Material Flow-Based Optimization of Process Chains (Move Rec)

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1. Introduction

The variety of waste electrical and electronic equipment (WEEE) make it difficult to determine the material composition of mixed composite inputs. Most of the types of equipment collected are of a very complex device structure, mechanical parts and electronic components, which imply a diverse composite material composition. Besides iron and nonferrous metals, a variety of non-metallic components of some electronic devices contain precious metals and rare earths. On the other hand, most devices contain hazardous components, which need a specific treatment and/or a controlled waste disposal process. These complexities make it difficult to determine the material composition of mixed WEEE or make it impossible to determine, in practice with reasonable effort, the content of certain materials or substances. There is limited information regarding components and recyclables that constitute small electrical and electronic equipment (sWEEE), this includes potential hazardous substances and preparations contained within–information vital for plants active in recovery and recycling of this waste fraction, as reported by Dimitrakakis [1].

The objectives of the project Material flow-based optimization of process chains (Move Rec) is to develop a method, database and software that supports and facilitates process selection and facility planning in the recycling of electrical and electronic equipment (EEE).

The database enables to model different variants of the process. This negates the necessity of extensive pilot plant tests, simulations for the implementation of different input compositions and evaluates the market while taking into account quality-related values.

Chancerel and Rotter [2] summarized the investigations dealing with the characterization of WEEE. Whereas some investigations aimed at characterizing equipment or assemblies and determining their content of valuable materials and/or contaminants directly, others aspired to develop adequate characterization methods or data gathering for other purposes such as a substance flow analysis.

2. Methodology

This project started with sWEEE. The term WEEE refers to electrical and EEE that due to their small size and weight are able to be disposed of in the general household refuse, and are also referred as *bin suitable* [1]. For the purpose of this project sWEEE include all appliances described as *small electronic appliances* at the EAG-VO (See Table 1). The database is still under construction and in the future, data from other groups (cooling appliances, display screens, lamps and large appliances) will be included to cover the whole WEEE stream. *The database is composed of* excel sets where the counting, classification and dismantling analysis data are stored (See Figure 1).

Table 1: WEEE included in this study according to the Austrian WEEE Ordinance (EAG-VO)

Collection and treatment categories	Equipment categories pursuant to Annex 1 of the Austrian WEEE Ordinance
Large appliances*	Large household appliances (excluding cooling appliances, refrigerators, freezers and air conditioner appliances) IT and telecommunications equipment (excluding display screen equipment) Large lighting equipment (excluding gas discharge lamps) Large electrical and electronic tools Large toys, leisure and sports equipment Automatic dispensers without refrigerating devices Large medical devices Large monitoring and control instruments
Cooling appliances, refrigerators and freezers	Cooling appliances, refrigerators and freezers as well as air conditioner appliances Automatic dispensers with refrigerating devices
Display screen equipment, including appliances with cathode-ray tubes	IT and telecommunications equipment – screens (with cathode-ray tubes, LCD and plasma screens) Consumer equipment – TV sets (with cathode-ray tubes, LCD and plasma screens) Monitoring and control instruments – screens
Small electrical appliances*	Small household appliances IT and telecommunications equipment (excluding display screen equipment)
	Consumer equipment (excluding display screen equipment) Small lighting equipment (excluding gas discharge lamps) Small electrical and electronic tools Small toys, leisure and sports equipment Small medical devices Small monitoring and control instruments Lighting equipment (gas discharge lamps)
Gas discharge lamps	Small Lighting equipment (LED Lamps with standard fitting

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

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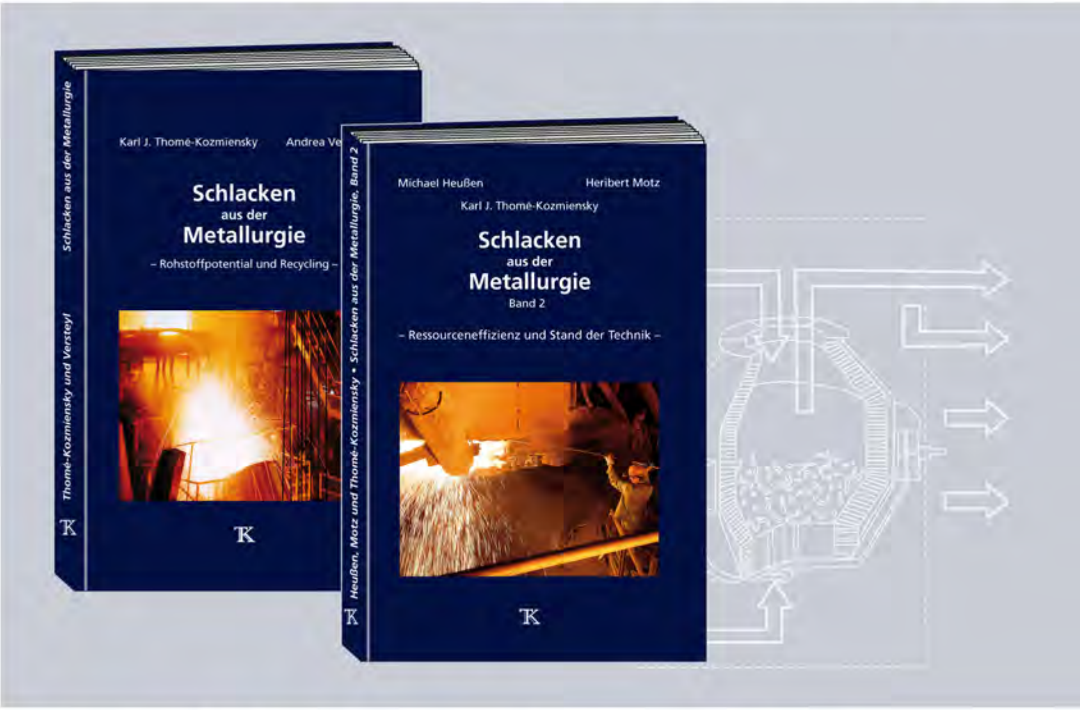

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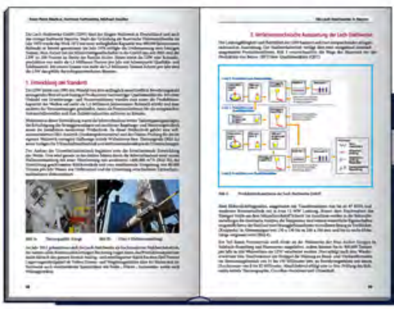

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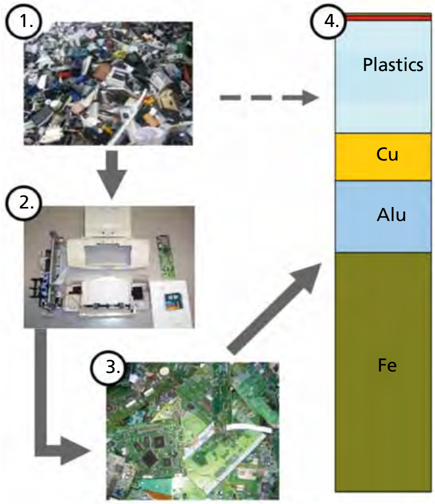

1. **Analysis of the material composition by equipment types**
   - Counting of WEEE at collection points or recycling plants
   - Estimation of WEEE amounts by analysis of volume of EEE placed on the market
2. **Device Classification**
3. **Dismantling Analysis**
   - Selection of appropriate samples of all WEEE types
   - Determination of the assembly composition of selected devices by dismantling analysis
   - Material composition of complex assemblies: Literature research and manufacturers data
4. **Database assisted administration and processing of data through iPoint Compliance Agent (iPCA)**

Figure 1: Scheme of database excel sets

2.1. Analysis of the material composition by equipment types

Within the KERP Project in cooperation with Demontage- und Recycling-Zentrum Wien (DRZ) Basket composition, sWEEE streams have been determined (2009-2011), to select the representative devices, in consideration of their frequency among the stream, which should be included in the database.

2.2. Device Classification

The device classification has been done in accordance to:

- Austrian WEEE Guideline, Elektroaltgeräteverordnung (EAG-VO), See Table 1
- European Directive on Waste Electrical and Electronic Equipment (WEEE)
- United Nation University (UNU) Guideline

2.3. Dismantling Analysis and Material composition of complex assemblies

The dismantling analysis sets include data regarding:

- Devices — Type of appliances, mark, model, etc.
- EEE-Phisical/ mechanical properties — Weight, material composition (visual caracterization)
- EEE-Chemical composition — Metal content of assemblies (literture review and chemical analysis)

An example of the information from the physico-chemical devices stored in the database are sumarized in Figure 2.

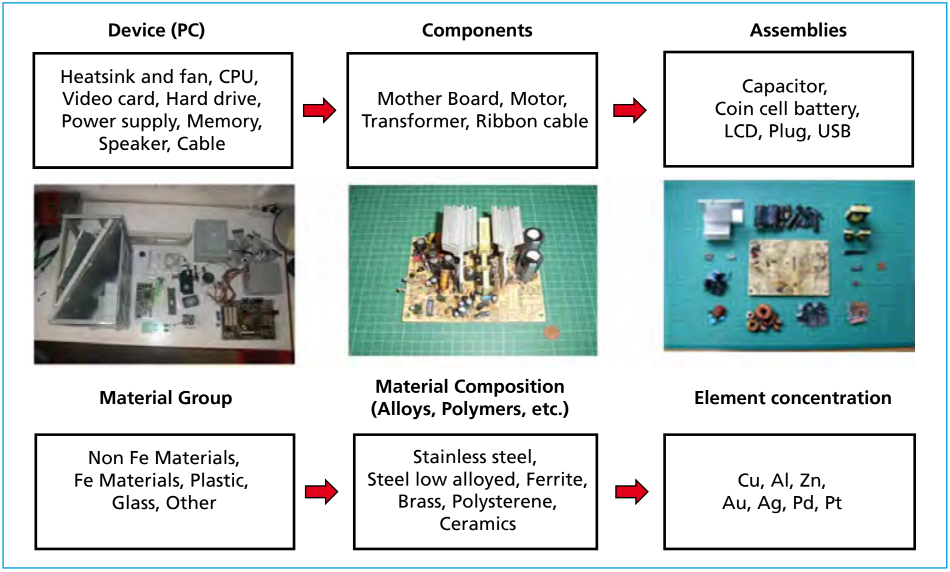

Figure 2: Example of the structure information registered in the database

The manual dismantlig work has been carried out at the DRZ located in Austria. For the dismantling analyses the weight of every appliance was determined with a scale (precision ± 0.5 g).

Each device was dismantled and separated into its parts and material groups. The total weight (before dismantling) per equipment and per dismantled pieces were recorded. The dismantled pieces were selected with consideration for the material fraction (e.g. iron, plastics, wood, etc.); if they were hazardous or environmentally relevant (e.g. batteries, Hg-switch, etc.) and/or contain a valuable metal (e.g. motherboards, Nd-magnet, cable, etc.).

Material Group	Material composition
Assembly	light bulb, luster terminal, micro switch, motor, dc switch, transformer
Fe Materials	chromed steel, galvanized steel, steel
Cable	cable shoe, low power cable
Non-Fe Materials	aluminum profile, brass, cast aluminum
Others	Ceramics, foam, glass, mineral fiber
Plastics	Elastomer, plastic foil, PMMA, undefined
Total	

Figure 3: Example dismantling analysis (right) and generic product model make-up of a projector (left); for each equipment the following information was determined: Material group, Material composition in % and grams as well as standard uncertainty

Examples of material groups identified visually are: Al, Fe, Cu, plastics, cable, HDD (with and without PWB), power supply, processors, printed wired board, motor (transformers), glass, hazardous, etc.

An example of the dismantling analysis is shown in Figure 3. For each equipment the following information was determined: Material group, Material composition in % and grams as well as standard uncertainty.

2.4. Database assisted administration and processing of data by iPCA

The selected appliances were manually dismantled, weighed and described in the Material Composition Groups Database. The generated information (mean-assemblies and total weight) as well as the complex assemblies material composition data from the literature was used to develop a *generic-Product-Model* per device (See Figure. 3). Standard uncertainty of each group product model was determined. Thereafter, this information was stored and managed by the **iPCA**, a software bundle based on integration and in house-applications for efficient material data management (Substances, Articles, Mixtures-Management = SAM-M) and for ensuring compliance with product-related, environmental legal requirements (ELV, REACH, RoHS, RRR, etc.). iPCA simplifies and automates the internal data collection and management, which in turn can be made available to external systems.

Figure 4 shows a pie chart example of the material composition from a test *Basket*. The required information to estimate the material composition of complex composite input streams using the software are: the total EEE basket weight or % and the total equipment weight (e.g. total basket weight includes X kg TV, X kg Monitors, etc.).

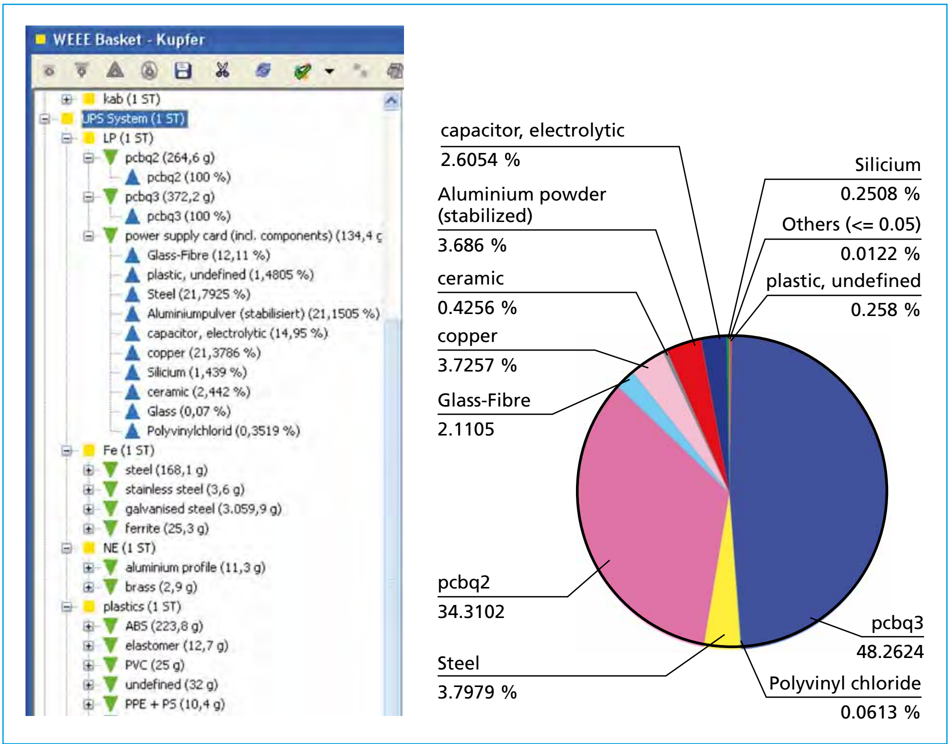

Figure 4: iPCA Screenshot of the material composition, pie chart for a *Test* Basket

3. Results

Throughout the duration of this project 600 dismantling analyses of small appliances, 120 Product Models (material composition), as well as the definition of 60 assemblies have been performed. The results enable the specific material composition (i.e. plastics, metals, Fe, non Fe, motherboard, hazardous, etc.) in electronic devices to be determined as well as other defined material groups (i.e. cable, assembly, etc.).

The project offers a variety of other application areas and valuable assistance for the following applications:

- To determine the material or chemical composition of a specific WEEE basket, EEE group or even single device
- To determine content or concentrations of hazardous or valuable materials, etc.
- To determine regional and national WEEE mass balances and material flow analysis.
- For expansion of existing WEEE recycling facilities or designing new systems for specific catchment areas
- Assessment of the impact of measures to sort devices in specific groups before the first treatment
- Impact of new materials to the future WEEE stream

Move Rec can optimize potentials by considering the entire process chain, regardless of operating limitations. This allows current and potential future yields and recovery rates to be visible in relation to the material input. This is currently only available in very limited degree.

Considering the database structure, new data from research and industry can be included in order to refine the existing product models.

4. Literature

[1] Dimitrakakis, E; Janz, A; Bilitewski, B.; Gidarakos, E.: Small WEEE: Determining recyclables and hazardous substances in plastics. Journal of Hazardous Materials 161(2009) 913-919, 2009

[2] Chancerel, P.; Rotter, V.: Recycling oriented characterization of waste electrical and electronic equipment. Eco-X Proceeding. Vienna, May 9-11, 2007

[3] Ordinance of the Federal Minister of Agriculture and Forestry, Environment and Water Management on Waste Prevention, Collection and Treatment of Waste Electrical and Electronic Equipment (Austrian WEEE Ordinance), BGBl. (Federal Law Gazette) II No. 121/2005 (EAG-VO). Non official translation http://www.lebensministerium.at/umwelt/abfall-ressourcen/abfall-altlastenrecht/awg-verordnungen/eagvo.html