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National and International Downstream Markets for DMF E-waste Dismantling Fractions – Metals, Printed Wiring Boards and Plastics

E-Waste Management Project in Ethiopia (EWaMP Ethiopia) funded by GEF

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The usage of the Step logo only illustrates that this publication has gone through a Step internal review process, also concluding that it is a valuable contribution towards sustainable solutions of the e-waste problem in addition to incorporating Step members’ expertise.

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Acronyms

CRTC	the Computer Refurbishment and Training Center in Akaki
DMF	the “Electronics Demanufacturing Facility” located in Akaki
EABMEI	Ethiopian Association of Basic Metals and Engineering Industries
EEE	electrical and electronic equipment
EICTDA	Ethiopian ICT Development Agency
EoL	end of life

EPI	Ethiopia Plastics Industry
FPB	fixed price business
GDP	Gross domestic product
GEF	Global Environmental Facility
(H)CFC	(hydro) chlorofluorocarbon
IBLF	International Business Leaders Forum
ICT	information and communication technology
LME	London Metal Exchange
MCIT	Ethiopian Ministry of Communication and Information Technology
MEF	Ethiopian Ministry of Environmental Protection and Forestry
METEC	Metals and Engineering Corporation
MIDI	Metal Industry Development Institute
MoFED	Ministry of Finance and Economic Development
PBB	polybrominated biphenyls, a group of brominated flame retardants
PBDE	polybrominated diphenyl ethers, a group of brominated flame retardants
PCB	polychlorinated biphenyl(s)
PM	precious metals
PPPDS	Public Procurement and Property Disposal Service
PWB	printed wiring boards, also printed circuit boards
RFQ	request for quotation
StEP	Solving the E-Waste Problem Initiative
t	metric ton (tonne); 1,000 kg
TM	target metals
TP	target plastics
UEEE	used electrical and electronic equipment
UNIDO	United Nations Industrial Development Organization
WtE	waste to energy

Definitions

Akaki Center	the DMF and the CRTC located in Akaki
Buyer	processor buying e-waste, components and fractions thereof like metal scraps, printed wiring boards and plastics, excluding brokers and traders
Category of (U)EEE	electrical and electronic equipment grouped according to overall functions or uses, e.g. cooling and freezing equipment, consumer equipment, information and telecommunication equipment, etc.
Disposal[1]	Any operation which does not intend the recycling or incineration with energy recovery of materials from e-waste or fractions thereof
End of life	life cycle phase of electrical and electronic equipment or components thereof once it has become e-waste until its reuse, recycling or disposal
End-processing	also final processing; recycling of metals, plastics and other materials from e-waste, components and fractions thereof, or the disposal of components, fractions and materials that cannot be reused or recycled
End-processor	operator conducting end-processing, e.g. iron and copper smelters, plastics recyclers, or the disposal of components, fractions and materials that cannot be reused or recycled
E-waste	electrical and electronic equipment which the owner has to or intends to dispose of
Final processing	cf. end-processing
International	in the context of this report relating to countries beyond Ethiopia and its vicinity, e.g. international markets for PWB, i.e. in Europe, Northern America, Japan
Local	in the context of this report relating to Ethiopia, e.g. local markets for scrap metals
Operator	person, company or organization in the end-of-life chain (collection, storage, transport, treatment, disposal) accepting and processing e-waste, materials or fractions thereof

[1] European Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste (Waste Framework Directive), retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098, accessed 19 May 2014; modified

Pre-processing	also pre-treatment; any treatment preparing the recycling or disposal of materials from e-waste, parts or fractions thereof, e.g. by dismantling, removal of hazardous components and substances
Pre-processor	entity pre-treating e-waste via manual dismantling or mechanical pre-processing, e.g. the DMF
Recycling[2]	any operation by which waste materials are reprocessed into materials or substances either for the original or other purposes
Regional	related to Ethiopia's vicinity, e.g. Kenya and Uganda
Smelter	if not specified otherwise, e.g. as iron or aluminum smelter, in this document used for primary and secondary copper and similar smelters smelting and refining copper and precious metals containing non-ferrous metal fractions others than iron and aluminum from e-waste dismantling and mechanical pre-processing
Sorting	compilation of e-waste or used electrical and electronic equipment based on specific criteria, e.g. type of electrical and electronic equipment, content of hazardous materials, content of precious metals, required specific pre-processing, etc.
Target metals	metals, e.g. in PWB, for which end-processors copper smelters pay, i.e. copper and precious metals like gold, silver, palladium
Target plastics	plastics, e.g. from e-waste, for which plastics recycler pay, i.e. ABS, (HI)PS, PC, PE and PP without brominated flame retardants
tonne	1,000 kg (metric ton)
Treatment	any pre- and end-processing operations, e.g. disassembly, removal of hazardous substances and valuable components for recycling, shredding and subsequent mechanical separation, recycling of metals and plastics in smelters and plastic recycling plants, including (preparation for) disposal on landfills or incineration, etc.
Type of (U)EEE	(used) electrical and electronic devices under the various categories, e.g. refrigerator, freezer, air condition under the category of cooling and freezing equipment
Used EEE	electrical and electronic equipment that is not new but has been used regardless of its functional status

[2] European Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste (Waste Framework Directive), retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098, accessed 19 May 2014; modified

1 Executive Summary

The Government of the Federal Democratic Republic of Ethiopia and UNIDO with funding from the Global Environmental Facility (GEF) have launched the “E-waste Management Project in Ethiopia” (EWaMP Ethiopia) in April 2013. The project aims to establish an e-waste management system that prevents the risks for public health and the environment and losses of valuable and scarce resources resulting from poor management of this highly complex type of waste. A main objective of the project is to upscale the Government-owned Electronics Demanufacturing Facility (DMF) in Akaki close to Addis Ababa.

The DMF has been collecting and dismantling mainly IT and accessories, communication and consumer equipment from Federal Government offices and international organizations in Ethiopia. The DMF produces and stockpiles materials from its dismantling operations, which need to be sold to local, regional or international markets. UNIDO commissioned this study to analyze national and international downstream markets for the above fractions, to link the DMF to these downstream markets, and to align the quality of the fractions and the business conditions to the market requirements.

Steel in particular, but also copper and aluminum have markets in Ethiopia. Identified buyers were screened whether they are registered as taxpayers to ensure they work in the formal sector. The formal sector companies and organizations were interviewed to learn about their quality criteria they apply to purchase materials, prices they are willing to pay for the various qualities, and their business conditions, in particular whether they are ready to buy under the specific rules applying to a public sector organization like the DMF.

For the steel fraction, ten companies and organizations in Ethiopia would be ready to pay around 7 to 11 Birr/kg (0.26 to 0.41 Euro). Only four potential buyers could be identified for aluminum, and three for copper. Only one of them processes the scrap aluminum to aluminum. Smaller amounts can be sold on the local market to workshops, but most of the aluminum and copper is sold for processing outside Ethiopia. The prices the potential buyers are willing to pay range between 15 and 20 Birr/kg (0.56 to 0.75 Euro) for the aluminum scrap, and around 40 Birr/kg (1.5 Euro) for copper. All prices are, however, subject to a quality inspection by the scrap metal buyers prior to purchase and to changing metal market conditions both locally and internationally. The high share of manual labor enables the DMF to produce fractions that are much purer than those generated in mechanical pre-processing of e-waste. It can therefore be assumed that the DMF metal fractions are of good quality and achieve good prices.

In parallel to the work in this task force, the Government has been developing new rules stipulating that public entities have to sell their metal scraps via the Public Procurement and Property Disposal Service (PPPDS), which operates under the Ministry of Finance and Economic Development (MoFED). The PPPDS sets the prices and selects the buyers of metal scraps on the Ethiopian market.

Printed wiring boards (PWB) as well as the plastic fractions produced and stored at the DMF do not have adequate markets either in Ethiopia or in the region. They will be sold on the international market. The PPPDS is not involved in these sales so that the DMF will have to select the buyers following the applicable Ethiopian and international regulations.

Potential processors of PWB – pre- as well as end-processors - are located in Europe, Northern America and Japan. They buy PWB and other materials offering two principle business conditions. The fixed price model is based on a price which is contractually agreed before the material is delivered. The price assessment can be based on photos of the material to be sold provided the PWB are sorted in qualities according to the buyers' requirements. The revenues will be transferred within days after the material has been delivered to the buyer's site. Minimum lot sizes per transaction mostly do not apply. The other possibility is the analysis-based model, where the material to be sold is analyzed on the buyer's premises for the concentration of precious metals and copper, whereupon the price is calculated based on contents of PM and copper and taking into account the treatment cost.

PWB and other end-of-life materials are categorized into high, medium and low grades based on their gold content. Like for steel, copper and aluminum fractions, the manual dismantling enables pure PWB fractions as the DMF can remove and sort all PWB from the e-waste devices. Based on the principle how smelters calculate the cost and revenues of PWB processing, the DMF dismantling process can be further optimized. High grade PWB can be treated directly in smelters and should not be mixed with lower grade PWBs. Pre-processing of lower grade PWB should target removing larger aluminum and iron parts in order to increase the precious metal and copper concentrations and with this the revenues from the treatment in the smelter. For low and in particular very low grade PWB, the DMF should consider a further mechanical pre-processing step. Selling smaller amounts of PWB is not advisable due to disproportionately high transport cost, and as processors of PWB may not accept lot sizes below certain minimum amounts. Depending on the individual buyer and the material, the minimum lot sizes for most materials range around five tonnes.

The plastics fraction stored at the DMF consists of several types of plastics including plastics with brominated flame retardants. Unlike plastics fractions from mechanical e-waste treatment, the DMF plastics fraction is not contaminated with non-plastics materials due to the manual dismantling process. It is therefore of good quality for recycling. Such a plastics fraction from manual e-waste dismantling can be sold for around 100 Euro[3] per tonne for 22 t of plastics incl. transport from Djibouti to the plastics recycler in a 40 ft container. The DMF will need respective equipment to shredder or compress the plastics parts. In principle, the quality of the plastics fraction can be further improved by various sorting options. The overall technical, economic and ecologic feasibility of such optimizations could be tested once the new Waste-to-Energy incineration plant at the Reppie landfill site is operational and can process plastics with brominated flame retardants. For the time being, the DMF should sell its plastics without further sorting. Using the plastics as a substitute for fossil fuels in cement kilns is not an option as no cement kilns could be identified that can process plastics with brominated flame retardants reliably preventing emissions of dioxins and furans.

The Ethiopian Government should urgently clarify the legal status of the DMF and the CRTC as the legal organization is crucial for the cash flow and for the motivation to become more effective and efficient. In the authors' opinion, it is crucial that the DMF receives feedback from the markets

[3] Plastics prices are highly volatile so that this price only applied at the time when this report was written.

on the quality of its fractions to spur the optimization of the output fractions. The revenues from the sales of the DMF fractions should be transferred to a DMF bank account. Otherwise, if the revenues go, for example, to a central government account, there is little incentive for the DMF to increase the capacity, efficiency and quality of its operations. In the medium and long run, a more commercial and market oriented legal form, e.g. as private or (semi-) private company, might be an alternative for the DMF to achieve an effective and efficient and market-oriented treatment of e-waste in Ethiopia. The Federal Government and the regional and local governments still would have the important role to set and enforce clear rules and standards, and to exert sufficient control to ensure the environment-friendly and safe treatment of the e-waste at the DMF and future other e-waste pre-processors in the Ethiopian market.

2 Background

UNIDO and the Federal Democratic Republic of Ethiopia with financial support from the Global Environmental Facility (GEF) have launched the E-waste Management Project in Ethiopia (EWaMP) to promote and upscale the management of E-waste in Ethiopia. The project was initiated and prepared by StEP with financial and organizational support from the US Environmental Protection Agency. EWaMP will assist the Ethiopian Government to establish a national E-waste strategy including: e-waste regulations, collection and treatment, a sustainable financing mechanism, capacity building and awareness raising, and a regional cooperation to create synergies and share best practices.

2.1 Objectives and Approach

UNIDO commissioned this downstream market study within the Ethiopian E-waste Management Project (EwaMP Ethiopia). The main objectives of the study are:

- Identify environmentally and socially sound potential local, regional and international buyers for those DMF dismantling fractions that are produced in higher quantities, i.e. steel, aluminum, copper, and printed wiring boards (PWB) and plastics.
- Analyze the purchasing conditions and business models of potential buyers and their branches and elaborate recommendations how the DMF can optimize its dismantling and sales procedures for the market requirements thereby enabling effective and efficient material sales at best prices.
- Investigate the administrative procedures the DMF as a government-owned entity has to follow when selling dismantling fractions to local, regional and international markets.
- Give recommendations concerning the legal status and organization of the DMF to incentivize effective and efficient treatment of e-waste in Ethiopia.

As a first step, the quantities and qualities of dismantled fractions produced and stored at the DMF were assessed in close cooperation with the DMF management. Local markets were given priority over regional and international ones. The informal sector dominates the scrap metal market in Ethiopia. Nevertheless, the informal sector was not taken into account in this study in detail as the DMF as a governmental organization cannot sell to the informal sector.

Potential buyers of steel, aluminum and copper scraps on the Ethiopian market were identified by checking national registers, internet sites, newspapers and other publicly available sources. Only those were taken into consideration that are listed as tax payers in the national register thus excluding informal processors. Potential buyers without own processing capacities such as brokers and traders of metal scraps were excluded to maintain the transparency on the downstream fate of these materials thus preventing damages to the environment and health of workers as far as possible. The potential buyers' sites were visited to investigate their interest in the dismantling fractions, and to learn about their business practices, quality criteria, environmental performance and the prices they are willing to pay.

In parallel to the work in this task force, the Government has been developing new rules stipulating that public entities have to sell their metal scraps via the Public Procurement and Property Disposal Service (PPPDS), which operates under the Ministry of Finance and Economic Development (MoFED). The PPPDS sets the prices and selects the buyers of metal scraps on the Ethiopian market. The steel, aluminum and copper scraps from e-waste dismantling at the DMF will therefore be sold via the PPPDS.

Printed wiring boards (PWB) as well as the plastic fractions produced and stored at the DMF do not have adequate markets either in Ethiopia or in the region. They will be sold on the international market. The PPPDS is not involved in these sales so that the DMF will have to select the buyers and export the materials following the applicable Ethiopian and international regulations. The authors identified potential buyers based on their expertise and contacts, and through internet search. Their business practices were investigated and analyzed via personal interviews, e-mail communication and internet investigations. To exclude buyers with environmentally unsound practices and adverse business conducts, only renowned processors of PWB and plastics were taken into account from which the authors know or reasonably can assume that they apply sound practices due to their location in countries with strict and consequently enforced environmental regulations in place[4,5]. Traders and brokers of PWB and plastics were not included to maintain maximum transparency about the downstream fate of the PWB and plastics.

[4] A „WEEE end-processing standard" finalized in 2014 may give additional guidance; the standard can be requested from the European Electronics Recyclers Association (EERA) via e-mail: ls@eera-recyclers.com; please indicate your name and company

[5] For (mechanical) pre-processing, standards may give additional guidance, examples being e-stewards (http://e-stewards.org/), WEEELABEX (http://www.weeelabex.org/) and R2 (http://www.sustainableelectronics.org/)

2.2 The Electronics Demanufacturing Facility

In 2006, the Ethiopian Government established the Computer Refurbishment and Training Center (CRTC) in Akaki close to Addis Ababa with a loan from the World Bank in the course of a project boosting the ICT capacity in the country. The center refurbishes second hand equipment, mostly information and communication technology (ICT) like computers and deploys them to educational institutions, health offices and community recipients at a minimal price. Thus, the CRTC provides a sustainable, integrated approach to meet the technology, training and capacity building needs of Ethiopia.

In conjunction with the CRTC, the Electronics Demanufacturing Facility (DMF) was established in 2009at the same location in Akaki to dismantle donated ICT equipment that cannot be refurbished and/or has become obsolete. The International Business Leaders Forum (IBLF), an NGO, managed the establishment of both the CRTC and the DMF on behalf of the then Ethiopian ICT Development Agency, which is now Ministry of Communication and Information Technology(MCIT).The MCIT is a key implementing partner in the EWAMP Ethiopia project. It provides in-kind support for the further development of the DMF. A new building for the DMF increasing its working capacities shall be finished by the end of 2014.

2.2.1 E-waste Supplies and Operations

Apart from a draft regulation on Management and Disposal of Electrical and Electronic Wastes prepared by the Ministry of Environment and Forestry (MEF), Ethiopia has no specific e-waste legislation in place, even though this legislation is under way(status October 2014).The Ministry of Finance and Economic Development (MoFED) hence plays a vital role in making the Akaki DMF operational. To secure the supplies of used electrical and electronic equipment (UEEE) to the DMF, MoFED issued a letter to all federal ministries in 2012 to hand over stored end-of-life electronic equipment to MCIT for refurbishment or dismantling at the Akaki Center (CRTC and DMF). However, there is no executive order or proclamation requiring all government organizations and offices to dispose their electronic waste to the DMF, and the MoFED letter does not include governmental and administrative levels below the federal level such as provincial and municipal offices.

The DMF currently receives equipment from federal government, nongovernmental and international organizations. Computers and accessories form the highest share in the incoming UEEE. Table 1 gives an overview on the types of UEEE arriving at the Akaki Center since its establishment. A more detailed list based on the DMF’s own input tracking system can be found in Annex I on page 62.

Table 1: Main used electrical and electronic equipment coming to the Akaki Center[6]

IT and Accessory Equipment	Communication, Consumer and other Waste EEE
CRT Monitors	CRT- and flat panel TVs
LCD Monitors	Telephone apparatus
Printers	Speakers
Keyboards	Photo copiers
Mouse	Type writers
Plotters	Refrigerators
Scanners	Electrical stoves
	Air conditioners

Currently, the DMF only accepts obsolete computers and their accessories due to a lack of storage capacity. Figure outlines the refurbishment and dismantling operations at the Akaki Center.

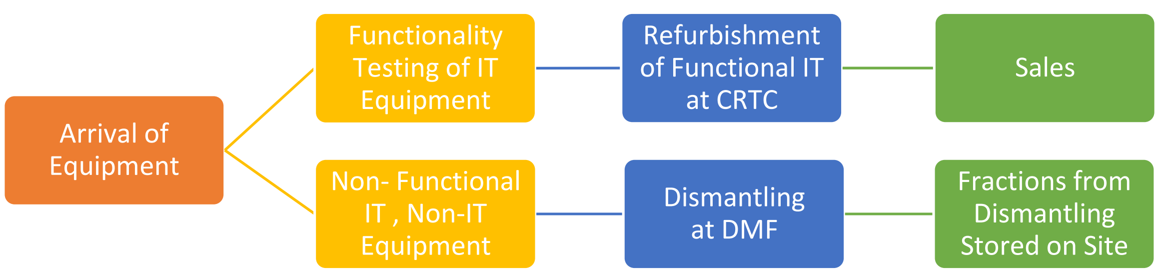

Figure 1: Overview of the Akaki Center operations

[6] Based on information received from the DMF; the list comprises the main used electrical and electronic equipment (UEEE) delivered to the Akaki Center, but is not complete, as some used electrical and electronic equipment could not be clearly identified and described

Once the UEEE arrives in Akaki, as a first step the CRTC conducts a functionality check of the IT and accessory equipment. The CRTC refurbishes functional equipment including the installation of licensed software, and sells it to public educational, health and rural extension services at affordable prices. Non-functional IT and non-IT equipment goes to the DMF for dismantling.

Technicians dismantle the e-waste manually with mechanical tools. The dismantling fractions are mainly steel, aluminum, copper, printed wiring boards (PWB) and plastics. These fractions are weighed and separately sorted for sale. As part of ICT equipment, cathode ray tubes (CRTs) are stored onsite, as the DMF does not have the technology to process them, or to have it treated regionally or internationally[7]. The same applies to refrigerators and air conditioners. They may contain (hydro) chlorofluorocarbons (H)CFC, a gas destroying the ozone layer and a strong greenhouse gas, which the DMF is not equipped to handle in an environmentally sound way.

2.2.2 Main Fractions Produced and Stored at the DMF

Table 2 shows the main types of fractions generated at the DMF, and their amounts stored at the DMF in April 2014. Annex II on page 62 gives a more detailed overview.

Table 2: Quantities of main fractions stored at the DMF

	Steel Scrap	Aluminum	Copper	Printed Wiring Boards	Plastics
Amounts Stored at DMF	Around 26 t	Around 0.45 t	Around0.32 t	Around 1.8 t	Around 8.3 t
Visual Quality	Pure steel scrap	Pure aluminum scrap	Mix of pure copper parts and others, e.g. cables with insulation	Mixture of low, medium and high grade quality; no removal of larger steel and aluminum parts	Mix of larger parts of different plastic types without non-plastics contaminations

Source: DMF[8], status March 2014; metal fractions are sold meanwhile on local markets

Steel, aluminum and copper can be sold in Ethiopia. For PWB and plastics currently there are neither local nor international markets.

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[7] Status October 2014

[8] Information sent via e-mail by Dereje Masresha, Manager of the DMF, to Otmar Deubzer, UNU, on 1 April 2014

2.3 Specific Business Conditions Applying to the DMF

The DMF as a public, government-owned entity has to follow public procurement rules when selling materials on national or international markets. Different rules apply for the sales of scrap metals on the local markets and exports of hazardous but valuable materials like PWB and plastics.

2.3.1 Legal and Administrative Procedures for Metal Sales on the Ethiopian Market

One of the objectives of this study was to clarify the procedures the DMF has to follow for sales of scrap metals, i.e. steel, aluminum and copper on the local market, and to identify potential buyers. In parallel to these investigations, MoFED has prepared and issued a circular in February 2014. It was understood that the document, among other issues, calls upon

- the development of more efficient nationwide stipulations for the collection of metal scraps from public organizations;
- setting the prices based on the qualities and quantities of the metal scraps in the context of local and international market prices;
- setting up rules for the efficient sales of the scrap metals taking into account, among other issues, the various aspects that can influence the transaction cost like e.g. transportation.

A committee including the Metals and Engineering Cooperation (METEC), the Public Procurement and Property Disposal Service (PPPDS), and the Metal Industry Development Institute (MIDI) are developing these rules. In the meantime, until the stipulations are finalized and enacted, the circular requests all governmental organizations including the DMF to report and hand over their metal scraps to the PPPDS, which will then sell it to public and private companies. Figure 2 illustrates the sales procedure.

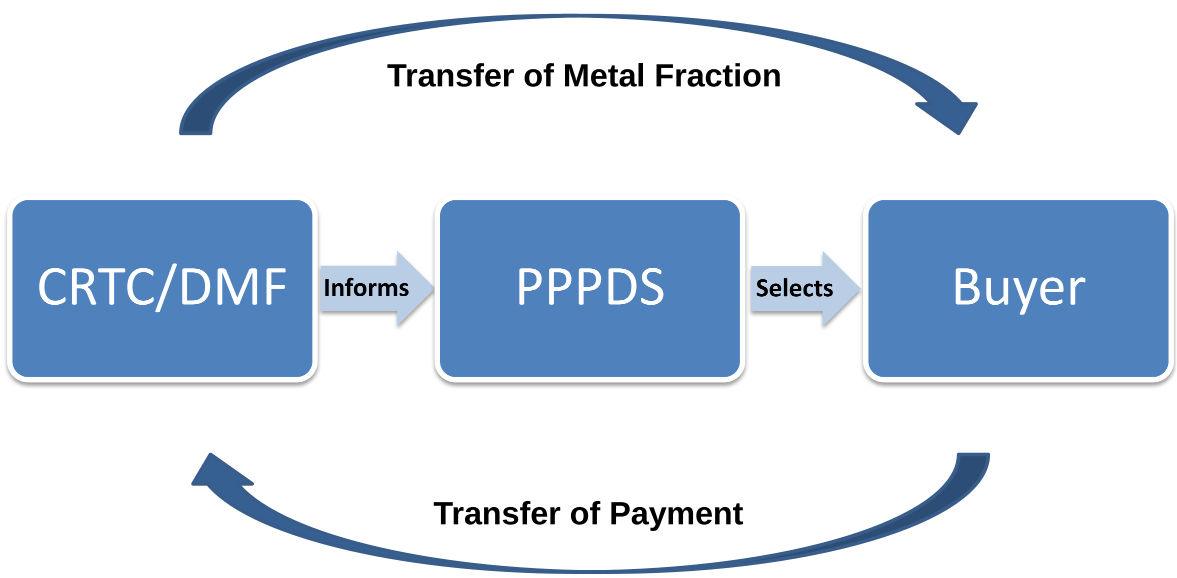

Figure 2: Sales procedure and cash flow for the DMF metal scraps

The DMF informs the PPPDS once there are sufficient quantities of metal scraps that can be sold. The PPPDS will then select buyers for these fractions, which are ready to buy for the prices set by the PPPDS. The buyers will then pick up the fraction at the DMF and transport it to a METEC compound in Debre Zeit city, around 40 km from the DMF, for weighing, and from there to their own compounds. Alternatively, the DMF organizes and pays the logistics costs, depending on the contractual agreement between the PPPDS and the buyers.

If a public entity like the DMF is listed at MoFED as a budgetary institution – an institution that is allocated its own budget in the public financial planning – the revenues from the metal scrap sales will be transferred to the central treasury at MoFED. Non-budgetary institutions that are public enterprises will receive the sales revenues for their own perusal.[9]The actual legal status of the DMF remains unclear, but the DMF has its own bank account, and it was understood that the revenues from the metal scrap sales will be transferred to this account.[10]

UNIDO and the authors of this study were not informed about the governmental efforts to regulate the DMF's sales practices. When this information became available in March 2014, it was decided to finalize the local downstream market study nevertheless. The outcomes and recommendations might be useful for the new public procurement rules and for other organizations that are working on e-waste related issues in Ethiopia, and the new rules do not apply to PWB and plastics as these are not metals.

2.3.2 Legal and Administrative Requirements for Export of PWB and Plastics

The PWB and the plastics fraction are hazardous but valuable wastes. Improper treatment may result in considerable environmental and health damages, e.g. through generation of dioxins and furans. The export of such wastes is a transboundary movement, which is relevant in the context of the Basel Convention. Additionally, in particular the combination of hazardousness and value of the waste material, requires following specific Ethiopian rules for exports of such materials. So far, such materials have never been exported from Ethiopia, and the procedures needed to be clarified. Figure 3 reflects the procedure like the authors of this study understood it from interviews with the involved ministries and public organizations[11].

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[9] Source: Mr. Tesfaye Berhanu, Deputy Director General at PPPDS: presentation at the Ehtiopian E-waste Management Working Group (EEEWoG) meeting on 12 June 2014, at the UNAIDS Regional Office, UNECA compound, old building, conference room on 2nd floor

[10] This was understood as the result of the discussion in the 12 June EEWoG meeting between Mr. Berhane Keleta, MCIT, and Mr. Tesfaye Berhanu, PPPDS

[11] Status October 2014

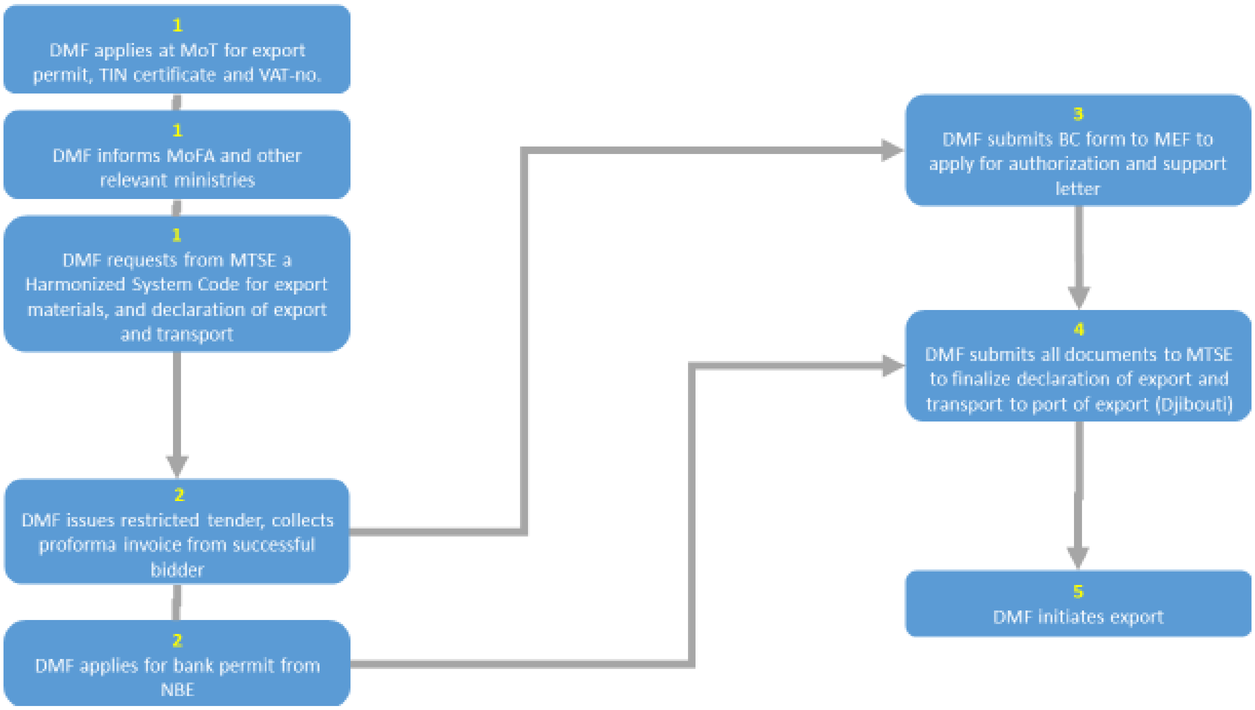

Figure 3: Administrative procedure for the export of PWB and plastics

Acronyms

MEF	*Ministry of Environment and Forest*
MoFA	*Ministry of Foreign Affairs*
MoT	*Ministry of Trade*
MTSE	*Maritim & Transit Service Enterprise*
NBE	*National Bank of Ethiopia*

Legend

Process steps with identical numbers linked with lines can be executed in parallel.
Steps connected with arrows have to be executed sequentially in the order of the numbering, as the successful finalization of the previous steps is the pre-condition for the next step.

In more details, the requirements for the various steps of the procedure are as follows:

1. The DMF applies at MoT for an export permit, a TIN (taxpayer identification number) and a VAT number (value added tax).

   In parallel, the DMF can send a letter to request a World Customs Organization Harmonized System code for the exports of PWB and plastics from MTSE for the customs procedures, as well as an export declaration of export and transport. The Ethiopian Revenue and Customs Authority will support MTSE if required.

   The DMF should also take initiative to get the relevant stakeholders onboard to facilitate the process The DMF should identify relevant line ministries, e.g. MoFA, and other stakeholders and discuss with them bilaterally, or possibly in a joint meeting with representatives of all stakeholders.

2. The DMF requests a permit from NBE. This is obligatory once foreign currencies are involved in business transactions. In parallel, the DMF can float a restricted tender to the potential buyers of the PWB and the plastics, e.g. those identified in this study.

3. The DMF will need a proforma invoice from the selected buyer.

4. The DMF applies at MEF for an authorization letter allowing the DMF to export the waste, and a support letter to all the respective Basel Convention Secretariat focal person/authorities along the proposed route of transportation. With the application, the DMF has to submit a completed Basel Convention Notification form[12]for exporting hazardous wastes.

5. The DMF submits all the forms and certificates obtained in the previous steps to MTSE, plus a packing list and filled out shipping instruction form so that MTSE can finalize the declaration for export and transport of the container to the port of export (Djibouti).

As the Basel Convention as well as the export legislation and custom rules apply to public as well as to non-public companies and organizations, such entities in principle should have to follow the same procedure for exports of PWB and plastics. One difference is, however, that non-public organizations have to apply for a business license[13] at MoT in step 1 and will then automatically be issued a TIN and a VAT number.

3 National Downstream Market for Steel Scrap in Ethiopia

Ethiopia's metal sector has gone through rapid growth in the last few years because of the country's overall economic growth. In particular, the soaring construction sector has boosted the demand for metal products. The demand for steel scrap has been increasing over the last years to around 200,000 t per annum according to the Ethiopian Association of Basic Metal and Engineering Industries (EABMEI)[14]. Steel scrap therefore has a market in Ethiopia.

3.1 Identification of Potential Buyers for Steel Scrap

Currently (status March 2014), 96 legally registered and tax paying steel sector factories are listed as members of the two legally government registered associations, the Addis Ababa Chamber of Commerce and Sectoral Associations(AACCSA)[15], and the Ethiopian Association of Basic Metal

[12] Revised notification and movement documents for the control of transboundary movement of hazardous wastes and instructions for completing these documents, retrievable from http://www.basel.int/Portals/4/Basel%20Convention/docs/techmatters/forms-notif-mov/vCOP8.doc; last access 10 October 2014

[13] Ministry of Trade, http://www.mot.gov.et/business-license-renewal; accessed 10 October 2014

[14] Personal communication with Mr. Solomon Mulugeta, EABMEI, on 24February 2014

[15] Addis Ababa Chamber of Commerce and Sectoral Associations(AACCSA), retrieved fromhttp://addischamber.com/, accessed March 2014

and Engineering Industries (EABMEI)[16]. Most of them import semi-processed steel to produce structural steel, machinery parts, water pipe products and furniture. Ten of the factories are equipped with electrical arc or blast furnaces and can therefore produce steel from steel scrap and ores. They are hence the only potential buyers for the DMF steel scrap. Except for the Akaki Basic Metals Industry[17] and the Ethiopian Iron & Steel Factory[18], the private sector owns and operates all of the factories.

Five of the ten factories are located in the vicinity of the DMF, in an average distance of six to ten kilometers. Habesha Steel Mills and Kotebe Metal Tools are located at a relatively fair distance of 25 km from Akaki. Another two, Abyssinia Integrated Steel and Steely R.M.C are based in Debre Zeit city at a distance of 45 km from the DMF. Walia Steel Industrial is located in Alem Gena city 80 km in the northeast of Addis Ababa. The distance from Akaki to Alem Gena via Addis Ababa is about 105 km.

In interviews with the respective representatives of the ten factories, all of them expressed their interest to buy steel scrap from the DMF. However, they have all requested to visit the DMF in order to inspect and evaluate the fractions and to categorize them according to their quality criteria described in section 3.3.1 on page 21.

3.2 Assessment of Potential Buyers 'Environmental and Social Performance

According to the Ethiopian investment law and Environmental Pollution Control Proclamation number 300/2002, all factories are required to perform an initial as well as periodical environmental assessments. The Proclamation has started to take effect. It allows financial fines of 20,000 to 100,000 Ethiopian Birr (ETB) and factory closures and the responsible persons may be sentenced to imprisonment between five and ten years.[19] The law further requires that manufacturers install appropriate waste disposal mechanisms. Part Two Article 3.3 states that "any person engaged in a field of activity which is likely to cause pollution or any other environmental hazard shall, when the Authority or the relevant regional environmental agency so decide, install a sound technology that avoids or reduces, to the required minimum, the generation of waste and, when feasible, apply methods for the recycling of waste."[20]

The Government of Ethiopia has a strong restriction on purchases of scrap material from the power or telecom sector. Due to high rates of theft and vandalism, the Government at times requires factories to show from where they have sourced the scrap material. Thus, factories require suppliers to record their purchases. All the factories identified have a clear policy of not purchasing

[16] Ethiopian Association of Basic Metal and Engineering Industries (EABMEI), retrieved fromhttp://www.eabmei.org/, accessed March 2014

[17] The factory works under the Metals and Engineering Corporation (METEC), which is owned by the Ethiopian Government

[18] The Ethiopian Government owns half of this factory

[19] Environmental Pollution Control Proclamation number 300/2002

[20] Environmental Pollution Control Proclamation number 300/2002

stolen goods from government agencies such as telecom, railroad or power plants. As observed from statements written by one of the manufactures in their property, they have made it clear to potential suppliers that providing items that look like from the power or telecom would conflict with their policy. However, they have no mechanism of counter checking if the goods they purchase from the dealers actually do not originate from public infrastructure.

None of the ten steel factories has a certified environmental management system[21], an occupational health and safety certificate[22], or follows any social labor standards[23]. Abyssinia Integrated Steel has almost finalized the ISO 9001-2008quality management certification[24]. A differentiation of the ten factories with respect to environmental, health and safety, and social performance is thus impossible, especially as the study team was not allowed to conduct own onsite inspections and interviews with workers.

3.3 Price and Business Conditions for Steel Scrap in the Ethiopian Market

3.3.1 Quality Criteria for Steel Scrap

Steel scrap prices are related to qualities. The quality criteria for steel scrap were investigated in interviews with the scrap metal purchasing divisions of potential buyers. The quality categorization is based on the source of scrap. Heavy weight thick scraps coming from machinery parts are first grade achieving the highest prices, third grade scraps are light weight thin scraps from materials like corrugated steel sheets, and the second scrap grade is related to scraps in between these two groups. The DMF steel fraction is estimated to be second grade steel scrap.

The price of the various steel scrap grades depends on additional, general quality requirements for steel scrap, which are[25]:

- The steel content measured in terms of weight percent of the total mass should be as high as possible. It should therefore not be mixed with other metals or organic substances;
- Any trace contaminations in the steel scrap, e.g. with copper, should be within the specified levels;
- The characteristics of the material should be consistent. A constant quality over all deliveries over time is favorable.

[21] For example ISO 14000 series Standard for Environmental Management

[22] For example OSHA, https://www.osha.gov/law-regs.html; accessed 30 March 2014

[23] For example International Labor Organization (ILO) standards, http://www.ilo.org/global/standards/lang--en/index.htm; accessed 30 March 2014

[24] ISO 9001:2008, Quality management systems – Requirements, retrievable from http://www.iso.org/iso/catalogue_detail?csnumber=46486; accessed 30 March 2014

[25] Harsco Metals & Minerals: Steel Scrap Qualities, Retrieved from http://www.harsco-m.com/216/Scrap-Sources.aspx, (modified); accessed 7 April 2014

Taking into account all quality criteria, the quality of steel scrap first of all depends on the source. Within the price range for this steel scrap quality, the above general quality criteria influence the exact price paid for a specific steel scrap fraction.

While compacting steel scraps is a good mean to reduce volume and transport cost, steel scraps should not be shredded, but be kept in larger pieces. In order to optimize the steel output quality in the steel smelters, the steel scrap input needs to be mixed according to various qualities. Workers are trained to visually identify the various steel scrap qualities and mix the input accordingly. Shredded steel scraps consist of small pieces of various qualities and can therefore not be sorted in order to prepare optimum input fractions.[26]

3.3.2 Potential Buyers' Business and Price Conditions

All potential buyers highlighted that they prefer purchasing higher quantities of steel scrap than the DMF currently can offer. Some of them like the Ethiopian Iron and Steel Factory and Arati Steel mentioned that they would like to do their own metallurgy tests and assessment prior to final price estimates. Table 3 gives an overview on the price situation.

Table 3: Summary of price estimates by factories for steel scraps from DMF

Factory	Price offered in Birr/ kg of Steel scrap
Abyssinia Integrated Steel	9-10
Akaki Basic Metals Industry	9
Arati Steel	9
Ethiopian Iron and Steel Factory	7-8
Radel Foundry	11
Steely R.M.C	9-10
Metals and Engineering Corporation[27]	9
Public procurement and property disposal service[28]	7- 9

Taking into consideration the above reservations, most of the steel factories gave a price estimation of 9 to 10 Birr/kg for the DMF steel scrap.

[26] Source: Interview with Mr. Tadesse Bayu, Habesha Steel Mill, Ethiopia, on 2 December 2014
[27] Status 2013
[28] Personal communication with Mr. Solomon Aynemar, asset evaluation and disposal business process owner at the PPPDS , on 19 March2014

4 National Downstream Markets for Aluminum and Copper

Like for steel, the informal market plays a major role in the scrap aluminum and copper markets. Informal collectors collect these metal scraps and sell it to dealers for storage and sales, in particular in the Merkato market in Addis Ababa. As the DMF is a governmental organization, it cannot sell to the informal market. The informal market is therefore not described in more details in this report.

4.1 The Aluminum Downstream Market

4.1.1 Overview of the Ethiopian Aluminum Market

The aluminum industry in Ethiopia mostly handles finished products or pre-products. It imports aluminum and related products for the construction sector like aluminum frames, windows, doors, partitions, and produces household utensils. The UN Commodity Trade Statistics Database indicates that 88 % of the total amounts of aluminum imported into Ethiopia in 2011 were in these categories. The growing demand of the construction industry in particular boosts this demand. No company could be identified that produces aluminum from raw materials. Currently, the Addis Ababa Chamber of Commerce has registered 41 private owned factories and businesses. Only one industry, B&C aluminum is interested to buy scraps form DMF. Though not registered in the Addis Ababa Chamber of Commerce, Gelila Industrial Engineering is one of the biggest aluminum producing factories in the country. It is located in Mekele City in the Tigray Region, unlike the others, which are located in Addis Abeba or in the vicinity of Addis Abeba. Another such factory is ET AL Aluminium which is located in Debre Brehan city in the Amhara Region 120 kilometers north east of Addis Ababa.

Vehicle workshops are the main users of scrap aluminum in the domestic market. They apply it for the modification and repair of car parts or of household utensils. These workshops are, however, small scale businesses that cannot absorb quantities of aluminum scrap as produced at the DMF.

Figure 4: Car part fixed using aluminum

Recycling aluminum saves more than 90 % of the energy that would be needed to create a comparable amount of the metal from raw materials.[29]Generally, the quality of aluminum scrap depends on the source of the scrap. The heavy weight scrap coming from car parts and machineries is considered high quality and thus sold at higher prices. Additional quality criteria include the purity of the aluminum scraps and the quantity available per transaction. So far, it has not yet been possible to assess the quality category into which manually disassembled and sorted aluminum scrap from e-waste produced at the DMF would fall. It can, however, be assumed that at least in terms of purity, the aluminum scrap is of high quality due to the manual e-waste dismantling process applied at the DMF.

4.1.2 Identification of Potential Buyers and Prices for the DMF Aluminum Fraction

In discussions with representatives of the factories registered in the Addis Abeba Chamber of Commerce business directory only one of them, B&C Aluminum uses or expressed interest in scrap aluminum. However, further discussions with potential steel scrap buying factories identified in this study, confirmed that Akaki Basic Metals Industry, ET Al aluminum and Radel foundry are interested to buy aluminum scrap from the DMF. The Akaki Basic Metals Industry is half owned by the Ethiopian Government and located in Akaki area while the latter two are private owned factories located in the vicinity of Akaki kaliti area.

Additional investigations revealed two legally registered private companies located in Addis Ababa, which collect aluminum scrap from informal collectors and sell it to local and international markets. The companies, MATEX and SADOR Plc., are interested to buy aluminum scrap from

[29] The Aluminum Association, retrieved from http://www.aluminum.org/sustainability/aluminum-recycling; last access 5 May 2014

the DMF under the government procurement rules. They want, however, sample and analyze the aluminum fraction's quality – e.g. purity and weight – before offering a final purchasing price. They favor quantities of more than 500 kg. Annex IV on page 67 gives the contact details of these four factories.

Taking into consideration the above reservations, the marketing representative of SADOR estimated the price of aluminum with 15 Birr/kg of aluminum. Radel Foundry gave a rough estimate of 20 Birr/kg, METEC indicated a general price of 15 Birr/kg[30] for 2013. The PPPDS, based on international aluminum scrap markets, lists a price of 15 Birr/kg (March 2014, price without linkage to specific quality) for aluminum scrap[31]. The actual prices depend, however, on the current international market prices, the purity and the quantities the DMF can supply.

The exports of scrap aluminum and other metals may be subject to legal limitations. It could not be finally clarified whether and to which degrees such legislative restrictions would apply to the export of aluminum scrap given the situation on the Ethiopian aluminum market.

4.2 The Copper Downstream Market

4.2.1 Overview of the Copper Market in Ethiopia

Scrap copper is sourced from various items such as plumbing pipes, appliances and wires. Though limited in amounts, scrap copper has a market in Ethiopia. It is processed in smaller workshops to make brass and bronze alloy, and it is used for making household utensils and artisan artifacts etc. These businesses are small scale and in parts informal sector activities.

For larger quantities, potential buyers on the Ethiopian markets are companies that mainly export the copper scrap. Based on data from the UN Commodity Trade Statistics Database, Ethiopia exported scrap copper worth 1.8 million USD and 757,000 USD in 2007 and 2008 respectively.

4.2.2 Identification of Potential Buyers and Prices for the DMF Copper Fraction

During the investigations, potential buyers of the DMF copper scrap stated that the quality of the scrap depends on its purity. High quality scrap is not mixed with other metals, plastics (wires with insulation covers), clean from impurities like dust, and corrosion. Usually they request high resolution pictures of the scrap to check the above conditions before offering price estimates. The minimum quantities they buy are at least three tonnes to reduce the cost of transportation.

[30] Personal communication with Mr. Misganaw, head of the METEC Logistic and Supply Management Office, on 18 February 2014

[31]Personal communication with Mr. Solomon Aynemar, asset evaluation and disposal business process owner at the PPPDS, on 19 March2014

Neither the Chamber of Commerce nor the Ministry of Industry or the Ministry of Mines and Energy have a list of copper exporters in Ethiopia. Via internet, three companies could be identified, from which only Ethio Metals Ltd.[32] and Econars General Trading[33] reacted on information requests. They supply copper cathodes and copper scrap to the international market. These private owned companies are both located in Addis Ababa. In telephone interviews they showed interested in purchasing copper from the DMF. For price estimates they requested clear pictures of the scraps and stated they would prefer quantities of more than three tonnes to reduce transportation costs.

Radel Foundry is a legally registered factory interested to buy the copper scraps for domestic uses, not for export. Radel Foundry roughly estimated the price for the DMF copper scrap at 40 Birr/kg. PPPDS indicates the price of copper with 52 Birr/kg[34] (status March 2014) without any reference to a certain quality. BMT Energy Telecom Industry is a private industry located in Sebeta city 23 kms from Addis Abeba in the Oromiya region. Annex V on page 69 gives detailed information about these three factories.

5 International Downstream Markets for Printed Wiring Boards

Printed wiring boards (PWB) have no adequate markets, neither local nor regional. They must therefore be exported for final processing in smelters. The term "smelters" is used as a collective name for copper and similar smelters smelting and refining copper, precious metals and non-ferrous metal fractions others than steel and aluminum from e-waste dismantling and mechanical pre-processing. Such smelters are multi-billion Euro investments, and their operation requires manifold and high level expertise, which the large international smelters have built up over decades. The establishment of such a smelter therefore requires time and careful preparation so that there will be no operational smelter available in Ethiopia in the coming years.

5.1 Principal Composition of PWB

PWB in principle are composed of organic materials, e.g. epoxy resin, various metals and fiberglass in varying concentrations. Figure 5 shows an example of a PWB composition.

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32 Alibaba.com, retrieved from http://www.alibaba.com/countrysearch/ET/copper-scrap.html accessed 19 May 2014

33 RecycleInMe, retrieved from http://www.recycleinme.com/rim-econars/home.aspx; accessed 19 May 2014

34 Personal communication with Mr. Solomon Aynemar, asset evaluation and disposal business process owner at the PPPDS , on 19 March 2014

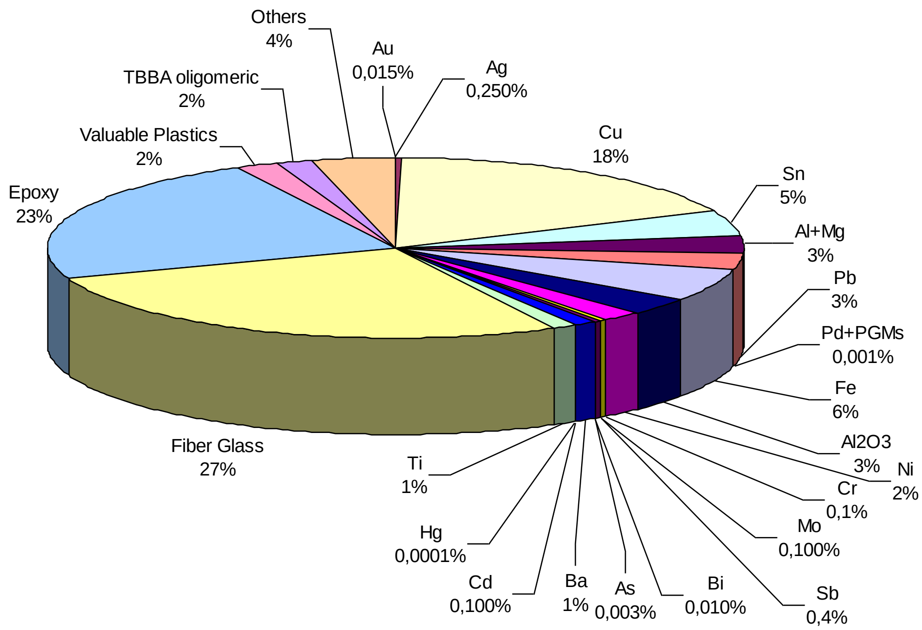

Figure 5: Example composition of a printed wiring board (in mass-%)[35]

Some of the metals are scarce and valuable like precious metals (PM, mainly gold, silver, palladium), copper, tin. Other metals are hazardous, like cadmium, lead, hexavalent chromium, mercury, beryllium. PWB contain (brominated) flame retardants, mostly TBBA (tetra-bromo-bisphenol A). Brominated flame retardants, in particular polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), may generate hazardous dioxins and furans if the PWB are treated in smelters that are not equipped to safely handle them, and without the necessary knowledge.

Even though the European RoHS Directive[36] and similar regulations worldwide ban the use of PBB and PBDE, as well as of cadmium, lead, mercury and hexavalent chromium, these substances are still present in EEE produced before July 2006 when the European RoHS Directive was enacted. The banned metals are also present in newer EEE due to exemptions for specific uses

[35] Source: Indumetal Recycling SA, in Deubzer 2007

[36] Cf. directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment; retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT; accessed 12 October 2014

where they cannot be substituted for technical or environmental reasons[37], even though in lower concentrations compared to older equipment.

From the recycling point of view PWB are highly complex materials whose treatment needs sophisticated knowhow and technology to recycle the valuable resources and to prevent damages to environment, health and safety. PWB are treated in primary and secondary copper smelters, or in secondary smelters specialized for the processing of complex metal mixtures, with or without pre-processing.

From the end of life point of view, e-waste, components and fractions thereof, e.g. PWB, are categorized based on the gold content. Figure 6 shows the classification as an average of several smelters. The exact lower and upper limits defining the individual grades are specific for each smelter.

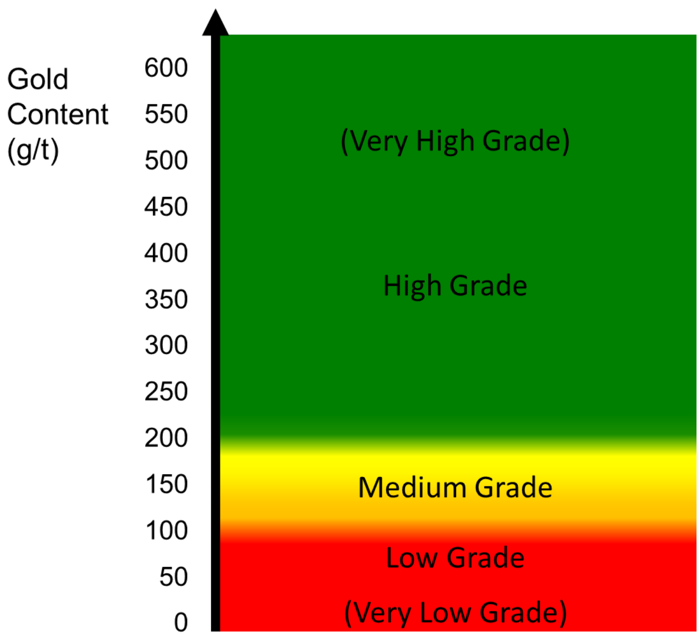

Figure 6: End of life quality categories of e-waste, parts and fractions thereof[38]

Table 4 gives an overview on the contents of gold, silver and palladium in PWB of various types of EEE.

[37] Cf. Annex III and IV of directive 2011/65/EU (RoHS Directive)
[38] Averages of several smelters

Table 4: Examples of precious metal contents of PWB in various types of EEE[39]

Type of Equipment	Au (g/t)	Ag (g/t)	Pd (g/t)
Telephone	-	2,400	-
Cathode ray tube TV	5	120	20
Stereo audio system	6	57	-
Air conditioner	15	58	-
Washing machine	17	51	-
Video cassette recorder	23	210	50
Radio cassette recorder	26	170	34
Fax machine	35	69	110
Printer	38	70	21
Refrigerator	44	42	-
DVD player/recorder	150	710	20
Liquid crystal display TV	200	600	-
Video game	230	740	43
Desktop PC	240	570	150
Plasma display panel TV	300	400	-
Portable CD player	370	3,700	10
Digital camera	530	5,000	970
Notebook PC	630	1,100	200
Portable MD player	940	3,400	550
Mobile phone[40]	1,500	3,800	300

E-waste, components like PWB, and fractions from e-waste dismantling have economic values due mainly to their contents of precious metals, in particular gold, silver and sometimes palladium, and copper. Figure 7 gives indicative examples of prices buyers pay for different grades of PWB taking into account treatment charges, but not transport cost.

[39] Source: Masahiro Oguchi, Shinsuke Murakami, Hirofumi Sakanakura, Akiko Kida, Takashi Kameya: A preliminary categorization of end-of-life electrical and electronic equipment as secondary metal resources, in the International Journal of Integrated Waste Management, Science and Technology, Waste Management 31 (2011) 2150 – 2160, ELSEVIER, 16 June 2011, www.elsevier.com/locate/wasman

[40] Please note that the precious metal concentrations for mobile phones are usually lower.

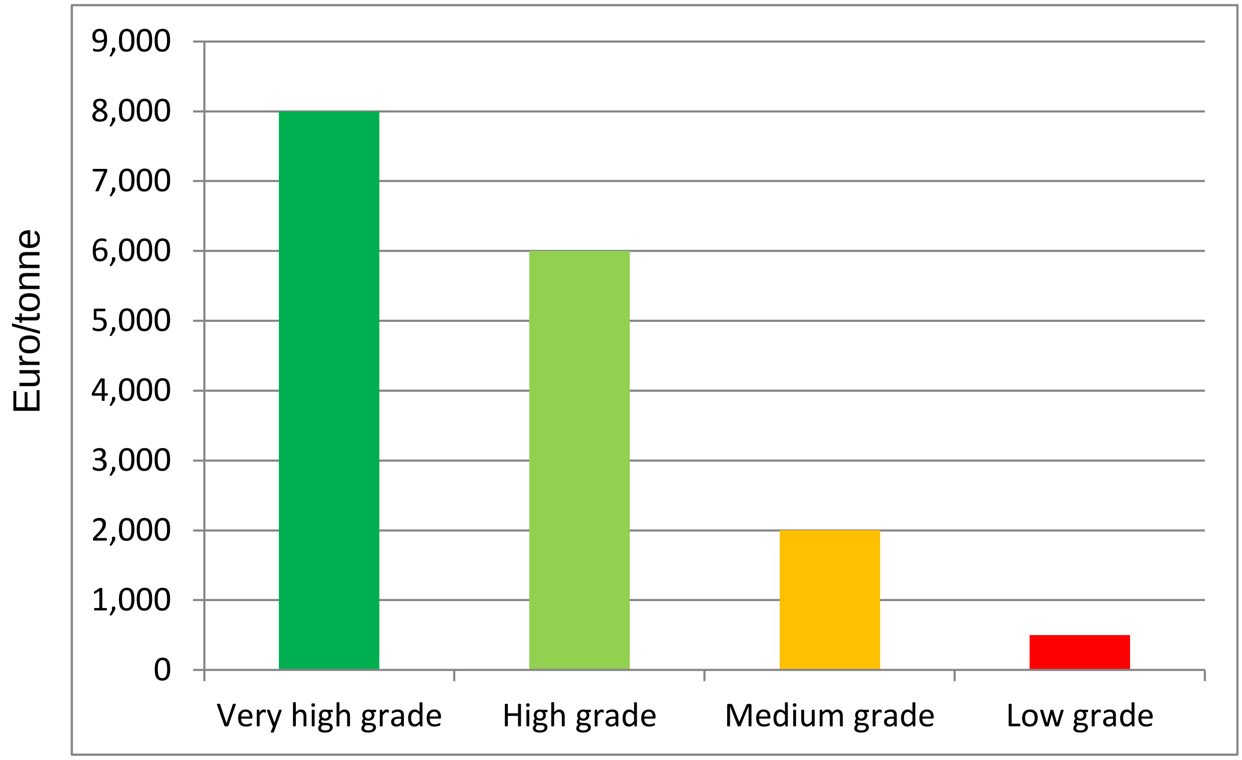

Figure 7: Indicative price examples for different material grades

The above prices are indicative. They are based on average prices of several pre-processors and smelters in 2014. The exact prices depend on the current metal prices, the exact contents of precious metals and copper, and on the business conditions of the individual processor.

Examples for very high grade e-waste are mobile phones without batteries. PWB from computers contain high grade PWB, and medium grade PWB can be found in DVD players and recorders. PWB from CRT-TV are low or even very low grade PWB as can be seen in the above Table 4.

5.2 Principles of Cost and Revenue Calculation in Smelters

Smelters pay the owner of PWB or e-waste (fractions) for the content of precious metals (mainly gold, silver, palladium), and copper, which are therefore addressed as target metals (TM) in the following. Smelters do not pay for other metal contents in the PWB. Vice versa, the customer pays for the processing of the PWB in the smelter. Smelters use a similar principal scheme to calculate the processing prices and the financial return to the customer, although, however, with variations.

Lot Charge

Fractions are treated in lots, ranging from a few tons up to 50 t and more of material per lot. The customer is charged a lot charge, which is a fixed amount per lot, not per tonne of material.

The lot charge in principle reflects the cost for the analyses of the metal content in the material to be treated, for example a copper fraction from mechanical pre-treatment of e-waste or high grade printed wiring boards . Not all smelters apply such lot charges, some also charge a certain amount per tonne of material for sampling and analyses.

Treatment Charge

The customer pays the treatment charge, which the smelter calculates per tonne of material to be processed in the smelter. The treatment charge goes back to the efforts for handling and processing the material.

Metal Credit and Minimum Deduction

For PM and possibly for copper depending on the individual smelter, not 100 % of the analyzed contents will be paid for, but the analyzed content will be reduced by certain percentage, the metal credits, for example 5 % for gold[41]. The metal credits can be different for each TM, and they are specific for each smelter. The technical background of the metal credit are the metal losses throughout the processing in the smelter.

When the contents of TM is below a certain threshold, e.g. in low and grade materials, the "minimum deduction" will apply. This minimum is specific for each metal. The minimum deduction is indicated as amount of metal content to be subtracted per tonne of material to be processed, e. g. 5 g/t for gold[41]. The minimum deduction goes back to the technical fact that the content of a metal in the slags cannot drop below a certain minimum.

The minimum deduction applies if the absolute reduction of the analyzed content resulting from the metal credit is less than the minimum deduction. In the above example for gold, the analyzed content of gold will be reduced by 5g/t once the metal credit is less than 5 g/t. The threshold level X can easily be calculated as quotient of the minimum deduction D and the metal credit C:

$$X = \frac{D}{C} = \frac{5\ \frac{g}{t}}{5\ \%} = 100\ \frac{g}{t}$$

Equation 1: Minimum deduction threshold

X minimum deduction threshold
D minimum deduction
C metal credit

Figure 8 illustrates the effect of the minimum deduction for the above gold example.

[41] The exact values of the metal credit and the minimum deduction are individual for each smelter!

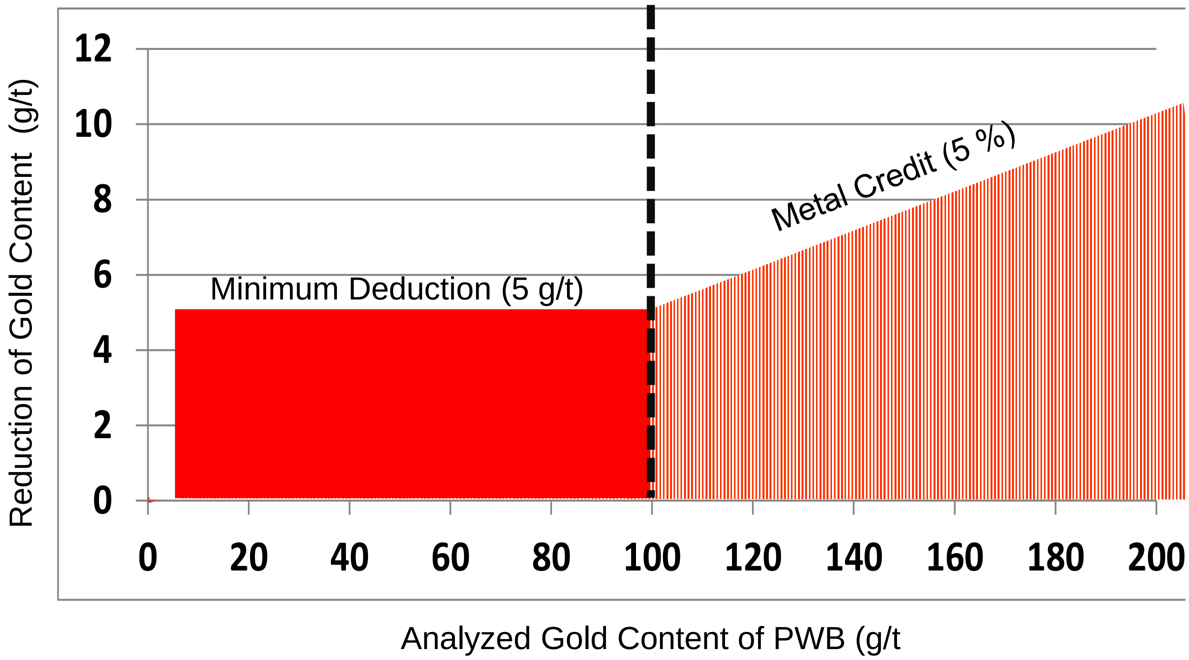

Figure 8: Reduction of gold content due to metal credit and minimum deduction

For gold concentrations below 100 g/t, the minimum deduction applies. The metal credit as well as the minimum deduction apply to gold, silver and palladium and all other precious metals, and in principle also to copper, even though with different values for the various metals.

The minimum deduction considerably reduces the revenues, and the negative effect increases with decreasing TM concentrations. Figure 9 shows, based on the above example of gold, that the percentages of reduced gold content increase exponentially with decreasing gold concentrations.

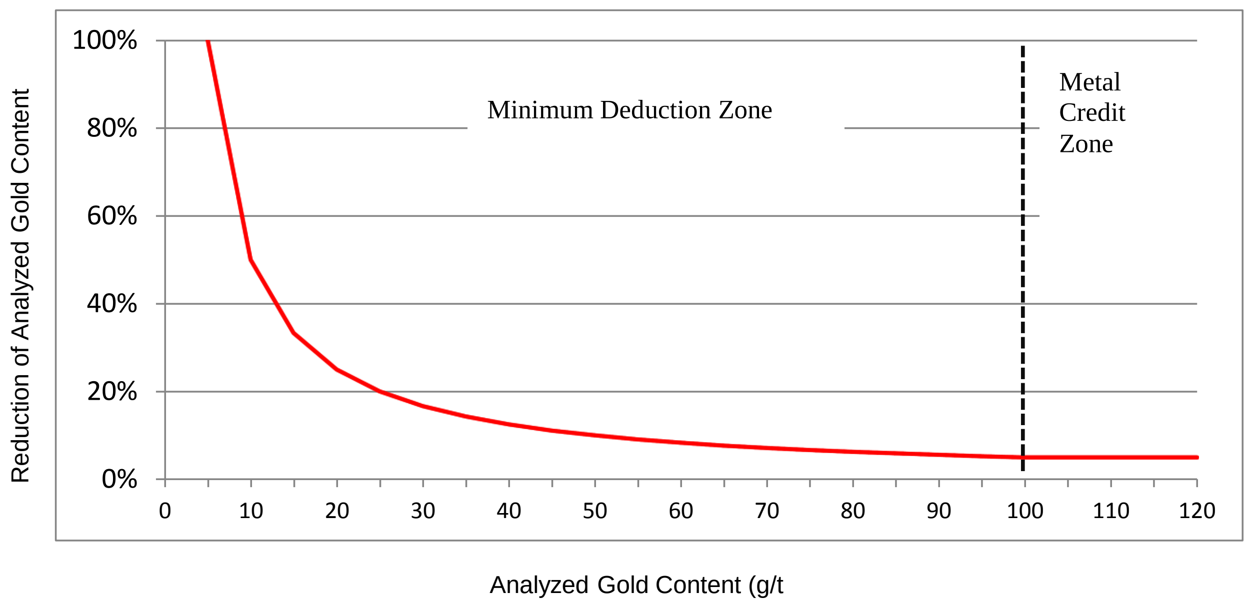

Figure 9: Reduction of gold content in percentage due to the metal credit and minimum deduction effect

The metal credit reduction is more favorable for the customer than the minimum deduction, as the minimum deduction is much higher in percentages than the metal credit. The above Figure 9 illustrates the exponentially growing percentage for which the analyzed gold concentration is reduced due to the minimum deduction. Starting from 5 % for a gold concentration of more than 100 g/t, the actual reduction of the gold content increases to 10 % at 50 g/t, to around 20 % at 25 g/t, and then steeply increases. The exact values for the metal credit and the minimum deduction are different for each smelter so that the effect varies, but the principle nevertheless applies in all smelters to all precious metals, and in parts also to copper. Depending on the individual smelter, the minimum deduction can already start taking effect for medium grade PWB. Mainly due to the minimum deduction effect, it is not profitable to treat low grade PWB directly in smelters without pre-treatment.

Reduction of the Reference Metal Price

In Europe, the payments for the metal contents is based on the LME/LBMA (London Metal Exchange/London Bullion Market Association) price. However, smelters reduce this price for a certain percentage. The percentage of this price reduction is specific for each metal and differs from smelter to smelter. The minimum deduction or the metal credit is subtracted from the analyzed TM contents. The smelter pays the owner of the material for these reduced contents according to the reduced LME price for each of the TM.

Refinement Charge

The smelter charges the customer for the refinement of the PM and copper, based on the analyzed metal concentrations less the metal credit or minimum deduction.

Penalties

Smelters can charge the customer for the presence of metals which induce additional costs to prevent for example that they disturb certain processes and/or contaminate the main products, e.g. copper. Whether and for which metals a smelter charges penalties depends on the process technology. The penalties are metal and smelter specific. Such metals can be nickel, cadmium, bismuth, beryllium or antimony, for instance.

They are generally indicated as payment per percentage of metal content over a certain threshold per tonne of material. As an example, a smelter may charge 7 Euro per 0.01 % of beryllium content over a threshold of 0.05 %per tonne of material to be treated. If the analyzed beryllium (Be) content would be 0.08 % in ten tonnes of material, the total penalty would be calculated as follows:

$$F_{Be}=(0.08\ \% - 0.05\ \%) \cdot \frac{7\ Euro}{0.01\ \% \cdot 1\ t} \cdot 10\ t = 210\ Euro$$

Equation 2 shows the general calculation scheme for penalties, which may, however, vary from smelter to smelter.

$$F = \sum_n [(A_n - t_n) \cdot f_n] \cdot M$$

Equation 2: Calculation of penalties

F	*penalties (Euro)*
n	*type of metal which is penalized (e.g. Ni, Be, Bi…)*
A	*analyzed metal content (%)*
t	*threshold (%)*
f	*charge per percentage of metal content (Euro/(%˙t))*
M	*total mass of material to be treated*

If more metals are penalized, for example beryllium and nickel, the overall penalty would be calculated as the sum of the individual penalties.

Shredding Charge

Shredding in smelters, if at all, normally only occurs as simple comminution of the PWBs to enable a proper sampling and/or processing of the WEEE fraction. It is not a part of a mechanical separation process as applied in pre-processing.

Overall Revenue Calculation

The next equation shows the overall calculation of recycling cost and revenues in a copper smelter for a copper fraction containing different metals. The penalties F will be calculated according to Equation 2.

$$P = M \cdot \sum_i [(A_i - a_i) \cdot (k_i \cdot K_i - R_i) - T - S] - L - F$$

$$P = M \cdot \sum_i [c_i \cdot A_i \cdot (k_i \cdot K_i - R_i) - T - S] - L - F$$

Equation 3: Price calculation with minimum deduction (top) and metal credit (bottom)

P	*price, revenue*
M	*total mass of material to be treated*
c	*metal credit (%)*
A	*analyzed TM content (g/t)*
a	*minimum deduction (g/t)*
K	*official metal price (in Europe London Metal Exchange (LME)) in €/g*
k	*Reduction of official price (%)*
i	*type of metal (Cu and precious metals)*
R	*refinement charge (Euro/t of metal to be refined after metal credit or minimum deduction)*
T	*treatment charge (Euro/t of material to be treated)*
S	*shredding charge (Euro/t of material to be treated); NOT mechanical separation*
L	*lot charge (Euro/lot)*
F	*penalties (Euro)*

The customer (owner of the material to be treated) will receive the revenue P for the contents of copper and precious metals. The revenues are calculated individually for each of the TM. The total payment to the customer is the sum of the revenues for each of the TM.

5.3 Conclusions from the Cost/Revenue Calculations for the Pre-processing of E-waste

The insights into smelters' cost and revenues calculation scheme can be used to optimize the pre-processing in order to maximize the economic benefits. The above Equation 3 can, however, only be a base for general principles and conclusions. Whether and to which degree these principles apply depends on the individual conditions of each smelter and must be checked with the smelter's conditions to which the DMF will sell the material.

5.3.1 Basic Optimization Strategies

The above Equation 3 contains charges and revenues with different dependencies:

- The lot charge L in most cases is a fixed price[42], which neither depends on the analyzed TM contents A_i nor on the size M of the lot.
- The treatment charge T (and the shredding charge S, if applicable) only depend on the size M of the lot, they are independent from the TM content.
- The revenues as well as penalties depend on the analyzed concentration A_i of the TM and on the total mass M of the lot. Penalties depend on the analyzed concentration of substances which smelters penalize above a specific threshold and on the total mass M of the lot (see Equation 2 on page 34).

These basic insights into the cost and revenue calculation of smelters can give guidance for the optimization of the pre-processing in order to maximize the economic benefits.

Minimum Lot Size and Optimization of Lot Size

The lot charge does not depend on the amount of material per lot, but it is paid per delivery of a container or material to the smelter. The same lot charge thus applies for a container of 5 t like for a container of 10 t. It is therefore favorable to deliver larger lot sizes. For example, instead of delivering two 20 ft container per year, it is more economical to ship one 40 ft container. The lot charge would be the same, which means that it can be reduced for 50 % per tonne of material delivered with the larger delivery.

Not all smelters apply the lot charge. Smelters set or recommend, however, at least minimum lot sizes. Depending on the material, these minimum sizes are around 5 t and more, but can also be as

[42] This does not necessarily apply for all smelters. The lot charge may also be calculated depending on the lot size.

low as 1 t only, e.g. for specific very high grade materials.[43] The minimum lot sizes are different for each smelter. While a smelter may, for example, only accept a minimum of five tonnes for all kinds of input materials, others may have minimum lot sizes for each grade of input material from one tonne to several tonnes. In any case, it is more economical to deliver larger lot sizes, even if a smelter does not apply a lot charge. The cost of transport for a 40 ft container from Djibouti to Europe is, for example, around 1,100 Euro, which is only around 100 Euro more expensive than for a 20 ft container[44].

The exact conditions and requirements concerning minimum lot sizes, packaging and transport conditions depend on the individual smelter.

Reduction of the Treatment Charge

The treatment charge depends on the total lot size. It is charged per tonne of material to be treated, regardless of the TM concentration in this material. The treatment charge can therefore be reduced if all parts which do not contain TM are removed from the material. Low grade PWB, for example, contain larger parts made from aluminum and steel. Removing these parts reduces the total weight of the PWB lot and thus the treatment charge.

Increase of the TM Content

The revenues directly depend on the concentration of TM in the material to be treated in the smelter. It is therefore beneficial to increase the TM concentrations as far as possible in the pre-treatment phase, in particular for low grade materials.

Removing heavier and larger parts that do not contain TM from PWB is a first and crucial step to increase the TM concentration. The total weight of the fraction goes down, while the amount of TM in the fraction remains the same. The TM concentration thus increases, and the treatment charge is reduced, as described above. At least for low and very low grade materials, a further mechanical pre-processing may be required to remove non-TM metals and plastics.

5.3.2 Recommendations for Pre-processing

The above basic optimization strategies must be applied in the daily operations of manual e-waste dismantling at the DMF. The following sections give recommendations for the dismantling, sorting and manual pre-processing of PWB.

Separate Storage and Treatment of High Grade PWB

Figure 9 on page 32 shows that the minimum deduction effect rapidly reduces the analyzed content of the TM and thus the economic profit. The minimum deduction effect should therefore be avoided. High grade PWB should therefore be removed from e-waste and be stored and treated

[43] Data from various smelters
[44] Source: Worldloop

separately in smelters. They should not be mixed with other PWB grades. As high grade PWB contain high amounts of gold, a dilution of such PWB with lower grades would result in high economic losses in case the total concentration sinks to a degree where the minimum deduction applies.

Removal of Larger Steel and Aluminum Parts from PWB

The lot charge and the treatment charge are calculated based on the weight of the material to be treated. The smelters only pay the contents of copper and PM. All other materials should in principle be removed from PWB. They increase the weight and thus the lot and treatment charge, but do not contribute to the revenues. In practice, only few materials can be removed without additionally loosing copper and PM.

In a manual disassembly process, trained staff can in particular remove larger steel and aluminum parts, e.g. heat sinks or steel cores from inductor coils. Steel and aluminum cannot be recycled in copper smelters but will form slags, while they can be sold as secondary raw materials when removed from the PWB prior to their treatment in the smelter.

An example calculation shows the economic benefits of removing larger components of metals that are not TM. Assuming a 10 t lot of low grade PWB for example from CRT-TV has the composition in Table 5.

Table 5: Exemplary contents of TM in a low grade PWB

Lot Size (t)	Cu (kg/t)	Ag (g/t)	Au (g/t)	Pd (g/t)
10	120	280	16	8

Very low and low grade PWB often contain larger pieces of non-TM, mostly aluminum or steel parts, which should be removed to prepare them for the smelter treatment and to improve the economic yield. Assuming the removal of larger steel and aluminum parts in a pre-treatment step reduces the weight of this fraction for 25 %, the same amount of copper, gold, and silver would be concentrated in an 8 t lot resulting in higher concentrations of these metals in the lot as illustrated in Table 6.

Table 6: Concentrations of metals in lot after removal of steel and aluminum parts

Reduced Lot Size (t)	Cu (kg/t)	Ag (g/t)	Au (g/t)	Pd (g/t)
8.0	150	350	20	10

In an exemplary calculation, the treatment of the original and the pre-treated lot in a smelter would yield the revenues and cost displayed in Table 7.

Table 7: Comparison of profits from copper smelter treatment of original and pre-treated lot of10 t of low grade PWB

	Charges (Euro)	Revenues (Euro)	Total Overall Revenues (Euro)	Revenues per tonne (Euro/t)
Pre-treated Lot	-7,911	9,574	1,663	208
Original Lot	-9,602	8,864	-739	-74
Differences	**1,691**	**710**	**2,402**	**282**

Note: The calculation is only indicative and does not apply to individual smelters. Individual smelters' charges and revenues are confidential and can therefore not be disclosed.

Even though the figures in the above table are only indicative, they show that the treatment of unprepared low grade PWB in a copper smelter economically does not make sense. Such PWB should undergo a pre-processing, which at least removes larger aluminum and steel parts.

Additionally, the pre-processing generates steel and aluminum fractions that can be sold locally, while these materials would be lost in the copper smelter treatment. In the above example, 2,000 kg of steel and aluminum parts were removed from the PWB, which generate additional income. The additional income for 2,000 kg of steel scrap would be 520 Euro based on a price of at least 0.26 Euro[45] (7 Birr) per Kilogram of steel scrap. Aluminum scrap is more expensive (15 Birr/kg). If part of the metals removed from the low grade PWB are aluminum, the total value of the both fractions would generate more than 520 Euro instead of increasing the treatment charge in the smelter.

Further on, the pre-processing would reduce the volume and weight of the remaining PWB fraction and thus also decrease the logistics cost for shipping the PWB to the copper smelters, which are outside Ethiopia, e.g. in Europe, Canada or Japan.

The labor cost for the removal of these parts must, however, be subtracted from the overall profit. A cost benefit analysis must show whether the overall economic result is sufficiently positive to justify the additional efforts for the removal of the steel and aluminum parts. In countries of lower income levels with cheaper manual labor like in Ethiopia compared to, for example, most European countries, there is a good chance to improve the economical and the ecological benefit, and additionally create jobs by a deeper dismantling level of PWB. The profitability will be assessed in the Business Model task force which will be started later in 2014.

5.3.3 Mechanical Pre-processing of Lower Grade PWB

Compared to high grade PWB, in particular (very) low grade PWB, besides larger steel and aluminum parts, contain higher shares of organic materials (e.g. resins forming the PWB base) that

[45] Exchange rate of 7 July 2014

just increase the volume and the weight and thus the transport cost, and the lot and treatment charge in the smelters. The removal of these plastics could therefore further increase the revenues of a smelter treatment. These plastics can, however, not be removed manually. After the removal of all pure materials like aluminum and steel parts, a mechanical shredding and separation process is to be taken into account. Shredding and mechanical separation in principle result in four main fractions:

- non-ferrous metal fraction (copper fraction, target fraction for Cu, PM, Sn, Pb, etc.)
- aluminum fraction
- steel fraction
- plastics fraction

The mechanical treatment thus in principle separates non-TM from the TM resulting in a concentrate of copper with a higher concentration of TM compared to the untreated PWB.

A shredding and mechanical separation process can, however, not achieve a complete separation of all TM into the copper fraction, but will produce losses of these metals to the other fractions from which they cannot be recycled.[46] As very high and high grade PWB contain high amounts of PM and copper, these PWB and possibly also medium grade PWB should be treated directly in copper smelters after a manual pre-, but without a mechanical pre-processing. Loosing, for example, 40 % of the PM from high grade PWB in the mechanical pre-processing causes considerable economic losses. For lower grade PWB, this effect is acceptable, because loosing 40 % of small amounts of PM economically is less damaging than the positive effects of the increasing TM concentration achieved in the copper fraction.

Additionally, the steel and aluminum fractions can be sold, which otherwise would become slags in the smelter. The plastics fraction can be incinerated in incinerators with energy recovery or cement kilns with flue gas cleaning. Recycling might be an option as well.[47]

5.3.4 Removal of Valuable Components

PWB can contain valuable components with metals that are not TM in smelter treatments. An example are tantalum capacitors, which are mainly used in mobile phones and other mobile products. Figure 10 shows examples of tantalum capacitors.

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[46] A more detailed assessment of precious metal losses for different mechanical pre-processing approaches can be found in Chancerel 2010 and in Schöps 2010

[47] Cf. section 6 on page 25 about plastics

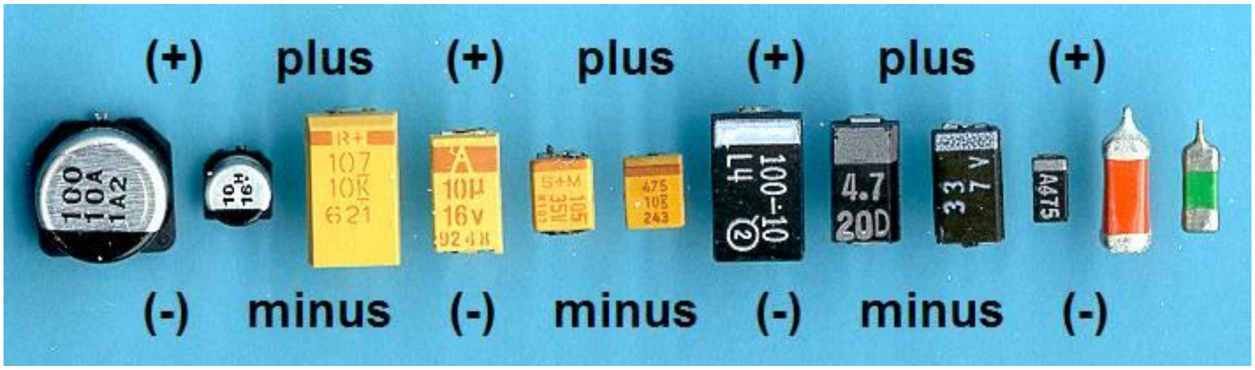

Figure 10: Tantalum capacitors[48]

Tantalum is an expensive metal, and a conflict mineral. Its price is around 400 Euro/kg[49], which is similar to silver. The tantalum from capacitors can be recycled, and there are companies buying and processing scrap tantalum capacitors.[50]

When components are removed from PWB, it must be made sure that they do not contain precious metals, which may then be lost in the subsequent recycling steps. The removal of components therefore needs care and proper training of staff to avoid economical and financial losses. The additional labor cost must be balanced with the additional income generated from the sales of removed components.

5.3.5 Reduction of Penalized Metals

Penalized metals, for example nickel and/or and beryllium depending on the smelters, may be difficult to remove. Nickel is, e.g., used as a diffusion barrier in components and therefore common in PWB. Beryllium is also a constituent of some components and in rare cases of ceramic PWB. Their removal may thus result in loss of precious metals and is thus not recommended. If thresholds are foreseeably exceeded, mixing PWB fractions with other PWB or materials may be possible as long as they are of the same grade. These operations require profound knowledge about the composition of fractions, and the penalties depend on the individual smelter. Activities to avoid penalties should therefore only be taken if such penalties actually result in considerable reductions of the revenues, which in most cases is not to be expected.

Different smelters charge different penalties. In case fractions permanently have higher contents of problematic metals, possibly the choice of an appropriate smelter may solve the problem as long as the overall economic outcome is favorable.

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[48] Source: Wikipedia, retrieved from https://upload.wikimedia.org/wikipedia/commons/d/d8/Cap-elko-smd-polarity.jpg, accessed 9 April 2014

[49] Metal pages, http://www.metal-pages.com/metalprices/tantalum/, accessed 9 April 2014

[50] For example see Tantalum Recycling, http://tantalumrecycling.com/; more companies buying and processing scrap tantalum capacitors to be found on the internet

5.4 Potential Buyers and Business Conditions

Potential Buyers and Business Partners

Pre-processing operators and smelters could be identified as potential buyers, and WorldLoop, a non-governmental organization (NGO). Annex VI on page 70 lists the contact details. The selected buyers are assumed to operate environmentally sound and in compliance with environmental and health and safety regulations due to their locations in the European Union, Japan and Canada, where strict environmental regulations and controls are in place. It is advisable, nevertheless, to require environmental, health and safety certificates in the request for quotation to make sure the DMF materials are processed adequately.

In the investigations, principal types of business conditions and business models of potential buyers crystallized. The buyers will provide their individual conditions for purchase and transportation to the DMF upon a request for quotation (RFQ).

5.4.1 Content-based Model

Once the material is delivered to the smelter, it will be analyzed for its contents of TM, and the smelter will calculate the revenues for the customer as described on page 30. The exact terms and conditions are beforehand agreed on in a contract. Further requirements and conditions apply as described below.

Payment Delay

There is generally a delay of several weeks to months between the delivery of the material and the actual payment to the customer. The exact conditions may differ from smelter to smelter. Smelters may pay a certain percentage of the approximate material value upon delivery of the material already. The technical reason for the delay between delivery and payment is that it can take weeks until the TM contained in a fraction are actually physically available to be sold.

Minimum Lot Sizes

Smelters either do not accept materials below a certain threshold, the minimum lot size, or at least prefer quantities larger than that. Generally, minimum lot sizes are in the range of one to five tonnes or even higher depending on the material grade, as explained on page 35.

Exclusion of Materials and Components from Treatment

Some smelters may not accept PWB or other fractions containing certain components, or penalize certain metals. Examples are large capacitors, which may contain polychlorinated biphenyls (PCB). “Large” may mean for example capacitors with more than 2 cm of diameter. The definition depends on the smelter. These capacitors need to be removed. Otherwise, the smelter possibly will not accept the material, or charge an extra penalty.

Smelters do not treat all kinds of PWB. Depending on the individual smelter, for example untreated PWB from TV or similar equipment containing massive, large aluminum and steel parts may not be accepted, or fractions with a high share of plastics.

5.4.2 Fixed Price Business Model

Companies offering fixed price business (FPB) conditions buy PWB for a price, which is contractually fixed prior to delivery. In the detail of the business conditions, the individual buyers are different. This business model offers some advantages in particular for smaller scale businesses. The entire delivery will be paid within some days after the buyer has received the material, and the customer (e.g. the DMF) has no price risk related to metal prices and actual metal contents of the PWB based on analyses. The buyers contacted in the course of this downstream market study do not set minimum amounts of materials per transaction and per PWB quality.

Buyers may allow several grades of PWB to be delivered in one container, others require a separation of the materials into several grades and subgrades. The customer has to organize the transport and to cover all logistics cost for the transport to the buyer. As all of these buyers are located in Europe or elsewhere outside Ethiopia, site visits to inspect the materials are impossible. The prices can be fixed based on photos of the materials to be sold.

The advantages the FPB model offers for customers creates risks for the buyer, as the actual average composition of the materials in a lot is unknown. Accordingly, buyers will set prices with a safety margin to prevent financial losses.

5.4.3 Framework Contract Business Models

Besides the above business models, WorldLoop, an NGO, offers a package comprising all or several kinds of components and fractions from e-waste treatment. WorldLoop does not buy the material, but has an agreement with a smelter, and organizes further (mechanical) pre-processing of the PWB or other materials if required. WorldLoop offers a framework contract including the following services and conditions:

- The NGO manages all contractual relations with the transporter, the pre-processing operators and the smelter
- All kinds of PWB grades are accepted
- Analysis-based business model in cooperation with a smelter
- Transport
    - The NGO organizes the transport from the port (Djibouti) to the final destination (, or possibly another country if further pre-processing is required)
    - Transport to the port has to be organized by the customer (DMF)
    - The customer (DMF) covers all logistics cost, from its own site to the port and from the port to the final destination
- The NGO charges a service fee for each transport for the above services

6 International and National Downstream Markets for Plastics

The plastics fraction stored at the DMF is not sorted according to types of plastics and therefore is a mix of different plastics. The fraction contains all types and qualities of plastics as dismantled from the e-waste treated at the DMF. As at least some of the plastics contain brominated flame retardants, the plastics fraction must be considered to be hazardous.

6.1 Properties and Quality Criteria for Plastics from E-waste

Quality criteria for plastics fractions are, among other criteria[55]:

- Homogeneity, meaning the plastics fraction ideally should only consist of one type of plastics
- The fraction should consist of ABS, (HI)PS, PP or PE without brominated flame retardants
- The plastics parts in the fraction are free of stickers or other adhesions
- No contaminations with non-plastic materials, e.g. wood and metals

6.1.1 Brominated Flame Retardants

Plastics with brominated flame retardants are considered as hazardous wastes. The European RoHS Directive[51] even bans two specific groups of brominate flame retardants, polybrominated biphenyls (PBB) and polybrominated biphenyl ethers (PBDE), from use in EEE from 2006 on. Many other countries have adopted regulations similar to the European RoHS Directive. PBB and PBDE have a large potential to generate highly toxic dioxins and furans in case of fire or if they are incinerated in incinerators that are not equipped to handle such materials. As the bans affect the globally manufacturing electrical and electronics industry worldwide, these flame retardants have been phased out in most EEE. Nevertheless, they may still be found in older electrical and electronic equipment, in particular PBDE, while PBB has hardly been used in EEE[52]. Primary or recycled plastics containing more than 0.1 % (weight) of one of these flame retardants can therefore not be used in new EEE, and they should not be used in other applications either due to the hazardous properties of these flame retardants. Beyond that, brominated and other flame retardants may also change the physical properties of plastics, resulting in inferior performance of recycled products and in "downcycling" of the materials.[53]

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[51] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast RoHS Directive); retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT; accessed 5 June 2014

[52] Source: European e-waste pre-processor

[53] Shaw 2010

Other brominated flame retardants besides PBB and PBDE are not banned, and their potential to generate dioxins and furans is lower compared to PBB and PBDE. As the analytical differentiation of the various brominated flame retardants in plastics is a complex and thus costly task, only the content of BFR is analyzed in plastics from e-waste, knowing however, that it may contain a certain share in particular of PBDE. The various types of BFR are therefore not differentiated in the following sections, but generally addressed as BFR including banned and still legally used ones.

6.1.2 Types of Plastics in E-waste[54]

Acrylonitrile butadiene styrene (ABS), high impact polystyrene (HIPS), polystyrene (PS), polypropylene (PP) and polyethylene (PE) are the economical drivers for the recycling of plastics from E-waste and are hence the target plastics (TP) for the dismantling and recycling activities. ABS, (HI)PS, PP and PE from e-waste may always contain BFR. Markets for recyclates from other types of plastics are under development, but are currently not yet available. Figure 11 shows the average quantities of plastics with flame retardants in the plastic mix from e-waste. There can be large variations though, e.g. up to 70 % of the plastics from monitor housings can have BFR.

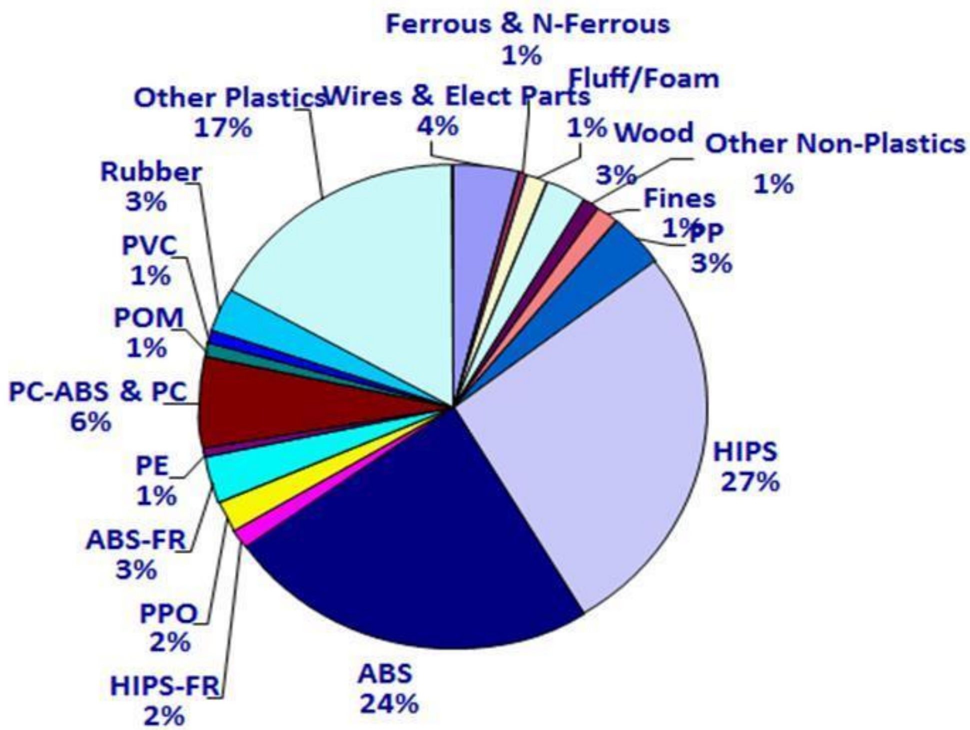

Figure 11: Typical plastics fraction from mechanical e-waste treatment[55]

FR: brominated flame retardants incl. PBB and PBDE

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[54] Source of information in this section if not otherwise indicated: European e-waste pre-processor
[55] Source: European e-waste pre-processor

(HI)PS and ABS that are free of flame retardants have the highest share in such fractions. The contents of PE and PP are only around 1 – 3 %. PE and PP can, however, easily be separated from such plastics mixes with water. They are the only types of plastics that are lighter than water and thus float on the water surface, while all other plastics sink to the bottom. Once separated, PP and PE can be recycled.[56]

6.2 Potential Buyers, Prices and Conditions for Sales of the DMF Plastics Fractions

Unlike mechanical treatment, the manual dismantling of e-waste can generate purer plastics fractions that are not mixed with metals and other contaminations like the plastics fraction from a mechanical pre-processing in the above Figure 11. A typical mix of plastics from manual dismantling of e-waste consists of around 60 % of ABS, (HI)PS, PP and PE[57]. Potential buyers of the DMF plastics fraction were investigated on national and international level.

Currently, there are sixty private owned factories registered under the Addis Ababa Chamber of Commerce[58] working in the plastic industry sector in Ethiopia. Almost all of them use imported semi processed plastics or have the capacity to recycle plastic bags, jerry cans, water bottles, oil containers or old plastic shoes and other similar materials preferably of their own brands. Discussions with their respective procurement officers revealed that only one of them, Ethiopia Plastic Industry[59] (EPI), which is a government owned public enterprise, may be interested to buy the plastic fractions. Prior to offering price and business conditions for purchasing the plastics, EPI would like to assess the quality of the plastics fraction to determine the compatibility of its chemical and physical properties with their products and their processes in their plants. EPI indicates a minimum of 500 kg per transaction to minimize transportation cost and save time for testing. However, at the time when the study was finalized in November 2014, the team was informed that the industry has sufficient amount of used plastics in stock and would only take further steps for testing and initiating a purchasing process once these stocks are sufficiently processed. It could therefore not be finally clarified whether and under which conditions EPI would buy the plastics, and what the company would actually do with it.

On the international market, the DMF plastics fraction can achieve prices of around 100 Euro per tonne[60] including logistics cost for transport from Djibouti to the recycling plant, provided the following conditions apply[61]:

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[56] Source: European e-waste pre-processor

[57] Source: Plastics recycling company, status March 2014

[58] Addis Ababa Chamber of Commerce and Sectoral Association, retrieved from http://addischamber.com/cd2013/asp/sectorser.asp; last access 28 November 2014

[59] This industry is a Public Enterprise owned by the Ethiopian Government and operated under the Metals and Engineering Corporation (METEC), which is also owned by the Ethiopian Government

[60] Plastics prices are highly volatile. The above price is only valid for March 2014 when this information was investigated.

[61] Source: Plastics recycling company, status March 2014

1. The material consists of plastics only.
2. The material contains around 60 % of ABS, (HI)PS, PP and PE
3. Stickers or other adhesions should be removed from the plastics parts
4. The material will be delivered to Djibouti.
5. The material will be put in a 40 feet HC container.
6. The container is filled with at least 22 t of plastics.

Figure 12 illustrates a standard 40 ft HC (high cube) container.

Door Opening Dimensions

Inside Dimension

Measure	Length	Width	Height
Millimeters	12,032	2,350	2,700
Feet	39' 5 5/8"	7' 8 1/2"	8' 10 1/4"

Capacity	76.3 cbm / 2,694 cbft
ISO Type Group	45 GP
ISO Size Type	45 G1

Weight

Measure	Max Gross	Tare (Weight)	Max Payload
Kilograms	32,500	4,010	28,490
Pounds	71,650	8,840	62,810

Figure 12: Standard 40 feet high cube (HC) container[62]

[62] Source: Hapag Lloyd, retrieved from http://www.hapag-lloyd.de/en/fleet/container_40_standard_highcube.html; accessed 14 July 2014

Based on visual inspection, the plastics fraction stored at the DMF does not contain non-plastic parts and thus complies with the first condition. As all plastic parts were dismantled from e-waste, the second condition should be met as well if a 60 % content of ABS, PS, PP and PE is typical for plastics fractions from manual e-waste dismantling.

The DMF can currently not comply with the other conditions. It has stored around 8 t of plastics only[63], which is far below 22 t. Further on, a 40 feet HC container has around 76 m^3 internal volume[64], and 22 t of plastics will only fit into such a container if the plastics are comminuted or pressed into bales.

6.3 Improvement Options

6.3.1 Achieving Economy of Scale Amounts of Plastics for Sales

The DMF should check whether it is economically profitable to purchase a shredder or a press that comminutes the plastics parts or presses them into bales. The comminution or compression would reduce the volume of the plastics fraction and increase the DMF's storage capacity. The higher sales prices, the economy of scale benefits for the plastics fractions and the overall more efficient use of the DMF's storage capacities must at least compensate the purchasing and operation cost of such equipment, or the cost of the service.

The profitability of a plastics shredder, a press or any other equipment, requires a long-term secured and permanent inflow of e-waste to the DMF. Such purchases should therefore be flanked by legislative measures and awareness campaigns to make sure e-waste can be collected from public entities, private companies and private households, and will be treated at the DMF. The profitability and sustainability of purchasing equipment can be assessed in the task force facility optimization and in the business plan development task force.

6.3.2 Improving the Quality and Prices of the Plastics Fractions

The DMF with its manual dismantling process can avoid contaminations of the plastics fractions with metals and other materials, and stickers and labels can be removed from the plastics parts to maintain or increase the current quality according to the quality criteria of plastics for recycling.

In principle, the DMF could further improve the quality and thus the achievable prices if the share of TP in the plastics fraction increases. As a rule of thumb, the price of a plastics fraction rises for around 4 Euro per tonne if the share of ABS, (HI)PS, PC, PP and PE increases for around 1 % in

[63] Status March 2014
[64] Source: Hapag Lloyd, retrieved from http://www.hapag-lloyd.de/en/fleet/container_40_standard_highcube.html; accessed 14 July 2014

total.[65] While a fraction with 60 % of TP achieves a price of around 100 Euro per tonne, a fraction with 70 % of these plastics could be sold for around 140 Euro per tonne. Fractions of pure ABS, (HI)PS, PE, PP or PC can achieve higher prices. Pure fractions of ABS or PC can be sold at highest prices with around 400 Euro per tonne[66].

Principle Improvement Options

Figure 13 illustrates principal steps based on the international market conditions and taking into account the required technical means to improve the quality of the DMF's plastics output.

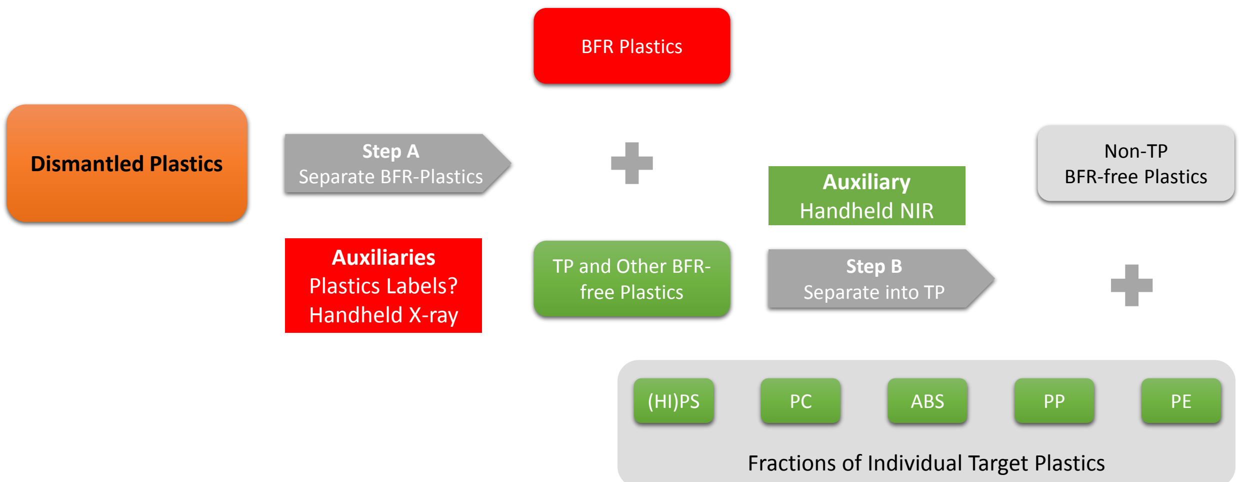

Figure 13: Principle Plastics Sorting Options[67]

The plastics fractions could in principle be improved in two steps:

A. Separation of BFR-containing plastics from the dismantled plastics fraction resulting in

   1. a mix of BFR-free TP and other BFR-free plastics;

   2. a mix of BFR-plastics;

   The mix of BFR-free TP and other BFR-free plastics contains a higher share of TP and thus achieves a higher price. The mix of BFR-plastics would have to be disposed of, It should best be incinerated under controlled conditions. PVC, even if BFR-free, should be added to the BFR-plastics fraction, as its incineration may generate dioxins and

[65] As plastics prices are highly volatile, this rule only applies for the time when the investigations for this part of the report were finalized (March 2014).
[66] Cf. Bleher 2014, page 9; Plastics prices are volatile and can meanwhile differ from the above indicated price!
[67] More information about identification and sorting of plastics options can be found in the reports of Bleher 2014 and UNEP 2012.

furans and other toxic substances like polyaromatic hydrocarbons, pyrene and chrsysene[68].

The above plastics sorting steps require discriminating BFR and BFR-free plastics using technical auxiliaries like e.g. a handheld X-ray device.

B. Separation into individual TP fractions resulting in

3. fractions of individual TP, i.e. ABS, (HI)PS, PC, PE and PP;

4. a mix of BFR-free non-TP plastics;

If the individual TP fractions in B3 are pure enough, they can be sold at higher prices than the mix of TP in A.1. The BFR-free non-TP fraction in B4 could be sold as fuel substitute e.g. in cement kilns.

The proper identification of the TP requires technical auxiliaries, e.g. a handheld near infrared (NIR) device.

The viability of the above improvement steps crucially depends on how reliably the BFR-plastics and the individual TP plastics can be identified and sorted.

Viability of Sorting Based on Plastics Labels

Plastics parts, at least the larger ones, should be stamped or labeled to indicate the type of plastics and whether the plastics contain brominated flame retardants. The markings on the plastics parts, however, often are incorrect. No data were accessible to clarify the percentage of wrongly declared plastics types. It is therefore unclear to which degree of purity plastics can be separated based on these labels. Possibly, the share of wrongly declared plastics is so high that the sorting might result in fractions that are not or only insignificantly purer than the unsorted plastics fractions. This sorting process would then just increase labor cost. Additionally, even small contaminations can heavily affect the quality and thus the price of the fractions. This applies in particular for the individual TP fractions in B3, and for the fractions of BFR-free non-TP in B4. The latter, if contaminated with BFR, must be treated as hazardous material, best in a controlled incineration plant, and cannot be used as substitute for fossil fuels unless the facility is equipped to treat such materials safely.

The sorting of plastics according to step B therefore probably does not make sense based on the plastics labels, as contaminations affect the value of the generated fractions that their sales is not likely to outweigh the related labor and other cost of the sorting process.

Step A may be viable, as the increase of BFR-free TP in the generated fraction increases the achievable price for around 4 Euro per tonne and percent if the share of ABS, (HI)PS, PC, PE and

[68] Chemie.de Information Service, Polyvinylchlorid: http://www.chemie.de/lexikon/Polyvinylchlorid.html#PVC-Entsorgung; accessed 29 December 2014

PP increases[69]. This applies even if the fraction is not completely free of BFR-plastics. Wrong plastics identification labels may, however, also result in TP being sorted into the BFR-plastics TP fraction, which reduces the amount of saleable TP. The benefit in the end depends on the degree of incorrectly labeled plastics. This is unknown, and it would therefore require tests whether the various sorting exercises are profitable. Without such tests, it is not advisable to start any sorting activities based on the plastics identification labels.

Technical Means of Plastics Identification

For step A, handheld x-ray devices could be beneficial. Such devices can identify BFR-plastics. Step B would additionally require near infrared (NIR) handheld devices to identify individual plastic types.

The prices for such handheld devices start at around 15,000 Euro. Annex VIII on page 83 lists functional principles and examples for such devices. A proper training is required to achieve to achieve the maximum plastics identification reliability the devices can offer. In particular the x-ray devices need to be handled with utmost care to prevent health damages!

In principle, a float-sink-analysis with water could be used to separate PC and PE from other plastics. Unbrominated and unfilled PC and PE are lighter than water and therefore will float on the surface while other plastics types will sink to the bottom. PE and PC from WEEE normally are free from brominated flame retardants. In case they are brominated, their density is probably higher than that of water, as during the last years no such brominated plastics could be identified with a density below that of water.[70] Brominated and filled PC and PE will therefore not float on the water surface but sink to the bottom with the other plastics. The further separation of PC and PE would require further technical means like a NIR device for separation. It is, however, questionable, whether such an operation would actually increase the overall economic result. The separation causes additional cost, and, while a mix of pure PC/PE will achieve a higher price, the share of TP in the remaining plastics fraction and thus its price decreases.

The various sorting options should be carefully tested for their overall economic viability, and whether they can actually produce sufficiently pure fractions taking into account the reliability of the devices in practice and the local conditions. Otherwise, contaminations may reduce the prices of the fractions and depreciate the labor and analytical efforts of sorting resulting in a negative overall economic balance.

Additionally, sorting the plastics would make it even more difficult to achieve economy of scale plastics amounts within a reasonable time as the larger unsorted fraction from dismantling would be split into smaller sub-fractions. To achieve economy of scale for exports and to save storage capacity on its site, the DMF requires equipment to reduce the volume of the plastics fractions,

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[69] As plastics prices are highly volatile, this rule only applies for the time when the investigations for this part of the report were finalized (March 2014).

[70] Source: Martin Schlummer, Fraunhofer IVV; information provided via e-mail on 30 December 2014

e.g. a baler or a plastics shredder, which may be purchased in the course of upgrading the DMF's efficiency and capacity.

6.3.3 Disposal of Plastics with Brominated Flame Retardants in Ethiopia

Controlled Incineration[71]

The improvement options discussed in the previous section will generate a fraction of BFR-plastics. Poor-quality incineration of these plastics generates and releases high quantities of toxic degradation products, including dioxins and furans. Controlled incineration of materials with halogenated flame retardants, while costly, substantially reduces releases of toxic byproducts.[72] These plastics therefore require a sound treatment, best in an incinerator equipped for the treatment of such plastics, or possibly in cement kilns provided they are equipped accordingly. It was investigated whether such BFR-plastics could be adequately treated and disposed of in Ethiopia. These plastics fractions would otherwise have to be exported for proper treatment at high expenses.

While no appropriate cement kilns could be identified in Ethiopia, the country is currently building an incineration plant at the Reppie landfill site, the old landfill of Addis Ababa, with a capacity of around 1,200 t of waste per day.[73] The Koshe (Reppie) Waste-to-Energy (WtE) Power Plant is planned to be finished in 2016 and will then be the first of its kind in Africa.

The plant is designed according to European standards for the incineration of low calorific waste. The Ethiopian Government has decided to adopt the emission limits stipulated in the European Directive 2000/76/EC on the incineration of waste and its future amendments, which are binding for the Reppie WtE incineration/power plant. In municipal waste incineration, dioxins and furans are generated from halogenated flame retardants and other precursor substances in the "dioxin window" between 300 to 600 °C with a maximum between 300 and 400 °C[74]. The Reppi WtE incinerator therefore works at higher temperatures (flue gases are guaranteed to be over 850 ° for at least 2 seconds) to prevent the generation of dioxins and furans in the incineration process. On its passage to the flue gas cleaning devices, the flue gas cools down during a short period to temperatures within the dioxin window so that a certain amount of dioxins and furans is expected to rebuild. The flue gas cleaning therefore includes addition of activated carbon, which in combination with a baghouse filter absorbs dioxins and furans so that the emissions clearly remain below the threshold limits.

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[71] If not otherwise indicated, all information in this chapter was obtained from an interview with Mr. Jan Teir, Ramboll as the Owners' Engineer, Mr. Robin Murray, project manager of the WtE project, and Mr. Samuel Alemayhu, both Cambridge Industries Ltd., consortium partner for constructing the incineration plant for the Ethiopian Electric Power Corporation (EEPCo)

[72] Shaw 2010

[73] Ethiopian Electric Power Corporation (EEPCo), Waste to Energy Project, http://www.eepco.gov.et/project.php?pid=27&pcatid=9; accessed 8 December 2014

[74] McKay 2002

The Reppie WtE incinerator can probably accept around 1 % of plastics with brominated flame retardants in the input, resulting in a total capacity of around 12 t of such plastics per day. The plastics should be shredded to particle sizes less than 5 – 10 cm. This will facilitate mixing these plastics with other waste in the waste bunker to ensure that the feed material to the incinerator will have a constant quality. It is planned to test the acceptable amounts during the ramp up of the WtE incinerator. The input of brominated plastics will be increased step by step up to 1 % combined with emission monitoring to ensure the dioxin and furan emissions remain below the legal threshold limits.

The proper operation and maintenance of the plant will be key for the future environmental performance of the Reppie WtE incinerator. Damages or improper functioning of the flue gas cleaning system, e.g. due to reduced usage of activated carbon, improper maintenance of the filter bags, or even waiving the expensive activated carbon infeed to save cost, would severely increase the dioxin and furan emissions and result in major pollutions of the surrounding areas. An issue remaining to be solved is the fly ash, where no solution for save disposal is available yet in Ethiopia.

The Reppie WtE incinerator is not equipped to process and reliably destroy PCB-containing materials such as larger electrolytical capacitors and (H)CFC from cooling and freezing equipment.

The incineration of the plastics in the WtE incinerator will cause additional cost. Precise data on prices are currently not yet available.

Landfilling

Brominated flame retardants, including PBDE, have been observed leaching out of landfills in industrial countries, including Canada and South Africa. Some landfill designs allow for leachate capture, which would need to be treated. These designs also degrade with time.[75]

A new landfill for Addis Ababa is under construction in Sendafa. It will have a hazardous waste section, but no details are available on the actual technical and environmental standard. Unless there is clear evidence of the opposite, it is assumed that BFR plastics cannot be disposed of at this site, nor at any other landfill in Ethiopia. The principal option of landfilling BFR plastics as well as the technical, environmental and geological requirements for such a disposal site should be assessed in a separate study.

6.4 Conclusions and Recommendations for the Plastics Fraction

A manual dismantling process can yield a good quality plastics fraction free from contaminations with non-plastics materials. The DMF should maintain its manual dismantling process as long as

[75] Shaw 2010

the labor cost is low enough and, if necessary, improve it further by removing stickers and other non-plastics adhesions from the dismantled plastics parts.

The quality and the price for the plastics fraction can in principle be further improved by sorting out BFR plastics and by sorting out individual fractions of target plastics. The technical and economic feasibility of these options must, however, be tested taking into account the overall economic and ecologic cost-benefit situation. Currently, there is no solution available in the country for the sound environmental treatment of the BFR plastics fraction, which the additional sorting will generate.

The unsorted sales of the plastics fraction from manual dismantling is therefore recommended as the currently best overall option. If this fraction is sold unsorted to an environmentally sound plastics recycler, the responsibility for the treatment of the plastics with brominated flame retardants is with this recycler. Due diligence in selecting the downstream buyer for the plastics is, however, mandatory to ensure the proper treatment of the hazardous BFR plastics fraction.

Once the WtE incineration plant is operational and can properly process BFR plastics, and once the prices for the incineration are known, the DMF could reconsider improving the quality of the plastics fraction in order to maximize its overall economic benefit.

7 Overall Conclusions and Recommendations

The steel, copper and aluminum fractions produced at the DMF have local markets in Ethiopia. For plastics and PWB, no such markets could be identified neither in Ethiopia nor in the region. These fractions should therefore be should on the international market.

7.1 National Markets for Steel, Aluminum and Copper

Steel fractions from the DMF have a broad market in Ethiopia. The possibilities are limited for scrap copper and aluminum, as the investigations for this study showed that there few industries that can remelt and reprocess to secondary copper and aluminum in Ethiopia. They can therefore be sold to these industries or to buyers on the Ethiopian market that mainly export these metals. Alternatively, instead of selling to companies that export these metals, the DMF could consider exporting its aluminum and copper fractions directly provided they actually cannot be processed in Ethiopia, and if such exports are legal.

Table 8 sums up the prices and conditions investigated for steel, aluminum and copper scrap on the Ethiopian market, and the approximate value of the steel, aluminum and copper fractions stored at the DMF.

Table 8: Prices and conditions for scrap steel, copper and aluminum in Ethiopia

Metal Scrap	Average Price in Birr/kg (Euro/kg[76])	Minimum Quantities Accepted (t)	Quantities Stored at the DMF	Approximate Total Value of the fractions stored at the DMF (rounded) Birr (Euro[76])
Steel	9 – 10 (0.34 – 0.38)	25	26 t	234,000 – 260,000 (8,800 - 9800)
Aluminum	17.5 (0.66)	0.5t	0.45 t	7,900 (300)
Copper	40	3	0.32 t	13,200 (500)
			Totals (rounded)	**255,000 – 281,000 (9,600 – 10,600)**

Annex I on page 62 lists the various items stored at the DMF. The list should be systemized using categories for main fractions and subsuming the various parts under these categories. Such categories should, for example, be printed wiring boards (PWB) comprising the various grades of PWB, "populated" circuit boards, motherboards, IC chips, RAM module scrap, etc., as long as there are not good reasons to keep all these items as own categories. It is also unclear whether these items are disassembled down to the final stage already, or whether a further disassembly makes sense economically. This exercise should be conducted with all items in the list.

Manual dismantling generates purer steel, aluminum and copper fractions, which achieve higher prices compared to such fractions from mechanical pre-processing, which are contaminated with other metals, plastics and various other materials contained in e-waste. The DMF should continue exploiting this manual labor advantage and maintain pure qualities of the generated fractions.

A cost-benefit analysis should, however, be conducted to assess the optimum dismantling degree. The higher revenues from purer fractions and better sorted items that are rich in precious metals must at least compensate the additional labor cost for deeper dismantling. Such cost-benefit-analyses will be part of the task forces "Business Model for the DMF" and of the task force "Factory Optimization".

Investigations with some of the Aluminum and Cooper processing industries interested in buying scraps from DMF showed that they have no minimum limit with regards to their capacity to absorb all the scrap metals from DMF. However, on the other hand, the biggest part of these scrap metals seems to be exported due to a lack of an adequate processing capacity in the country. It may

[76] Status 21 May 2014

therefore make sense that the DMF or PPPDS exports these metals itself rather than selling it to other companies that export it, thus increasing the revenues from the metal sales or sales to the industries in the local market. It should, however, be checked which option is more beneficial for Ethiopia financially and in terms of supply security given the fact that the country has to import aluminum and copper.

7.2 International Markets for PWB

7.2.1 Basic recommendations for the sorting and dismantling of PWB

Subject to a more in-depth analysis of the situation by the Facility Optimization and Business Model task forces, the following recommendations can be given.

- High grade PWB should be removed from e-waste and be stored and treated separately from lower grade PWB.
- Pure steel and aluminum parts and other parts that do not contain copper or precious metals should be removed manually from PWB, in particular from low grade PWB.
- Components containing higher amounts of PM or copper should be removed from medium and low grade PWB and be treated with high grade PWB.
- Electrical and electronic components consisting of valuable materials others than copper and precious metals may be removed manually. Examples are copper in inductor coils, and tantalum capacitors from PWBs of mobile products. It must, however, be avoided that components containing precious metals are removed as well.
- In a final pre-processing step, after the removal of parts and components, lower and, depending on the conditions of the individual smelter, possibly medium grade PWB should undergo a mechanical pre-processing that generates a copper fraction with PM for treatment in copper smelters, and a steel and an aluminum fraction that can be sold and thus generates additional income.

The above recommended measures should, however, be subject to an overall cost assessment taking into account

- the cost of the additional labor required to remove parts and electrical/electronic components;
- the additional revenues that can be generated from these removed parts and components;
- whether the storage capacity at the DMF is sufficient to allow the separate storage of different PWB qualities until the minimum amounts are achieved which copper smelters set for the various PWB qualities
- how long it takes for the various PWB qualities to achieve these minimum amounts copper smelters set for the various PWB qualities;
- and the influence on the logistics cost.

The overall operational and economic optimization of the DMF operations will be conducted in the Facility Optimization and the Business Model task forces.

7.2.2 Buyer-specific Optimization of the Dismantling and Sorting Process

The above recommendations are deduced from the cost and revenue calculations in smelters and derived from potential buyers' general principles. Beyond this, each potential buyer of the PWB scraps will have its own specific conditions, in particular concerning the sorting of PWB grades and components. Complying with these conditions will increase the revenues from the PWB sales, and in some cases may even be the precondition to effect the sale of the materials.

The DMF should therefore aspire a longer-term relationship with a buyer of the PWB material in order to optimize the PWB and other materials containing precious metals and copper to its conditions concerning, e.g., the sorting into different grades and subgrades, and the removal of components, etc.. From time to time, the DMF should check the market again and send out requests for quotations to ensure optimum revenues from its sales.

For the PWB already stored at the DMF, the DMF in principle has several options:

1. Sell the stored PWB as they are and start sorting of newly dismantled PWB

   The stored PWB are unsorted. Concluding from the DMF's input register, the PWB are from various types of e-waste ranging from computers to printers and CRT TVs, and the stored PWB from the dismantling of these devices thus are a mixture of high grade down to low and very low grade PWB. It should in principle be possible to find a buyer for these PWB. The small quantity of around two tonnes, however, may be less than minimum lot sizes potential buyers accept, or at least affects the revenues from the sales due to disproportionately high transport and smelting costs.

   The DMF could continue dismantling e-waste and producing unsorted PWBs until potential buyers' minimum quantities are achieved and efficient transport and treatment are possible.

2. Start treatment and sorting of PWB from newly dismantled e-waste and in parallel treat and sort the stockpiled PWB.

   The DMF could start treating the dismantled PWB, e.g. the removal of larger steel and aluminum parts, and the sorting of PWB grades from now on. This option would require sufficient space for the separate storage of at least two PWB fractions, high grade PWB and other grades of PWB, until sufficient amounts are collected to enable their efficient sale. Even more than two PWB fractions may be advisable, dependent on whether the DMF already sorts according to the conditions of a future buyer.

   While the storage space in the old building is limited, possibly the DMF has sufficient storage capacity available once the new building is finished.

   The parallel treatment (e.g. removal of larger steel and aluminum parts from lower grade PWB) and sorting of the already stockpiled PWB could be conducted in the course of clearing the old building as then these PWB have to be moved anyway.

The preferable option should be assessed based on a cost benefit analysis taking into account the specific conditions of the DMF – labor cost, storage capacity, etc. – on the one hand, and the conditions and prices of potential buyers on the other hand. In case the DMF cannot solve this task itself, it will become part of the task force "Facility Optimization".

7.3 International and National Downstream Markets for Plastics

The incineration of the dismantled plastics in cement kilns to substitute fossil fuels, or in incinerators, for environmental, health and safety reasons is currently not an option. No adequately equipped cement kilns or incinerators could be identified in Ethiopia. The incineration of plastics containing brominated flame retardants may therefore generate dioxins and furans and cause major damages to the environment and to people's health.

The plastics fraction stored at the DMF due to the manual dismantling process is free of contaminations with non-plastics materials and can therefore be sold for recycling at a price of around 100 Euro per tonne[77] on the international market. The DMF should therefore continue its current dismantling practice without a further sorting of the plastics. This facilitates achieving economy of scale amounts, or at least amounts which are sufficiently efficient to be sold and/or match the minimum amounts of plastics which recyclers are willing to buy. Foregoing any further sorting also avoids that plastics with brominated flame retardants remain at the DMF, which currently cannot be treated adequately in Ethiopia and therefore would generate further cost.

Once the new WtE incinerator in Reppie becomes fully operational and can properly process plastics with brominated flame retardants, the DMF could reconsider improving the quality of the plastics fraction by various sorting options. These options must, however, be tested carefully for their technical, economic and ecological feasibility taking into account the overall cost and benefit.

The compacting of the plastics parts will be crucial to make more efficient use of the DMF's storage capacity, and to achieve the necessary filling degree of containers so that the transport is more efficient, and the minimum amounts of potential buyers of the plastics fractions can be achieved. Respective equipment could be purchased provided the legislative conditions and an effective and efficient collection system reliably secure the DMF's long-term supply with e-waste.

The DMF should apply due diligence and carefully assess potential buyers of the plastics fraction in terms of environmental, health and safety standards to prevent severe environmental and health damages due to emissions of dioxin and furan and other toxic substances.

[77] As plastics prices are highly volatile, this rule only applies for the time when the investigations for this part of the report were finalized (March 2014).

7.4 Legal Status of the DMF

During the investigations, it became obvious that there is confusion about the legal status of the DMF. In particular, there is no common understanding about the DMF's institutional relationship to the CRTC, the ownership and supervision by MCIT, its status as a budgetary institution, and the resulting competences for the DMF and its management in terms of administrative procedures to be followed and entrepreneurial freedom. This situation causes considerable inefficiencies in the sales procedure and in general decision-making. The Government should urgently clear the DMF's legal status and take care all key players understand it and act accordingly.

As an alternative to the current status, the Ethiopian Government might considered to give the DMF more freedom to operate like a commercial private enterprise in the market, or to transfer it to a private entity. This would give more flexibility to the operations and in particular the sales of the dismantling fractions. If the DMF shall be kept in Government ownership, there may be legal possibilities to establish the DMF as a body with more entrepreneurial freedom like e.g. a public enterprise Municipal waste management authorities in Germany and other countries are, for example, organized as corporations under public law. Once the DMF is upgraded and generates higher outputs, such a legal organizational form might be an alternative that could combine the competitive incentives provided by a free entrepreneurship with the degree of public control the Ethiopian Government deems appropriate. Various forms of public private partnership schemes might be another possibility. In the face of the expected rise in e-waste quantities, a dynamic system will be required anyway that allows balancing the amounts of e-waste with the capacities for its proper collection and treatment, and efficient and dynamic sales procedures for e-waste fractions on national and international markets.

Any commercial independence and operational freedoms given to e-waste operators require, however, adequate monitoring and control by public authorities to enforce applicable regulations so that e-waste collectors, transporters and processors work in accordance to the applicable national and international legislation and social and environmental standards.

7.5 Sales Procedures and Financial Incentives

The sales of the PWB and the plastics on the international market has to follow a complex administrative procedure involving several Governmental institutions, as illustrated in figure Figure 3 on page 18. This export procedure has not yet been tested, and changes as well as delays may occur throughout the process. The DMF is highly recommended to start this procedure in time to be ready for export once the minimum required amounts of PWB and plastics are available at the DMF. In particular, the DMF should already start now those parts of the procedure like e.g. applying for a VAT number and an export license, etc., which are necessary to create the pre-conditions for the further steps.

During the investigations for this report, the Government established a new sales procedure the DMF and other public institutions have to follow for metal sales on the national market[78]. The steel and other metal fractions stored at the DMF meanwhile were sold via this new procedure.[79] The new procedure involves the PPPDS into the sales of fractions so that the DMF cannot sell them directly.

The willingness of potential buyers to actually buy and pay reasonable prices next to quality also depends on the amounts per transaction, and on the steadiness of the material flows. In this respect, it is highly desirable that the DMF increases the input of e-waste to generate higher and steadier outputs to benefit from the economy of scale effect. As this is difficult to achieve in short term, the available storage space should be used optimally or even be increased to make sure that at least the minimum amounts buyers request per material transactions can be met.

The economy of scale effect could, however, even be met with smaller amounts of scrap metals if the PPPDS takes them over and unites them with other scrap metal streams of similar quality. The economy of scale effect may thus be achievable with the final buyers as the PPPDS still can offer larger amounts of scrap metals. The EwaMP project team has no insights into the quantities and qualities of the metal scraps administrated by the PPPDS. The amounts of scrap metals stored should be optimized jointly with the PPPDS, the DMF and the task forces “Business Models” and “Factory Optimization” in case the PPPDS can actually collect and unite several metal scrap streams of similar quality to sell them in larger quantities on the Ethiopian market. This would require, however, that the PPPDS takes over the metals and stores them until economy of scale amounts are achieved.

The revenues from the sales of the DMF metal fractions on the national markets should be transferred to the DMF as currently foreseen. This mechanism links the revenues the DMF produces from high quality fractions to the financial resources it has available. This would incentivize producing high volumes of high quality output fractions with the available human and other resources. As a further incentive, it may be considered to either add a bonus component to the salaries or change part of the salary to such a bonus for the employees working at the DMF. This bonus should be strictly related to the economic result of the DMF operations as a motivation to increase the quantity and quality of the operations.

In line with this, if EEE producers shall at least in parts finance the e-waste management system via an extended producer responsibility scheme, clear and transparent rules for price setting by the PPPDS will be required that ensure the prices are adequate. Otherwise, producers may consider this construction as eliminating competition, and prices for fraction sales might be perceived to be too low thus overly increasing expenses for the financing of the e-waste management system.

[78] Cf. section 2.3.1 on page 16
[79] Status October 2014

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Annexes

Annex I Input of E-waste into the DMF[80]

No.	Description	Unit	Quantity			Total	Remark
			Sep 2011-Aug 2012	Sep 2012-Aug 2013	Sep 2013 – May 2014		
1	System Unit	Pcs	1,830	1,188	700	3,718	
2	CRT Monitor	Pcs	199	-	-	199	
3	Keyborad	Pcs	490	-	-	490	
4	Mouse	Pcs	698	-	-	698	
5	Printer	Pcs	214	327	91	632	
6	Fax Machine	Pcs	46	102	25	173	
7	Duplicating Machine	Pcs	6	13	9	28	
8	Copier	Pcs	21	44	3	68	
9	Scanner	Pcs	5	18	1	24	
10	Projector	Pcs	6	16	16	38	
11	Manual Typewriter	Pcs	17	49	36	102	
12	Electrical Typewriter	Pcs	35	76	30	141	
13	Air Conditioner	Pcs	-	20	-	20	
14	UPS	Pcs	-	11	-	11	
15	Oven	Pcs	-	5	-	5	
16	X-Ray postic	Pcs	-	1	-	1	
17	Server	Pcs	-	2	-	2	
18	Telephone switchboard	Pcs	-	-	1	1	
19	Various Radio/TV studio equipments	Pcs	-	-	163	163	
20	Miscellaneous	Pcs	218	201	9	428	
					TOTAL e-Products	**6,922**	

[80] *Source: Dereje Masresha, Manager DMF*

Annex II Dismantling Parts and Fractions Stored at the DMF[81]

No.	Type of Scrap	Quantity (pieces)	Quantity (weight in kg)
1	Processors scrap		
2	IC chips		
3	Transformers & transformer windings	233	422
4	Scrap Ink Jet Cartridges	57	
5	Scrap Laser Toner Cartridges	207	
6	Scrap Printer drums		
7	CD ROM drive scrap	683	
8	Floppy drive scrap	870	
9	Hard Disk drive scrap	634	
10	Populated Circuit Boards		
11	Unclipped Internal wires and connector scrap		
12	Unclipped external wires and cables scrap		315
13	External connector scrap		
14	RAM module scrap		
15	PC Power Supply Units		
16	Copper Yokes scrap		
17	Copper Heat Sinks scrap		
18	Aluminum Heat Sinks scrap	2,514	446
19	Mixed Plastic scrap		
20	Plastic drive gears scrap		
21	Electric motors scrap	910	229
22	Computer Plastic cooling Fans	1,890	190
23	Screws		
24	IDE/data cables scrap	2,516	105
25	Steel scrap		26,227.50
26	Mixed Plastic scrap		8,381.80
27	Degaussing wire		
28	Speakers	408	23
29	Tape recorder head	59	38
30	PC mother boards		
31	Low grade printed wiring boards		
32	Medium grade printed wiring boards		
33	High grade printed wiring boards		

[81] Information sent via e-mail by Dereje Masresha, Manager of the DMF, to Otmar Deubzer, UNU, on 1 April 2014; the above table reflects the status as of March 2014

34	Mixed metal/plastic scrap		
34	UPS		
35	UPS batteries		
36	Lithium Batteries		
37	NiCd batteries		
38	NiMH batteries		

The above list needs to be further systemized with respect to materials that can be disassembled further at the DMF and those materials that cannot be further processed at the DMF and therefore should be handed on to downstream markets or must be disposed. A further categorization is required as well as some of the items listed above may fall under a common category; e.g. PC mother boards and low, medium and high grade printed wiring boards. This work needs further onsite investigations and discussions with the DMF to make sure all goods are correctly identified and classified.

Annex III Potential Buyers for the DMF Steel Fraction

No.	Name of factory	Owner-ship	Location and distance from Akaki	Certificates	Contacts	Source of raw material	Price offered for Steel in Birr/kg
1	Abyssinia Integrated Steel	Private	Debre Ziet, 45 kms	Finalizing ISO 9001 certification	Mr.Rajesh Gupta; 0913325236	Informal market at Merkato, METEC import from China and Ukraine	9-10
2	Akaki Basic Metals Industry	Govern-ment	Akaki, 6 kms	No	Mr. Misganaw, Head of Logistics and Supply management office of METEC; 0115506012	METEC	9
3	Arati Steel	Private	Gelan, 10 kms	No	Mr. Afendi 0912982244	Import from India	9
4	Ethiopian Iron and Steel Factory	Public-private	Akaki, 5kms	No	Mr. Million ,Head of Scrap metal purchasing department;0911872016	Informal market at Merkarto, andMETEC	7-8
5	Habesha Steel Mills	Private	Dukem, 22 Kms	TMT certified	Mr. Nebeyu General Manager, 0116635188	Informal market at Merkarto, and import from China and Ukraine	Didn't disclose
6	Kotebe Metal Tools Factory	Private	Addis Ababa, 25kms	No	Mr. Alemayehu 0116464056/0116465068	-	Didn't disclose
7	N.A Metal Industry and Engineering	Private	Gelan, 10 kms	No	Mr. Esayas 0911510691/0911215724	-	Didn't disclose
8	Radel Foundry	Private	Akaki kality, 5 kms	No	Mr. Amnauel Head of the factory 0911201427/ 011 439 0951	-	11

9	Steely R.M.C	Private	Debre Zeit, 45 kms	No	Mr. Tezazu 0911697791		9--10
10	Walia Steel Industrial	Private	Alem Gena 105 kms	No	Mr.Asehnafi 0113-870843	-	Didn't disclose

Annex IV Potential Buyers of the Aluminum Fraction

No.	Name of factory	Ownership	Location and distance from Akaki	Environ-mental Manage-ment System	Contacts	Main source of raw material	Price offered for Al in Birr/kg
1	Akaki Basic Metals Industry	Government	Akaki, 6 km	No	Mr. Misganaw, Head of Logistics and Supply Management, METEC; 0115506012	METEC	15
2	Radel Foundry	Private	Akaki kality ,5 km	No	Mr. Amnauel Head of the factory 0911201427/ 011 439 0951	-	20
3	MATEX Private Company	Private	Addis Abeba, 25 km	No	Mr. Tewodrose Sheferaw 0924 11 69 36	Mainly Informal Collectors	Interested to buy but didn't disclose price estimate
4	SADOR Private Company	Private	Addis Abeba, 25 km	No	Mr. Indris 251- 911 71 78 80	Mainly Informal Collectors	Interested to buy but didn't disclose price estimate
5	ET Al Aluminium[82]	Private	Debre Berhan, 145 km	No	0912-616362	-	Interested to buy but didn't disclose price estimate;
6	B&C Aluminum[82]	Private	Akaki Kality, 5 km	No	Mr. Haimanot 0911618042	-	Interested to buy but didn't disclose price estimate

[82] Source: Tesfaye Berhanu, PPPDS; this potential buyer was not selected based on the approach described in section 4.1.2 on page 27

7	Tana Engineering[83]				+251911223094		Willingness to buy was not checked.
8	Ahmed, Musema & Zeynu Metal Works[83]				+251911657422		Willingness to buy was not checked.

[83] Source: Dereje Masresha, Manager DMF, via e-mail on 15 December 2014 to Otmar Deubzer, UNU; this potential buyer was not selected based on the approach described in section 4.1.2 on page 27

Annex V Potential Buyers of the Copper Fraction

No.	Name of factory	Ownership	Location and distance from Akaki	Environmental Management System	Contacts	Price offered for Cu in Birr/kg
1	Radel Foundry	Private	Akaki kality, 5 km	No	Mr. Amnauel, head of the factory 0911201427/ 011 439 0951	40
2	Econar General Trading	Private	Addis Abeba	No	Mr.Daneil 0911601894	Didn't disclose
3	Ethio Metal	Private	Addis Abeba	No	251-1-6611411	Didn't disclose
4	BMT Energy Telecom Industry[84]	Private	Sebeta , 48 km	No	Mr. Tesfaye 0930101232	Didn't disclose

[84] Source: Tesfaye Berhanu, PPPDS; this potential buyer was not selected based on the approach described in section 4.2.2 on page 28

Annex VI Potential Buyers of PWB Fractions

Contact Details of Potential Buyers/Processors of PWB[85]

	Potential Buyer	Type of Business	Location and Website	Contact	Remarks
1	**Umicore Precious Metal Refining**	End-processing: Secondary smelter specialized on precious metal refining from e-waste and other secondary sources	Adolf Greinerstraat 14 B-2660 Hoboken–Antwerp Belgium Internet: http://www.preciousmetals.umicore.com/PMR/	Thierry Van Kerckhoven P: +32 3 821 F: +32 3 821 78 07 E: preciousmetals@umicore.com	
2	Boliden Group, Rönnskär Smelter	End-processing:Primary copper smelter	Rönnskär Postal code 932 81 Skelleftehamn Sweden Internet: http://www.boliden.com/Operations/Smelters/Ronnskar/	Boliden Rönnskär Rönnskär 932 81 Skelleftehamn Sweden T: +46 910 77 30 00	
3	Montanwerke Brixlegg	End-processing: Secondary copper smelter	Werkstrasse 1 Austria Internet: http://www.montanwerke-brixlegg.com/en/	Katharina Resch P: +43 5337 6151 118 E: katharina.resch@montanwerke-brixlegg.com	
4	Glencore	End-processing: Primary copper smelter	Glencore Canada Corporation 100 King Street West Suite 7200, P.O. Box 405 Toronto, Ontario	E:recycling@glencore-ca.com	

			Canada M5X 1E3 Horne Smelter in Rouyn-Noranda, Canada; http://www.norandarecycling.com/EN/Facilities/Pages/Horne.aspx		
5	Aurubis AG	End-processing: Primary (Hamburg) and secondary (Lünen) copper smelter	Hovestr. 50 20539 Hamburg Germany Internet: http://www.aurubis.com/en/corporate-group/group-structure/aurubis-worldwide/sites/show/1054/ Kupferstraße 23 44532 Lünen Germany Internet: http://www.aurubis.com/en/corporate-group/group-structure/aurubis-worldwide/sites/show/1038/	Metal Recycling Hamburg Thorsten Steenbock P: +49 40 7883-2211 F: +49 40 7883–2255 E: t.steenbock@aurubis.com Metal Recycling Lünen Christian Coesfeld P: +49 2306 1082-21 F: +49 2306 1084-49 E: c.coesfeld@aurubis.com	
6	Dowa Kosaka Smelting & Refining	End-processing: Primary copper smelter	Kosaka Japan Internet: http://www.dowa-eco.co.jp/en/recycle.html	Dowa Eco-System T: +81-3-6847-1230 E: ecoinfo@dowa-eco.co.jp	
7	E.R.N. Elektro-Recycling NORD GmbH	Pre-processing	Peutestrasse 21-23 20539 Hamburg Germany http://www.ern-gmbh.de/index.en.html	Oliver Carstens Phone: +49-40-780478-0 Fax : +49-40-780478-78 E-mail: carstens@ern-gmbh.de	E.R.N GmbH is an affiliate company of Aurubis dealing with smaller scale business. Hence Mr. Carstens can act as contact for both Aurubis and E.R.N GmbH

8	Electrocycling GmbH	Pre-processing	Electrocycling GmbH Landstraße 91 38644 Goslar Germany Internet: http://www.electrocycling.de/en/welcome	Kai Kramer P: +49(0)5321 / 3367-0 F: +49(0)5321 / 3367-11 E: Kai.Kramer@electrocycling.de	
9	WorldLoop	Non-governmental organization	c/o Vrije Universiteit Brussels Pleinlaan 2 1050 Brussels Belgium Internet: www.worldloop.org	Thomas Poelmans P: + 32 (0)2 614 82 03 F: + 32 (0)2 400 71 25 E: thomas.poelmans@worldloop.org	WorldLoop offers a framework contract for the sales of e-waste and fractions thereof including further services like support for logistics and legal clearances for transboundary transports

The above entities were identified based the authors' personal contacts and on internet investigations. The list is not exhaustive, and it is not a recommendation. The DMF is advised to apply due diligence when selecting business partners ensuring they follow sound environmental, health and safety practices as well as integer business conduct, e.g. in sampling of PWB contents. A „WEEE end-processing standard" finalized in 2014 may give guidance. The standard can be requested from the European Electronics Recyclers Association (EERA). Please indicate your name and company when sending e-mail to: ls@eera-recyclers.com.

For (mechanical) pre-processing, standards may give additional guidance as well, examples being e-stewards (http://e-stewards.org/), WEEELABEX (http://www.weeelabex.org/) and R2 (http://www.sustainableelectronics.org/).

Some of the above potential buyers gave information about general or their specific business conditions, while others could not be contacted directly, or considered such information as confidential to a degree that it should not be published here. This information is provided in the below section.

Specific Conditions Electrocycling GmbH[86]

Electrocycling offers a fixed price purchasing model, but can also work with a content-based approach. For the fixed price model, Electrocycling has no principal minimum amount of material for deliveries, but accepts smaller amounts of high grade materials like processors and connectors. In any case, the various materials should be kept separate in different receptacles, e.g. big-bags.

The material should fall into the classification B1110 of regulation EG Nr. 1013/2006.[87] This means, among others, that hazardous components such as mercury containing switches and PCB-capacitors must be removed from e-waste and fractions thereof, and the fractions may not contain glass from CRT, or batteries, and may not be contaminated with PCB, lead, mercury, cadmium, etc. For details check the regulation.[87]According to Electrocycling, the material can then be shipped to Germany as green listed material without a notification process.

The client receives the agreed payment around two weeks after the material has arrived on Electrocycling's site. Electrocycling GmbH accepts mixed PWB materials, but does not give price indications. Electrocycling sorts mixed PWB on site first, reducing the price for the additional sorting cost, into high, medium and low grade materials as illustrated below.

[86] Source for all information and pictures in this chapter: Electrocycling GmbH, personal communication and e-mail exchange between November 2013 and January 2014

[87] For details see REGULATION(EC) No 1013/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCILof 14 June 2006on shipments of waste, retrievable from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006R1013-20130410&from=DE; accessed 21 November 2011

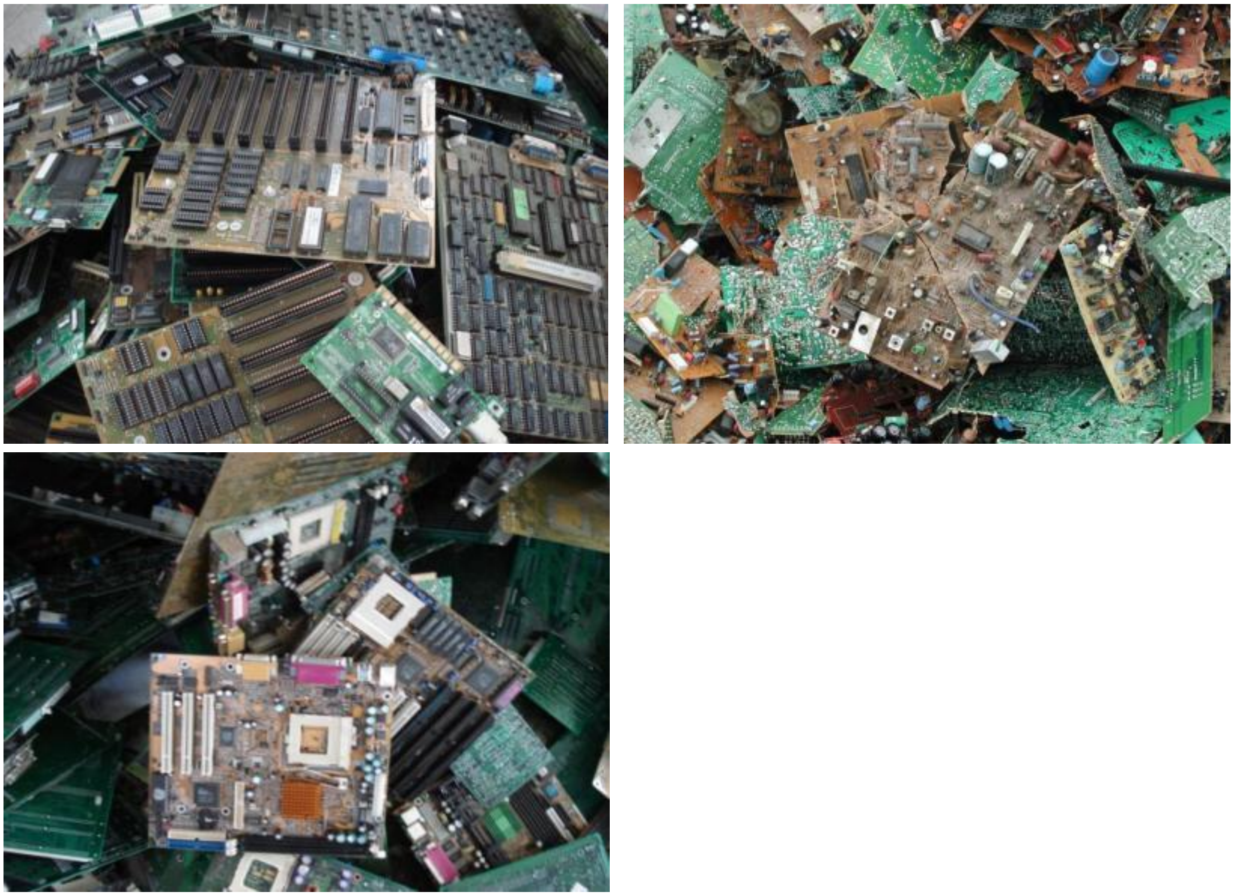

Figure 14: Low grade PWB like from consumer electronics, TVs and monitors (top left), medium grade PWB from telecommunication equipment (top right) and high grade PWB from old generation personal computers (older than Pentium IV, bottom left)

Older generation PWB from personal computers - older than Pentium IV - are high grade materials, while later ones are medium grade. The below illustrations show pictures of such older generation PWB.

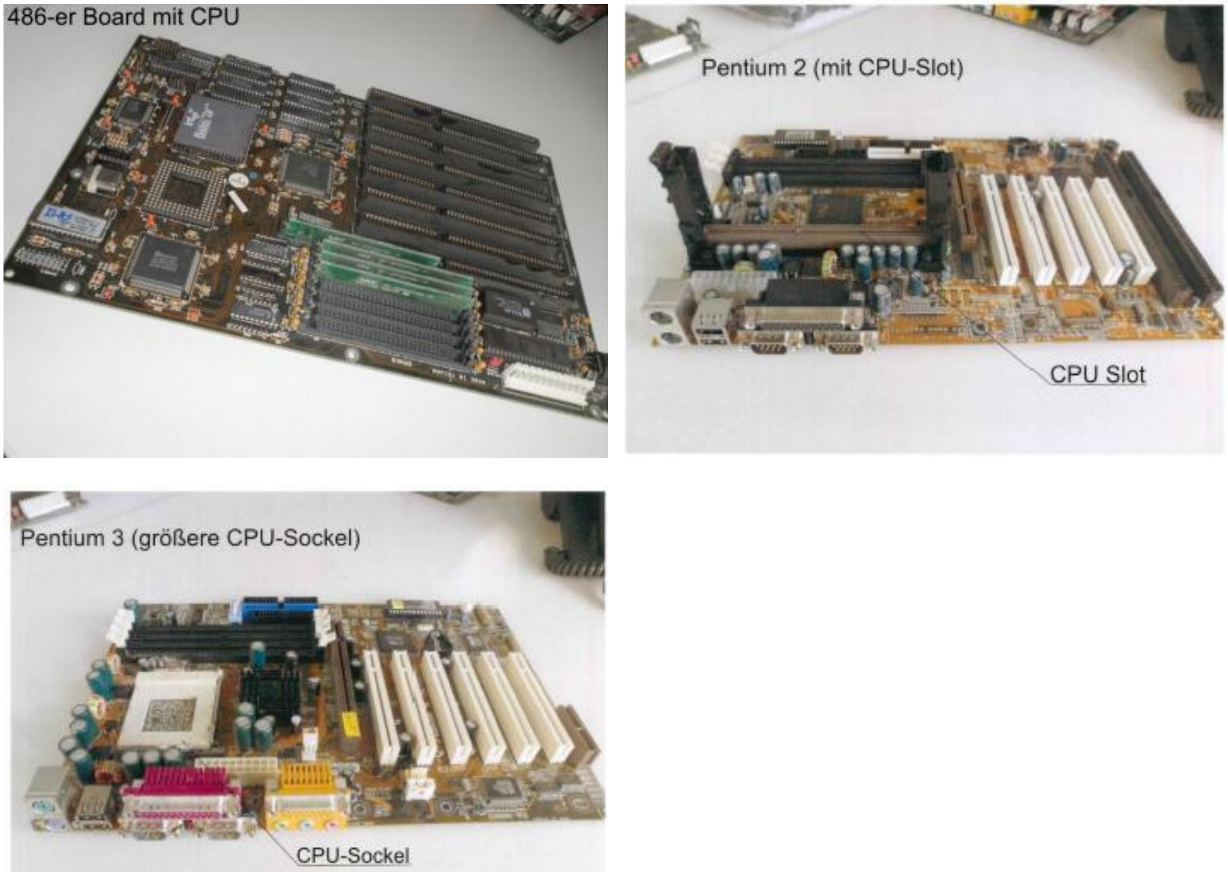

Figure 15: Older generation PWB from personal computers

Pentium IV PWB and higher are new generation PWB, which are of lower value. They have other colors then green, or are green but with smaller CPU slots/sockets. Figure 16 shows examples.

Figure 16: New generation PWB from PCs (Pentium IV and higher)

Prices for the various PWB grades the pre-processor pays the customer are in the range of[88]

- around 400 Euro/t for low grade PWB,
- around 1,200 to 2,400 Euro/t for medium grade PWB,
- around 5,000 Euro/t for high grade PWB.

Electrocycling accepts more e-waste and fractions thereof as shown below.

[88] Source: Electrocycling GmbH, status January 2014; prices are indicative, and metal prices are volatile and change depending on metal market prices. The above indicated prices therefore reflect the status of January 2014 only.

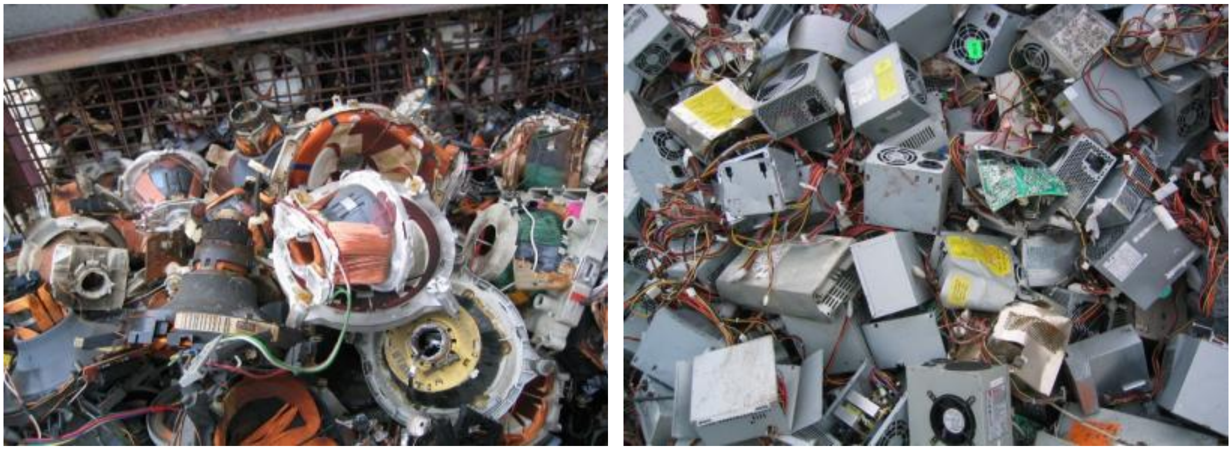

Figure 17: Copper yokes from TVs (left) and power supplies with cables (right)

Figure 18: CD/DVD drives (left) and hard disk drives

Figure 19: Power transformers (left) and PWB without components

Figure 20: 36 % cable mix[89] (top left) and 12 to 18 % cables from telephone (top right) and connecting cables from PCs (bottom left)

[89] The percentage values indicate the copper content of the cables. Cables connecting EEE to the public power grid contain up to 40 % of copper, the rest being plastics. Cables from phones are lower quality cables containing around 12 – 18 % of copper.

Figure 21: E-meters (left) and wall power supplies

Figure 22: Iron (left) and aluminum motors

As an alternative to the fixed price model, Electrocycling also offers a content-based business model. Electrocycling then expects amounts of around 20 t at least, and the customer pays the cost for the analytics. After an initial pre-payment, it can take around months until the final payment is transferred to the customer (cf. section of E.R.N. GmbH below). Electrocycling states that the content-based model only makes sense for high grade materials of unknown origin. For PWB fractions from computers only, the fixed price model is the better choice as the contents are known if the PWB material is sorted as described above.

E.R.N. GmbH[90]

E.R.N. is an affiliate company of Aurubis. It handles the smaller scale business in the dimension of what the DMF currently and in the near future will be able to deliver. E.R.N. offers both a fixed price business model as well as the content-based model in cooperation with Aurubis. If needed, E.R.N. will pre-process the materials and forward components and fractions that need treatment in a copper smelter to Aurubis for end-processing, and other fractions to other end-processors.

E.R.N. has no minimum delivery amounts for the fixed price business, and it accepts mixes of PWB delivered in one container. Based on photos, the company indicates prices for materials. The client is paid the agreed price within seven working days after arrival of the material at E.R.N. In the content-based business, E.R.N. pays 50 % of the price within seven working days, the rest around 90 days after arrival of the material at the E.R.N site. E.R.N. recommends minimum deliveries of 5 t for all PWB qualities.

As described by Electrocycling, for environmental and legal reasons PCB capacitors, batteries and mercury-containing switches have to be removed from PWB. E.R.N. defines all capacitors larger than 2 cm as potentially containing PCB.

World Loop[91]

WorldLoop recommends the below minimum amounts for the sales of various materials.

Table 9: Recommended minimum sales quantities for e-waste fractions and components

Materials containing precious metals	**Recommended minimum quantities**
High grade material, e.g. cell phones, RAM, memory boards (Au > 200 ppm)	min. 2 tonnes
Medium grade material, e.g. ICT printed circuit boards (Au > 100 ppm)	min. 4 tonnes
Low grade material, e.g. CRT monitors (Au < 100 ppm)	min. 7 tonnes
Other materials	
Mix of complex electronic components (hard drives, power supplies, CD-ROM/floppy drives, mixed cables, printed circuit boards, etc.)	min. 10 tonnes
CRT tubes or glass	min. 12 tonnes

90 All information based on interviews and e-mail exchange with Oliver Carstens, E.R.N. GmbH, from November 2013 to January 2014

91 Source of all information in this section: WorldLoop

WorldLoop gave price examples for various e-waste components and fractions.

Table 10: Estimated net values of various material qualities[92]

Material	**Estimated Net Value (Euro)**
8.5 t of mobile phones	~ 84,000
7 tons of computer motherboards	~ 41,300
14 tons of CRT boards	~ 19,800

WorldLoop accepts non-valuable materials as parts of the package.

WorldLoop indicates the following prices for transport.

Table 11: Transport prices and conditions

Transport	**Cost (Euro)**
Djibouti - Antwerp : 20 ft container (+/- 7 tonnes)	1,010
Djibouti - Antwerp : 40 ft container (+/- 15-20 tonnes)	1,139
For mix of materials: additional transport & handling costs	550

World Loop charges a service fee for its services within the framework contract.

[92] Prices reflect the status of December 2013; they are volatile, depend on the exact composition of the material and are hence indicative only

Annex VII Potential Buyers of Plastics Fractions

Potential Buyers of the DMF Plastics Fraction

	Potential Buyer	Type of Business	Location and Website	Contact	Remarks
1	MBA Polymers Austria Kunststoff-verarbeitung GmbH	Plastics recycling	Wipark, 12. Straße 8 3331 Kematen/Ybbs Austria Internet: http://www.mbapolymers.com/home/mba-polymers-austria-kunststoffverarbeitung-gmbh	Chris Sljikhuis P: +43 7472641810 E: slijkhuis@mgg-recycling.com	
2	Ethiopia Plastic Industry	Government owned public enterprise, processing, among others, waste plastics	P.O.Box: 2340 Addis Ababa Ethiopia Internet: www.ethioplastic.com.et	Tel +251 11 5512666 Fax:- +251 11 5517890 E-mail: ethplast@ethionet.et	The company expressed potential interest to buy the plastics, but wanted to check the material, which to do was not possible for the company before the finalization of this report.

Annex VIII Handheld Devices for Identification of Plastics and Bromines[93]

Fundamentally, three types of handheld devices can be used to identify types of plastics and contents:

1. **NIR (near infrared) handheld devices to identify light coloured plastics.**[94]

   These devices can identify colored plastics, but not dark or black plastics. An example for this kind of appliances is the LLA Kusta 4004S, www.lla.de

2. **NIR handheld device to identify light and dark colored plastics**

   - These devices can also identify dark plastics, but they are much slower and more expensive. Examples for such appliances are Bruker Alpha (http://www.bruker.com/de/products/infrared-and-raman-spectroscopy/ft-ir-routine-spectrometers/alpha/overview.html)
   - ThermoFisher Nicolet iS5 (http://www.thermoscientific.com/en/product/nicolet-is-5-ft-ir-spectrometer.html)

3. **XRF handheld devices to analyze elements such as bromine in plastics**

   XRF handheld machines can identify bromium as element in plastics, but not the individual congeners of the molecules. The machine is often used for large pieces of plastics to see whether the material contains brominated flame retardants. Typically, the devices are used to identify substances that are banned e.g. in the European RoHS Directive 2011/65/EU, e.g. cadmium and lead.

   These devices work with x-rays! If the handheld device is used continuously it is recommended to always use it against a metal backwall to absorb the radiation!

   Examples of such devices are:

   - ThermoScientific Niton XLt3 Serie(www.niton.com/en/niton-analyzers-products/xltpi/xlt)
   - Spectro XSort (http://www.spectro.com/pages/e/p010602_spectro_xsort_overview.htm)
   - Bruker S1 Turbo (*http://www.bruker.com/products/x-ray-diffraction-and-elemental-analysis/handheld-xrf/s1-turbo/overview.html*)
   - inovX Delta (http://www.olympus-ims.com/en/xrf-xrd/delta-handheld/)

Prices for these devices start at around 20,000 Euro. The above list of technologies is not exclusive, there may be other means of plastics and content identification.

[93] The mentioning of these product examples is not an endorsement or recommendation to use these products, but just a listing of example products.

[94] Source of all information in this chapter, if not otherwise mentioned: E-waste pre-processor

step

solving the e-waste problem