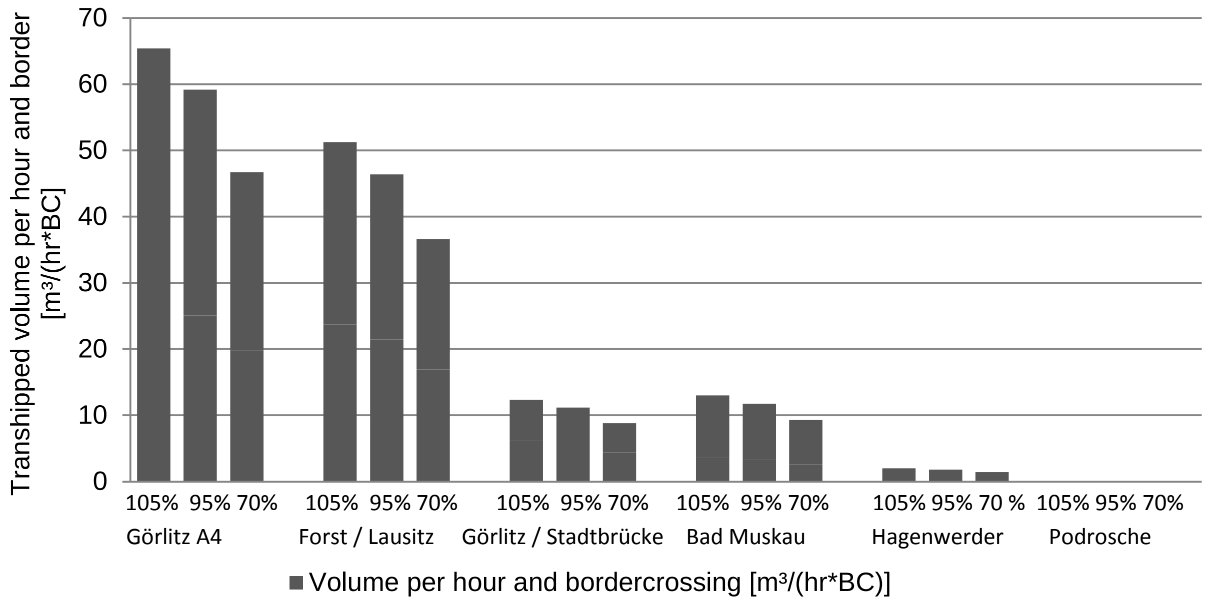

Figure A4 - 1: Transhipped volume per hour and border crossing (BC)

A5 Daily, weekly and seasonal correction factor

a) Daily correction factor (DCF)

Table A5 - 1: Basis of daily correction factor

Hour	Transhipped m³/hour	Percentage of transhipment
10 am – 11 am	12	16 %
11 am – 12 am	24	33 %
12 am – 1 pm	39	52 %
1 pm – 2 pm	52	70 %
2 pm – 3 pm	50	68 %
3 pm – 4 pm	54	73 %
4 pm – 5 pm	**74**	**100 %**
5 pm – 6 pm	60	81 %
6 pm – 7 pm	64	87 %
7 pm – 8 pm	62	84 %
23 pm – 7 am	0	0% (assumption)
7 am – 10 am	4	5% (assumption)
20 pm – 23 pm	15	20%(assumption)
Correction factor (DCF)		**739 %**

b) Weekly correction factor (WCF)

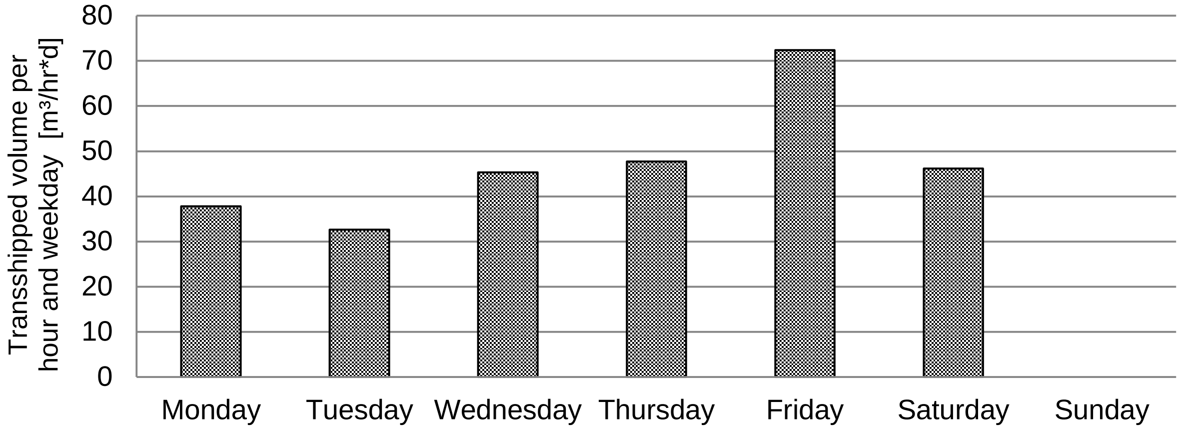

Figure A5 - 1: Basis of weekly correction factor I; transhipped volume per hour and weekday

Table A5 - 2: Basis for weekly correction factor II; Percentage of transhipped volume per hour and weekday

	MO	TUE	WED	THU	**FRI**	SAT	SUN	**WCF**
m³/hour* weekday	38	33	45	48	**72**	46	-	**-**
Percentage	15 %	13 %	60 %	76 %	**100 %**	77 %	0%	**340%**

c) Seasonal correction factor (SCF)

Table A5 - 3: Collected WEEE (all CGs) of the city of Dresden in tons per month (Statistics SRD, 2012)

TOTAL	Year 2008	Year 2009	Year 2010	Year 2011
Jan	599.81	483.76	469.48	653.64
Feb	528.22	550.33	589.83	622.90
Mar	588.46	790.05	851.38	863.87
Apr	655.94	868.58	870.12	822.99
May	738.73	732.1	754.67	796.66
Jun	541.06	724.43	702.74	659.80
Jul	592.33	801.98	747.40	759.91
Aug	589.00	724.40	808.63	787.06
Sep	610.55	775.63	758.73	726.71
Oct	601.52	745.03	807.52	733.71
Nov	562.45	769.94	717.00	727.77
Dec	454.12	600.80	343.87	609.65
Total	7062.19	8567.03	8421.37	8764.67

Figure A5 - 2: Curse of collected WEEE of city of Dresden in the years 2008 - 2011

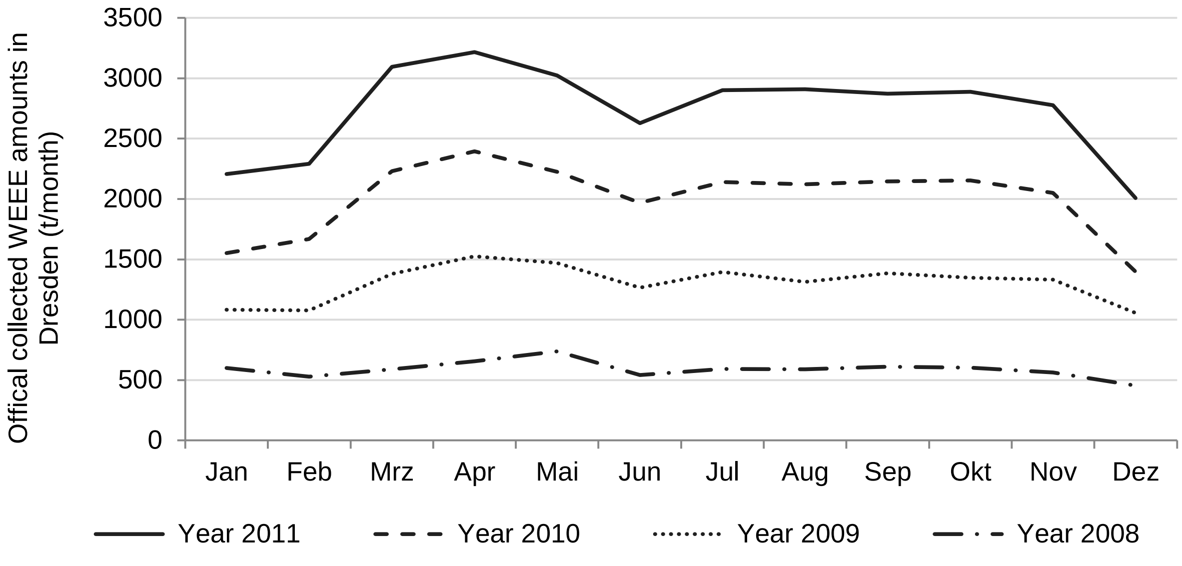

Table A5 - 4: seasonal correction factor based on statistic of collected WEEE of SRD

Jan	Feb	Mar	**Apr**	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**SCF**
69%	71%	96%	**100%**	94%	82%	90%	90%	89%	90%	86%	62%	**1020%**

A6 Transhipped volume per hour and border crossing

Table A6 - 1: Allocation of transhipped volume per hour and border crossing to considered border crossings along the eastern German border

Type of road	No. of road	Name of Border crossing / nearest city	Vol per hour [m³/h] 105%	Vol per hour [m³/h] 95%	Vol per hour [m³/h] 70%	tons trans. per year [m³/a] 105%	tons trans. per year [m³/a] 95%	tons trans. per year [m³/a] 75%
State road	115	Hintersee	1	1	1	1,032	934	688
Federal highway	104	Löcknitz	11	10	7	11,110	10,052	7,406
Highway	11	Nadrensee	101	91	67	103,590	93,724	69,060
Federal highway	2	Rosow	11	10	7	11,110	10,052	7,406
Federal highway	113	Staffelde	11	10	7	11,110	10,052	7,406
Federal highway	166	Schwedt/Oder	11	10	7	11,110	10,052	7,406
State road	283	Hohenwutzen	1	1	1	1,032	934	688
Federal highway	1	Küstriner Vorland	11	10	7	11,110	10,052	7,406
State road	5	Frankfurt/Oder	11	10	7	11,110	10,052	7,406
Highway	5	Frankfurt/Oder	101	91	67	103,590	93,724	69,060
Federal highway	320	Guben	11	10	7	11,110	10,052	7,406
Federal highway	97	Schlagsdorf	11	10	7	11,110	10,052	7,406
Federal highway	112	Forst/Lausitz	11	10	7	11,110	10,052	7,406
Highway	15	Forst/Lausitz	101	91	67	103,590	93,724	69,060
Federal highway	115	Bad Muskau	11	10	7	11,110	10,052	7,406
State road	8140	Podrosche	1	1	1	1,032	934	688
Highway	4	Görlitz/Ludwigsdorf	101	91	67	103,590	93,724	69,060
State road	125	Görlitz	11	10	7	11,110	10,052	7,406
State road	128	Hagenwerder	1	1	1	1,032	934	688
Federal highway	99	Hirschfelde	11	10	7	11,110	10,052	7,406
State road	146	Zittau	1	1	1	1,032	934	688
State road	132a	Zittau	1	1	1	1,032	934	688
State road	132	Luftkurort Lückendorf	1	1	1	1,032	934	688

State road	8641	Hain	1	1	1	1,032	934	688
State road	8651	Hain	1	1	1	1,032	934	688
State road	135	Großschönau	1	1	1	1,032	934	688
State road	141	Seiffenhennersdorf	1	1	1	1,032	934	688
State road	139	Seiffenhennersdorf	1	1	1	1,032	934	688
State road	148	Neuwalde	1	1	1	1,032	934	688
Federal highway	96	Ebersbach	11	10	7	11,110	10,052	7,406
State road	116	Sohland	1	1	1	1,032	934	688
State road	not named	Neudorf	1	1	1	1,032	934	688
State road	not named	Langburkersdorf	1	1	1	1,032	934	688
State road	154a	Sebnitz	11	10	7	11,110	10,052	7,406
Federal highway	172	Schmilka	11	10	7	11,110	10,052	7,406
State road	171	Hellendorf	1	1	1	1,032	934	688
Highway	17	Liebstadt	101	91	67	103,590	93,724	69,060
State road	not named	Fürstenau	1	1	1	1,032	934	688
State road	9033	Zinnwald	1	1	1	1,032	934	688
State road	184	Rehefeld - Zaunhaus	1	1	1	1,032	934	688
State road	211	Cämmerswald	1	1	1	1,032	934	688
State road	213	Seiffen	1	1	1	1,032	934	688
State road	214	Deutschneudorf	1	1	1	1,032	934	688
State road	not named	Rübenau	1	1	1	1,032	934	688
Federal highway	174	Reitzenhain	11	10	7	11,110	10,052	7,406
State road	not named	Jöhstadt	1	1	1	1,032	934	688
Federal highway	95	Bärenstein	11	10	7	11,110	10,052	7,406
State road	not named	Hammerunterwiesenthal	1	1	1	1,032	934	688
State road	not named	Oberwiesenthal	1	1	1	1,032	934	688
Federal highway	95	Oberwiesenthal	11	10	7	11,110	10,052	7,406
State road	not named	Breitenbrunn	1	1	1	1,032	934	688
State road	272a	Johanngeorgenstadt	1	1	1	1,032	934	688

State road	not named	Klingenthal	1	1	1	1,032	934	688
Federal highway	283	Klingenthal	11	10	7	11,110	10,052	7,406
State road	7841	Wernitzgrün	1	1	1	1,032	934	688
State road	not named	Bad Brambach	1	1	1	1,032	934	688
Federal highway	92	Schönberg	11	10	7	11,110	10,052	7,406
State road	7843	Reuth	1	1	1	1,032	934	688
State road	7843	Bad Elster	1	1	1	1,032	934	688
State road	308	Ebmath	1	1	1	1,032	934	688
State road	2179	Wildenau	1	1	1	1,032	934	688
Federal highway	303	Schirnding	11	10	7	11,110	10,052	7,406
Federal highway	299	Egerteich	11	10	7	11,110	10,052	7,406
State road	2167	Mähring	1	1	1	1,032	934	688
State road	2173	Bärnau	1	1	1	1,032	934	688
State road	2154	Frankenreuth	1	1	1	1,032	934	688
Highway	6	Waidhaus	101	91	67	103,590	93,724	69,060
State road	2155	Eslarn	1	1	1	1,032	934	688
State road	2146	Waldmünchen	1	1	1	1,032	934	688
Federal highway	20	Fürth	11	10	7	11,110	10,052	7,406
State road	2140	Eschkalm	1	1	1	1,032	934	688
State road	44	Rittsteig	1	1	1	1,032	934	688
Federal highway	11	Bayrisch Eisenstein	11	10	7	11,110	10,052	7,406
State road	2127	Mauther Forst	1	1	1	1,032	934	688
Federal highway	12	Phillipsreuth	11	10	7	11,110	10,052	7,406
State road	2130	Haidmühle	1	1	1	1,032	934	688
TOTAL					[m³/a]	945,719	855,650	630,479

A7 Official collected amounts per pick-up requests

Table A7 - 1: Pick-up requests, collected amounts and tons per pick up request per collection group in 2009, 2010 and 2011 [EAR, 2012]

Pick-up requests	CG1 (pick-up's)	CG2 (pick-up's)	CG3 (pick-up's)	CG5 (pick-up's)	TOTAL
2009	3,755	42,130	35,127	6,426	87,438
2010	3,478	39,979	37,442	6,610	87,509
2011	2,970	39,372	35,049	5,819	83,210
Average	3,401.0	40,493.7	35,872.7	6,285.0	86,052.3
Collected amount	CG1 (t)	CG2 (t)	CG3 (t)	CG5 (t)	TOTAL
2009	11,688	106,297	196,122	30,379	344,486
2010	14,000	110,228	277,071	45,503	446,802
2011	15,504	116,838	202,544	34,563	369,449
Average	13,730.7	111,121.0	225,245.7	36,815.0	386,912.3
Percentage of average	4%	29%	58% (2x29%)	8%	
Tons per pick-up request	CG1 (t/pick-up)	CG2 (t/pick-up)	CG3 (t/pick-up)	CG5 (t/pick-up)	
2009	3.1	2.5	5.6	4.7	
2010	4.0	2.8	7.4	6.9	
2011	5.2	3.0	5.8	5.9	
Average	4.1	2.7	6.3	5.9	

A8 Material composition of modelled scenarios

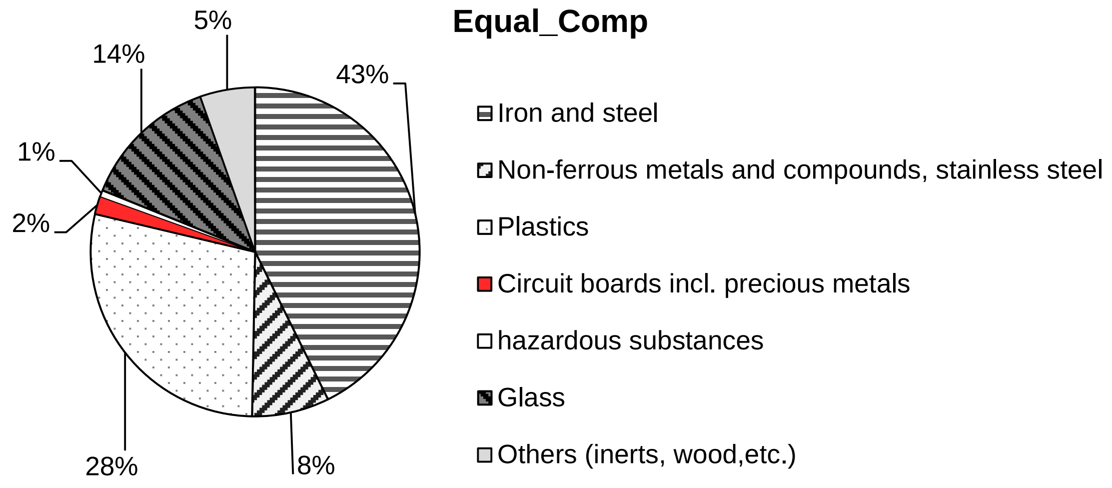

Figure A8 - 1: Material composition of Scenario Equal_Comp

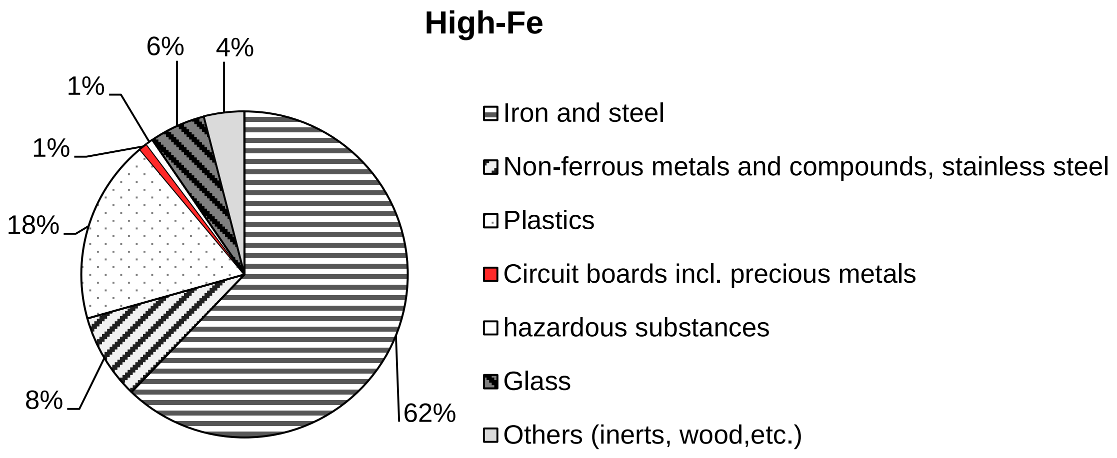

Figure A8 - 2: Material composition of Scenario High-Fe

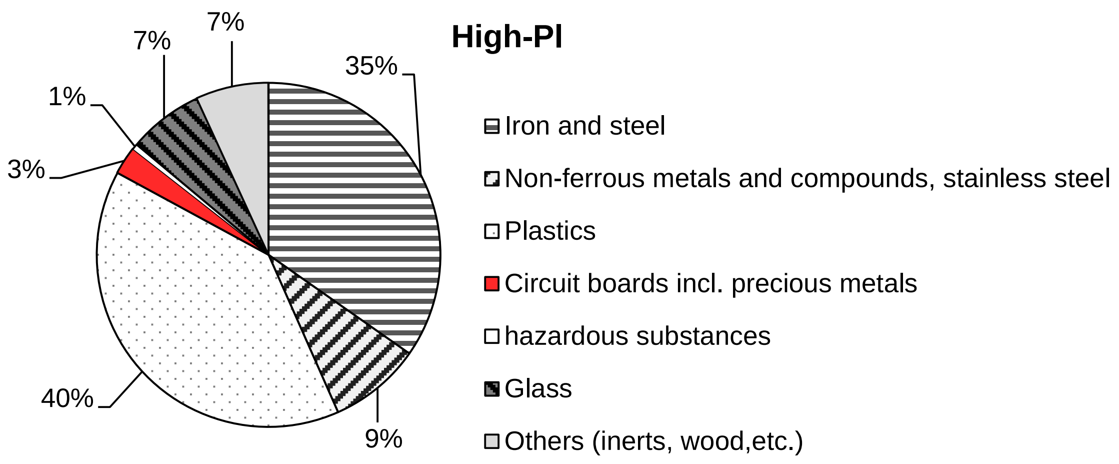

Figure A8 - 3: Material composition of Scenario High-Pl

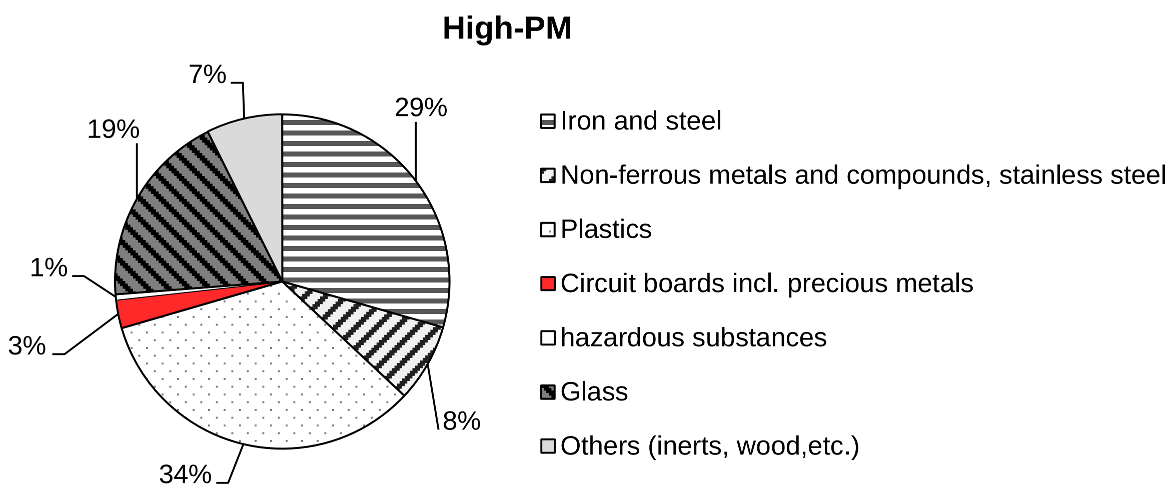

Figure A8 - 4: Material composition of Scenario High-PM

A9 Proportion of treatment duty and additional treatment amounts per producer

Formal collected WEEE amounts base on the official statistics of the EAR foundation and are displayed in table 20. It includes average data from 2009 to 2011.

Table A9 - 1: Official collected amounts per CG classified into Producer and WMA [EAR, 2012]

Formal collected WEEE per producer and WMA	Producers	WMAs	Producers + WMAs
CG1 (t/a)	13,731	83,860	97,590
CG2 (t/a)	111,121	3,498	114,619
CG3 (t/a)	225,246	69,323	294,568
CG5 (t/a)	36,815	76,163	112,978
Total	**386,912**	**232,844**	**619,756**
Percentage of total per producer and WMA	62.43%	37.57%	

Table A9 - 2: Proportion of treatment duty of producers

Formal collected WEEE per collection group [EAR, 2012]	Total formal collected WEEE	Producer treatment amount	%
Producer A, CG1 (t/a)	13,731	1,500	11%
Producer B, CG2 (t/a)	111,121	1,500	1%
Producer C, CG3a (t/a)	112,622	1,500	1%
Producer D, CG3b (t/a)	112,622	1,500	1%
Producer E, CG5 (t/a)	36,815	1,500	4%
Total	**386,912**		

Table A9 - 3: Calculation of additional amounts of producer according to modelled scenarios

		Formal amounts for treatment	Producer A (CG1)	Producer B (CG2)	Producer C (CG3b)	Producer D (CG3a)	Producer E (CG5)	TOTAL
	1	Total formal amount collected (table A9-1)	13,731	111,121	112,623	112,623	36,815	386,912
	2	Treatment obligation	1,500	1,500	1,500	1,500	1,500	
	3	Percentage of treatment obligation on total formal collected amount	11%	1%	1%	1%	4%	
		Formal and informal amounts for treatment						
Equal_Comp	4	Proportion of CGs of 'Equal_Comp', table 12	20%	20%	20%	20%	20%	
	5	Additional informal amount (% of 48,076 t/a (62.43%))	9,615	9,615	9,615	9,615	9,615	48,076
	6	Sum of total informal and formal amount (row 1+5)	23,346	120,736	122,238	122,238	46,430	434,989
	7	Percentage of treatment duty on total formal collected amount (row 3)	11%	1%	1%	1%	4%	
	8	**amount for treatment including informal amount (row 6*7)**	**2,550**	**1,630**	**1,628**	**1,628**	**1,892**	**9,328**
	9	Additional informal amount for treatment (row 8-2)	1,050	130	128	128	392	1,828
EAR	10	Proportion of CGs of 'EAR', table 12	4%	29%	29%	29%	10%	
	11	Additional informal amount, (% of 48,076 t/a (62.43%))	1,706	13,807	13,994	13,994	4,574	48,076
	12	Sum of total informal and formal amount (row 1+11)	15,437	124,928	126,617	126,617	41,389	434,989
	13	Percentage of treatment duty on total formal collected amount (row 3)	11%	1%	1%	1%	4%	
	14	**amount for treatment including informal amount (row 12*13)**	**1,686**	**1,686**	**1,686**	**1,686**	**1,686**	**8,432**
	15	Additional informal amount for treatment (row 14-2)	186	186	186	186	186	932
High_Fe	16	Proportion of CGs of 'High_Fe', table 12	45%	40%	5%	5%	5%	
	17	Additional informal amount, (% of 48,076 t/a (62.43%))	21,634	19,231	2,404	2,404	2,404	48,076
	18	Sum of total informal and formal amount (row 1+17)	35,365	130,352	115,027	115,027	39,219	434,989
	19	Percentage of treatment duty on total formal collected amount (row 3)	11%	1%	1%	1%	4%	
	20	**amount for treatment including informal amount (row 18*19)**	**3,863**	**1,760**	**1,532**	**1,532**	**1,598**	**10,285**
	21	Additional informal amount for treatment (row 20-2)	2,363	260	32	32	98	2,785

High_PI	22	Proportion of CGs of 'High_PI', table 12	5%	5%	40%	10%	40%	
	23	Additional informal amount, (% of 48,076 t/a (62.43%))	2,404	2,404	19,231	4,808	19,231	48,076
	24	Sum of total informal and formal amount (row 1+23)	16,134	113,525	131,853	117,430	56,046	434,989
	25	Percentage of treatment duty on total formal collected amount (row 3)	11%	1%	1%	1%	4%	
	26	**amount for treatment including informal amount (row 24*25)**	**1,763**	**1,532**	**1,756**	**1,564**	**2,284**	**8,899**
	27	Additional informal amount for treatment (row 26-2)	263	32	256	64	784	1,399
high_PM	28	Proportion of CGs of 'EAR', table 12	5%	5%	40%	30%	20%	
	29	Additional informal amount, (% of 48,076 t/a (62.43%))	2,404	2,404	19,231	14,423	9,615	48,076
	30	Sum of total informal and formal amount (row 1+29)	16,134	113,525	131,853	127,046	46,430	434,989
	31	Percentage of treatment duty on total formal collected amount (row 3)	11%	1%	1%	1%	4%	
	32	**amount for treatment including informal amount (row 30*31)**	**1,763**	**1,532**	**1,756**	**1,692**	**1,892**	**8,635**
	33	Additional informal amount for treatment (row 32-2)	263	32	256	192	392	1,135

A10 Distribution of cost items of variable and fixed costs

Table A10-1: Composition of variable and fixed costs of base case, displayed as proportion [%]

	Producer A (CG1)	Producer B (CG2)	Producer C (CG3a)	Producer D (CG3b)	Producer E (CG5)
Total specific variable costs	€34.00	€39.45	€30.27	€30.27	€30.77
Pick-up request	17.85%	23.05%	13.20%	13.20%	13.89%
Provision order	14.28%	18.44%	10.56%	10.56%	11.11%
Transportation costs to treatment facility	67.87%	58.50%	76.23%	76.23%	75.00%
Total specific fixed costs	€24.70	€441.36	€178.46	€146.26	€160.03
Fees for updating of guarantee (3 time/year)	0.23%	0.01%	0.03%	0.04%	0.04%
Fees for updating amount (1 time/year)	0.22%	0.01%	0.03%	0.04%	0.03%
internal administration (6 hours/month)	5.06%	0.28%	0.70%	0.85%	0.78%
EAR-guarantee costs	94.48%	99.69%	99.24%	99.07%	99.15%

A11 Costs and revenues for base case and modelled scenarios

Table A11 - 1: Specific costs and revenues of base case and modelled scenarios

Producer	Base case + Delivery costs	Base case + delivery revenues	Scenario	Modelled scenario + Delivery costs	Modelled scenario + delivery revenues
Producer A (CG1)	-€59	€90	Equal_Comp	-€49	€100
			EAR	-€56	€93
			High_Fe	-€44	€105
			High_Pl	-€55	€94
			High_PM	-€55	€94
Producer B (CG2)	-€531	-€451	Equal_Comp	-€496	-€416
			EAR	-€482	-€402
			High_Fe	-€466	-€386
			High_Pl	-€521	-€441
			High_PM	-€521	-€441
Producer C (CG3a)	-€259	-€174	EqComp	-€245	-€160
			EAR	-€239	-€154
			high-FM	-€255	-€170
			high-Pl	-€233	-€148
			high-PM	-€233	-€148
Producer D (CG3b)	-€227	-€37	EqComp	-€215	-€25
			EAR	-€210	-€20
			high-FM	-€223	-€33
			high-Pl	-€221	-€31
			high-PM	-€210	-€20
Producer E (CG5)	-€191	-€56	EqComp	-€158	-€23
			EAR	-€173	-€38
			high-FM	-€181	-€46
			high-Pl	-€136	-€1
			high-PM	-€158	-€23

A12 Net total of Producer A (CG1)

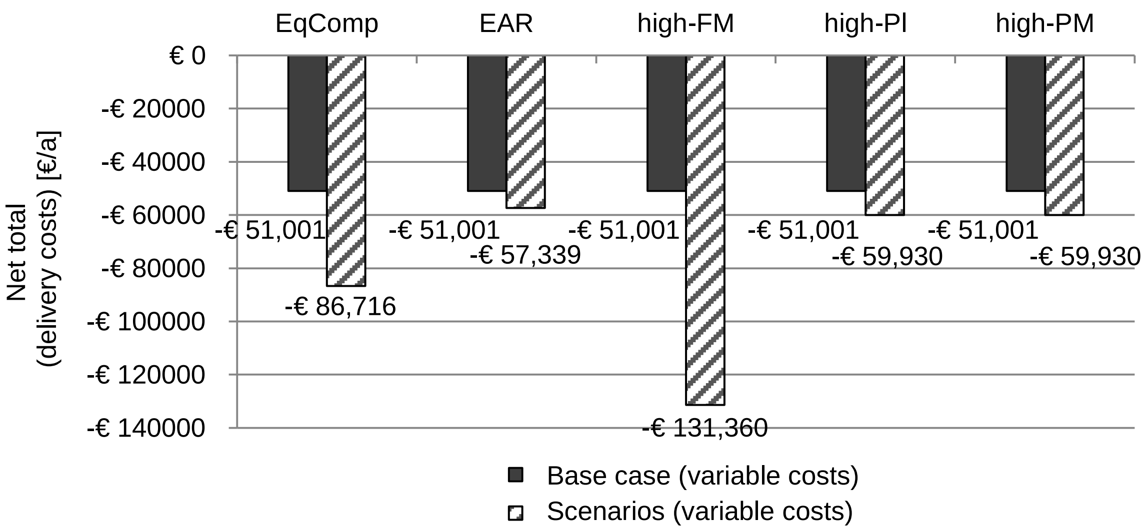

Figure A12 - 1: Comparison of net total of base case and scenarios, delivery costs (Prod. A)

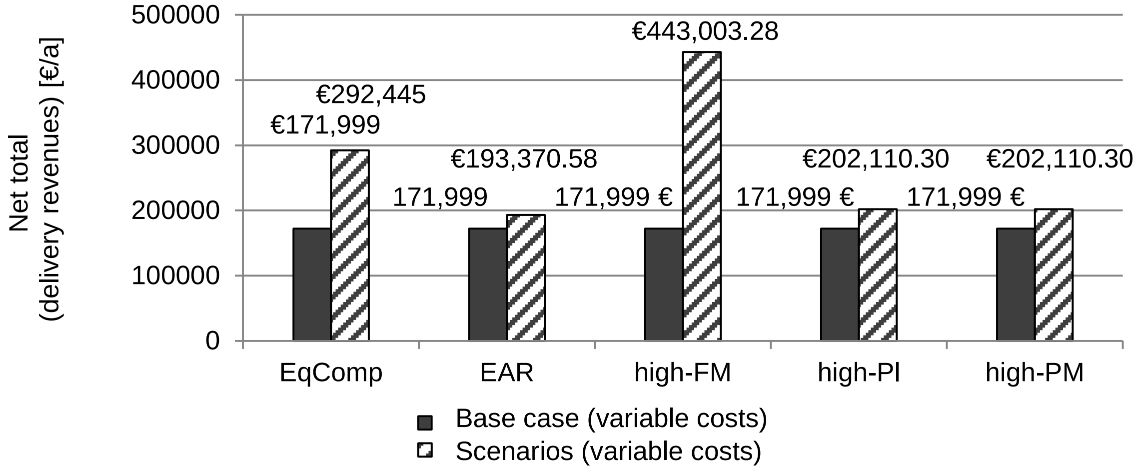

Figure A12 - 2: Comparison of net total of base case and scenarios, delivery revenues (Prod. A)

A 13 Specific total per ton of producers comparing base case and modelled scenarios

Table A13 - 1: Specific total including delivery revenues of all producers and modelled scenarios

Delivery Revenues	Equal_Comp	EAR	high_Fe	high_Pl	high_PM	Base case
Producer A (CG1)	€100.14	€92.70	€105.08	€93.65	€93.65	€89.97
Producer B (CG2)	-€415.66	-€402.03	-€385.69	-€441.46	-€441.46	-€450.81
Producer C (CG3a)	-€159.70	-€154.01	-€170.01	-€147.71	-€147.71	-€173.73
Producer D (CG3b)	-€25.03	-€20.37	-€33.48	-€30.55	-€19.93	-€36.53
Producer E (CG5)	-€22.66	-€38.11	-€45.99	-€0.89	-€22.66	-€55.80
Producer A (CG1)	1.113	1.030	1.168	1.041	1.041	1.0
Producer B (CG2)	0.922	0.892	0.856	0.979	0.979	1.0
Producer C (CG3a)	0.919	0.886	0.979	0.850	0.850	1.0
Producer D (CG3b)	0.685	0.558	0.916	0.836	0.546	1.0
Producer E (CG5)	0.406	0.683	0.824	0.016	0.406	1.0

In der Schriftenreihe „Beiträge zu Abfallwirtschaft/Altlasten“ des Institutes für Abfallwirtschaft und Altlasten sind folgende Bände erschienen:

		Preis EUR zzgl. Porto und Versand
	Erstes Abfall- und Altlastenkolloquium – Altholzseminar	vergriffen
Band 1	Möglichkeiten und Grenzen der Verbrennung von landwirtschaftlichen Reststoffen und Nebenprodukten für die Kalkproduktion	Vergriffen
Band 2	Steuerungsmöglichkeiten abfallwirtschaftlicher Gebühren	Vergriffen
Band 3	Prozessbezogene Silberbilanzierung bei der Diafilmentwicklung im Fotogroßlabor	begrenzt kostenlos
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Band 5	Steuerungsmöglichkeiten abfallwirtschaftlicher Gebühren in Großwohnanlagen	Vergriffen
Band 6	6 Jahre Verpackungsverordnung – eine Zwischenbilanz	Vergriffen
Band 7	Anaerobe biologische Abfallbehandlung	begrenzt kostenlos
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Band 20	Thermische Abfallbehandlung 2002	vergriffen

Band 21	Einfluss der getrennten Sammlung von graphischem und Verpackungspapier auf den Schadstoffgehalt im Altpapier am Beispiel von Pentachlorphenol und Polycyclischen Aromatischen Kohlenwasserstoffen	vergriffen
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