Stakeholder Consultation

Feasibility study for setting-up reference values to support the calculation of recyclability / recoverability rates of electr(on)ic products
Team

Commissioned by

JOINT RESEARCH CENTRE
Institute for Environment and Sustainability (IES)
Sustainability Assessment Unit
Fabrice Mathieux, Laura Talens-Peiro, Fulvio Ardente

Leaders of the study

TU Berlin
Research Center of Microperipheric Technologies
in cooperation with the Fraunhofer Institute for Reliability
and Microintegration (Fraunhofer IZM)
Perrine Chancerel, Max Marwede

Duration: June 2015 – June 2016
Supporting experts

Thomas Van Nieuwenhuyse
Pierre-Marie Assimon
Alice Bizouard

Renate Gabriel

Helmut Kolba

Andreas Nolte
Objectives of the stakeholder consultation on the technical report

• Share with the stakeholders the findings of the study, and answer questions

• Get feedback and input to improve the report

• Discuss the recommendations

• Discuss the next steps
Agenda

10:00 10:15  Welcome, presentation of meeting agenda
10:15 10:50  Presentation and discussion of background and objectives of the study
10:50 12:15  Presentation and discussion of the methodology
12:15 13:15  Lunch
13:15 14:45  Presentation and discussion of methodology testing
14:45 15:00  Coffee Break
15:00 16:30  Presentation and discussion of recommendations and conclusions
16:30 17:00  Discussion on next steps
17:00 17:30  Wrap-up of the outcomes of the discussions and conclusions
17:30  End
Background, objectives, and research approach of the study

Section 1, p. 12-15
Policy background (1):
Recyclability of products enhances resource efficiency

- The “Raw Material Initiative” COM(2008)699 already identified end-of-life products as being very important sources of secondary raw materials for the EU, including for high-tech metals.
- “Roadmap to a Resource Efficient Europe” (COM(2011) 571 final) states in its Section 3 “Transforming the Economy” that the EC will “address the environmental footprint of products, (...) through setting requirements under the Ecodesign directive, to boost the material resource efficiency of products (e.g. recoverability/recyclability)”
- Focus on products re-emphasized in the “EU Action Plan for the Circular Economy” (COM(2015) 614/2) from Dec. 2nd 2015:
  - section 1.1 is on product design (“recyclability of products”)
  - Products are seen as source of secondary (critical) raw materials (in section 4 and 5)
Policy background (2):
Recyclability of products enhance resource efficiency

- One of the first follow-up action is the publication of the standardization mandate concerning material efficiency to European Standardisation Organizations (C(2015) 9096 final), that states in its technical Annex that:
  - “deliverable shall deal with Reusability/recyclability/recoverability (RRR) indexes or criteria, preferably taking into account the likely evolution of recycling methods and techniques over time”;
  - “adopted deliverables shall as far as possible specify (…) definition of reference tables (or guidance on how to build representative and quality-assured tables)”

- Note: The study addresses recyclability of products (not recycling of products) in a product policy context (e.g. Ecoodesign), not in a waste policy context (e.g. WEEE Directive) (although obvious links, e.g. Article 4 of WEEE Directive)
Technical background:

• In the REAPRo method of JRC, the product performance is assessed according to six sets of criteria, including the “Re-usability/ recyclability/ recoverability rates” (per mass) of a product.

• Ardente & Mathieux (2013): “the availability of robust and representative data concerning the recycling rates of materials and parts is a key issue of the recyclability index. […] further research is needed on this subject, by developing more comprehensive and representative data sets.”

• iNEMI Repair and Recyclability Metrics project: “industry needs an incorporated metric that reflects actual recovery rates of the product in the region where the product is sold”
Objectives of the study

• Define key harmonized methodological aspects to calculate reference values to support the calculation of recyclability and recoverability rates of electr(on)ic products,
• Evaluate the activities needed to collect data and to maintain a data on a timely manner,
• Assess the benefits and limitations associated to the reference values
• Assess feasibility of defining reference values
• Identify possible next steps
Experts supported the progress of the study for instance by proposing options, sharing knowledge and contacts and commenting the reports.
Objectives of the reference values

- Provide required data for a harmonized methodology to calculate recyclability and recoverability rates as well as transparency on data quality and availability
- Include definition of the reference networks of economically viable treatment processes (which may strongly vary in time)
- Requires data on treatment networks to be collected, processed, saved and updated in a systematic, consistent and standardised way
- Support the development of product policies aiming at improving the recyclability of products (e.g. ErP preparatory studies)
Questions/Feedback?
Presentation and discussion of the methodology
Definitions

Section 2, p 16-49
Definitions

Recyclability (IEC/TR 62635)

- Ability of waste product to be recycled, based on actual practices
- Profitable and environmentally sound process based on the current practices and market
- Ratio of recyclable product mass to total product mass

The definitions of recycling, recovery and disposal are given by the Waste framework directive.
**Definitions: Recyclability metrics (IEC/TR 62635/REAPRo)**

<table>
<thead>
<tr>
<th>Rate</th>
<th>Formula</th>
<th>Variables</th>
</tr>
</thead>
</table>
| re-usability| \( R_{use} = \frac{\sum_{i=1}^{N} m_{\text{reuse},i}}{m} \cdot 100 \) \( \% \) | \( R_{use} = \) Reusability rate \( \% \)  
\( m = \) total product mass \( \text{[kg]} \)  
\( m_{\text{reuse},i} = \) mass of the \( i^{th} \) reusable part \( \text{[kg]} \)  
\( N = \) number of reusable parts |
| recyclability| \( R^{*}_{cyc} = \frac{\sum_{i=1}^{P} (m_{\text{recyc},i} \cdot RCR_{i})}{m} \cdot 100 \) \( \% \) | \( R^{*}_{cyc} = \) Recyclability rate \( \% \)  
\( m = \) total product mass \( \text{[kg]} \)  
\( m_{\text{recyc},i} = \) mass of the \( i^{th} \) recyclable part \( \text{[kg]} \)  
\( RCR_{i} = \) recycling rate of the \( i^{th} \) part \( \% \)  
\( P = \) number of recyclable parts |
| recoverability| \( R_{cov} = \frac{\sum_{i=1}^{Q} (m_{\text{reco},i} \cdot RVR_{i})}{m} \cdot 100 \) \( \% \) | \( R_{cov} = \) Recoverability rate \( \% \)  
\( m = \) total product mass \( \text{[kg]} \)  
\( m_{\text{reco},i} = \) mass of the \( i^{th} \) recoverable part \( \text{[kg]} \)  
\( RVR_{i} = \) Recovery rate of the \( i^{th} \) part \( \% \)  
\( Q = \) number of parts that are recoverable |

\( R^{*}_{cyc} \): Recyclability rate of product  
\( RCR_{i} \): calculated material-/part-specific recycling and recovery rate (RRR)

In this study: The term “recyclability and recoverability rate” refers to the recyclability of the product. The rates used for the product parts are called “calculated material-specific recycling and recovery rates”.
Presentation and discussion of the methodology
Scope: treatment chain, classification of products and materials, definition of end of life scenario

Section 2.4 & 2.5, p 21-34
Scope: Treatment Chain

Whole treatment chain (EN and TS 50625 standards/WEELABEX)

**start:** untreated collected WEEE  \(\rightarrow\)  **end:** end-of-waste status of fraction, final recovery or disposal of fractions

Only economically running treatment processes
- At industrial scale for at least one year
- Being named by at least two European treatment facilities in their reporting

**Interim technologies:** separation (or conditioning) processes where – a yield of – different output fractions are achieved (including preparing for re-use)

**Final technologies** aim at producing secondary raw materials (e.g. smelters), (re-use appliances and components), and incineration and disposal of output fractions e.g. at landfill sites
- Change of the physical characteristics (e.g. metal smelting processes, incineration, including plastics recycling = granulation/compounding)
- ‘final destinations’ (e.g. concrete production, landfills) (WF-Reptool)
Scope: Treatment Chain – Interim and final technologies

Interim technologies:

- First interim technologies
  - Fraction-specific interim technologies

Final technologies:

- Technologies intending recycling
  - Disposal technologies
- Technologies intending recovery
Scope: Classification at Product Level

Classification of EEE according to UNU (Wang, Huisman, Baldé, & Stevels, 2012)

- 10 product categories
- 58 sub-categories
- about 900 products

<table>
<thead>
<tr>
<th>Category</th>
<th>Subcategories</th>
</tr>
</thead>
<tbody>
<tr>
<td>104 LHHA Washing machines</td>
<td>1041 Washing machines, 1042 Washing machines + combi-dryers</td>
</tr>
<tr>
<td>105 LHHA Wash dryers and centrifuges</td>
<td>1051 Dryers, 1052 Centrifuges</td>
</tr>
<tr>
<td>107 LHHA Sunbeds</td>
<td>1071 Sunbeds (excl. face tanners)</td>
</tr>
<tr>
<td>108 C&amp;F Fridges</td>
<td>1081 Fridges (excl. combi freezers), 1082 Wine fridge, 1083 Absorption fridge</td>
</tr>
<tr>
<td>109 C&amp;F Freezers</td>
<td>1091 Freezers</td>
</tr>
<tr>
<td>110 C&amp;F Combi-fridges and freezers</td>
<td>1101 Combi fridges and freezers</td>
</tr>
<tr>
<td>111 C&amp;F Airconditioning</td>
<td>1111 HH airconditioning (moveable, ex split sys), 1112 HH airconditioning (fixed, split sys), 1113 Other airconditioning and dehumidifying</td>
</tr>
<tr>
<td>112 C&amp;F Other</td>
<td>1121 HH Watercoolers, 1122 Ice(cube) makers</td>
</tr>
<tr>
<td>113 PROF Cooling and Freezing</td>
<td>1131 PROF Watercoolers, 1132 PROF Ice makers, 1133 Cooling displays, 1134 PROF Fridges and freezers, 1135 PROF Kitchen C&amp;F Other</td>
</tr>
<tr>
<td>114 SLHA Microwaves</td>
<td>202 SHA Food</td>
</tr>
<tr>
<td>302 IT Desktop PC's</td>
<td>3021 Desktop personal computers</td>
</tr>
<tr>
<td>303 IT Laptop PC's</td>
<td>3031 Laptops, 3032 Tablets, 3033 Notebooks, 3034 Other laptops, palmtops</td>
</tr>
<tr>
<td>304 IT Printing and imaging</td>
<td>3041 HH Multifunctionals (fax, print, scan, copy, etc), 3042 Inkjet printers, 3043 Laserprinters, 3044 Other printers (matrix, thermal), 3045 Scanners, 3046 Typewriters, 3047 Faxes</td>
</tr>
<tr>
<td>305 IT Telecom</td>
<td>3051 Cordless phones, 3052 Telephones (fixed), 3053 Other HH telecom</td>
</tr>
<tr>
<td>306 IT Mobile phones</td>
<td>3061 Mobile phones, 3062 Smartphones, 3063 Other mobile phone devices (pagers)</td>
</tr>
</tbody>
</table>
## Scope of the reference values: Classification at Material Level

WF-RepTool List of Output Fractions based on ‘European Waste Catalogue’ (EWC)

- fractions from dismantling (mainly 16 xx xx)
- fractions from shredding (19 10 xx)
- fractions from further separation of fractions (19 12 xx)

<table>
<thead>
<tr>
<th>Material</th>
<th>Correspondance to WF-RepTool output fractions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>code</td>
</tr>
<tr>
<td>Iron</td>
<td>iron-rich' fraction from dismantling</td>
</tr>
<tr>
<td></td>
<td>iron-metals 'pure' from dismantling</td>
</tr>
<tr>
<td></td>
<td>iron fractions for further separation or for</td>
</tr>
<tr>
<td></td>
<td>'final processes'</td>
</tr>
<tr>
<td></td>
<td>16 02 16 / 01</td>
</tr>
<tr>
<td></td>
<td>16 02 16 / 02</td>
</tr>
<tr>
<td></td>
<td>19 12 02 / 01</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>stainless steel 'pure' from dismantling</td>
</tr>
<tr>
<td></td>
<td>stainless steel fractions for further</td>
</tr>
<tr>
<td></td>
<td>separation or for 'final processes'</td>
</tr>
<tr>
<td></td>
<td>16 02 16 / 08</td>
</tr>
<tr>
<td></td>
<td>19 12 02 / 02</td>
</tr>
<tr>
<td>Aluminium</td>
<td>aluminium-rich' fraction from dismantling</td>
</tr>
<tr>
<td></td>
<td>aluminium-metals 'pure' from dismantling</td>
</tr>
<tr>
<td></td>
<td>aluminium fractions for further separation or</td>
</tr>
<tr>
<td></td>
<td>for 'final processes'</td>
</tr>
<tr>
<td></td>
<td>16 02 16 / 03</td>
</tr>
<tr>
<td></td>
<td>16 02 16 / 04</td>
</tr>
<tr>
<td></td>
<td>19 12 03 / 03</td>
</tr>
</tbody>
</table>

Elimination of output fractions:
- wrongly allocated to WEEE
- not part of new devices
- not anymore used in new products (e.g. CCFLS)
- banned or restricted by the legislation (for instance RoHS directive)

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Table 3, Final Report
Questions/Feedback?
Presentation and discussion of the methodology
Method for data collection

Section 2.6 & 2.7, p 21-30
Methods for data collection

Possible options:

1. Use data on recycling and recovery rates compiled in WF-RepTool for WEEE input flows with which products/appliances would be treated and apply for the product/appliance. The used data have to be checked and validated for the RRR calculation, and combined with data on the input.

2. Conduct additional batch analyses at treatment operators, i.e. analyse the input and the output of treatment processes. In doing so, it is important to consider the whole treatment chain (all interim and final technologies). The analysis can be done e.g. in the frame of research projects or combined with other goals, e.g. certification processes.

3. Model the processes with simulation tools. This requires validating the product and process-related parameters through experimental analyses.

→ The three options are not independent, and none of them, taken separately, is sufficient to calculate RRR rates and understand the effect of product design on the RRR

→ Focus on option 1.
Methods for data collection
Use of the data on recycling and recovery rates

Aggregation of data on recycling and recovery rates along the treatment chain – considering the interdependence between the steps!
Method to calculate the material-specific RRR

Input WEEE

Total mass

WEEE treatment processes

Fractions recycled

Plast. Ferr. Met. Non Ferr. Met. ...

X Y Z

Fractions used for OMR and ER

Fractions disposed

Measured and reported in WF- RepTool for each operator
Method to calculate the material-specific RRR (1/2)

1. Association of the product with the corresponding WEEE flow, i.e. the mix of appliances, e.g. large household appliances for washing machines

2. Selection of operators that are representative and that treat the WEEE using the same generic EoL scenario:
   a. Definition of the generic EoL scenario for the WEEE input flow
   b. Selection of the panel of first step operators achieving the high recycling and recovery rates with their downstream acceptors

3. Determination of the total mass of the share of the final fractions classified as recycled or recovered after the treatment chain:
   a. Exploitation of batch report data: Determination of the mass of the final fractions produced by the selected operators
   b. Classification of the use of the final fractions in the final technology as recycling, energy recovery, other material recovery or disposal

4. Determination of the mass of the material contained in the WEEE input flow based on composition data collected
Method to calculate the material-specific RRR (2/2)

5. Calculation of the material- and operator-specific RRR by dividing the mass of the share of the final fractions classified as recycled or recovered after the treatment chain by the mass of the corresponding material contained in the WEEE input flow.

6. Combination of the data into one or a range of calculated material-specific recycling and recovery rate(s) per material by combining the data of the selected operators, under consideration of year N and year N-1 rates for sufficient temporal representativeness (section 2.8.1.3).

7. Association between the share of the final fractions which use is classified as recycled and recovered after the treatment chain and the “materials” of the bill of materials of the product.

8. Calculation of the recyclability and recoverability rates of the product based on the BOM.
Definition of the EoL scenario

Scheme

- EoL scenario summarizes for a considered product the treatment steps that it will undergo
- Whole treatment chain for collected WEEE
  - Start: untreated WEEE
  - End: end-of-waste status for fractions or final recovery or disposal of fractions
- Reference network of economically running treatment processes
- Not too detailed (specific treatment technologies and their order can vary depending on operators)
Methods for data collection

Selection of operators

- Operators using economically running best available techniques! Why?
  1. We assume that the BAT of today will be at least the average technologies of tomorrow.
  2. It encourages the stakeholders (producers, treatment operators and public authorities) to ensure that BAT become soon the average treatment techniques

- Selection of number of first step operators with their downstream acceptors achieving the highest recycling and recovery rates
  - Fix the number of first step operators achieving the highest RRR with their downstream acceptors → Methodology testing with 3 (and 5)
  - select a percentage of the operators for which data are available
  - consider the first step operators treating a large share of the WEEE flow
  - take all operators and calculate an average (no BAT approach).
Questions/Feedback?
Testing of methodology
Case studies, EoL scenario, bill of material, relevant materials

Section 3.1 & 3.2, p. 50-63
Steps to test methodology

1. Selection of case studies
2. Collection of bill of material of the product
3. Definition of the EoL scenario
4. Calculation of the material-specific recycling and recovery rates based on the reporting data
5. Calculation of the recyclability / recoverability rates of the product
1. Selection of case studies
Identification of relevant product groups

Factors for selecting product groups

- Market relevance
- Relevance for eco-design policy
- Complexity and data availability

- Laptops
- Washing Machines
2. Definition of EoL scenario

• Generic
• Reference network of economically running treatment processes
• Based on real treatment chain to cover interdependencies
• Specific type of treatment technologies for liberation and separation is not described (confidentiality, variations)
• Includes the final technologies
• Based on plant visits, state of the art scenarios in WF-RepTool by Renate Gabriel, input from Eco-systèmes
**EoL scenario for laptops**

1. Dismantling and sorting of display unit and battery
   - Remaining parts
   - Display unit
   - Battery

2. Further manual dismantling or mechanical crushing, separation and sorting
   - LCD panel

3. Further separation, sorting, and conditioning
   - Steel mill traditional
   - Cu smelter traditional
   - Cu smelter special
   - Al smelter
   - Other metal smelters
   - Plastic Recycling Production of other products of/with plastics
   - Landfill
   - Waste incineration
   - Technologies/markets under development
   - Battery sorting/ separation/recycling
EoL scenario for washing machines

1. Manual dismantling and sorting of materials and components
   - e.g. cables, capacitors, concrete

2. Mechanical opening

3. Manual sorting
   - e.g. cables, motors, printed circuit boards, PCB (suspect) capacitors, concrete

4. Shredding + manual and automatic sorting

Further separation, sorting and conditioning

- Steel mill traditional
- Stainless steel works
- Al smelter
- Other metal smelters
- Plastic Recycling
  Production of other products of/with plastics
- Road construction
  Defined construction purposes
  Concrete Production
- Landfill
- Waste incineration
- Cu smelter special
- Cu smelter traditional
- Hazardous waste incineration

Perrine Chancerel, Max Marwede
EoL scenario: Open questions

Use of several EoL Scenarios (and related RRR)

• Case by case decision
• Aspects to assess relevance of EoL scenario: distinction, market share, aim to influence eco-design or higher recyclability
• Proof, that product is treated in alternative EoL scenario, in case it is selected for the recyclability calculation

→ Possibility of calculate “average” product recyclability depending e.g. on market shares of EoL scenarios
EoL scenario: Open questions

EoL scenarios for new products/materials

How to consider new materials in the calculation?

1) In case the current EoL scenarios are able to recycle or recover the new material, estimate the RRR through in-situ treatment trials and expert knowledge

2) In case there is no recycling process yet in development for the new material and the current EoL scenarios are not able to recycle or recover it, set the recyclability rate for this material to zero

3) In case a dedicated treatment process is under development
   a. The material could be excluded from the calculation of the product recyclability and recoverability rate
   b. If a pilot process is available, the material-specific RRR of the pilot process could be calculated and used for the calculation of the recyclability and recoverability rate of the product

With periodic revision!
3: Collection of bill of materials

Bill of material: List of materials and their weight (share)

Challenges

- Differences between sources
- Data availability for current products on the market
- Break-down of complex assemblies into materials (e.g. motors, hard-disk drives …) or of materials into chemical elements (e.g. alloys, ceramics, glass, …)
- Range of designs (screen size, type of drives, …)
- Range of content
- Assignment of “new” materials (e.g. magnesium frame) to material list
- Sufficient data for representative average of product type
### BoM of Laptop

<table>
<thead>
<tr>
<th>Materials and components</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous material</td>
<td>11%</td>
</tr>
<tr>
<td>Aluminium material</td>
<td>4%</td>
</tr>
<tr>
<td>Copper cable and material</td>
<td>0.4%</td>
</tr>
<tr>
<td>Plastic</td>
<td>38%</td>
</tr>
<tr>
<td>Printed circuit board</td>
<td>16%</td>
</tr>
<tr>
<td>Battery</td>
<td>11%</td>
</tr>
<tr>
<td>LCD panels</td>
<td>8%</td>
</tr>
<tr>
<td>Drives</td>
<td>8%</td>
</tr>
<tr>
<td>Hard Disk</td>
<td>4%</td>
</tr>
</tbody>
</table>

FEM / IUTA 2011 (n=451)

**BoM Laptops:**
- Main constituents: plastic, PCB, ferrous metals, battery

**BoM Washing Machine**
- Main constituents: concrete, steel

### Washing Machine

<table>
<thead>
<tr>
<th>Materials and components</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acryl-Butadien-Styrol (ABS)</td>
<td>1.7%</td>
</tr>
<tr>
<td>Aluminium</td>
<td>3.2%</td>
</tr>
<tr>
<td>Brass</td>
<td>0.1%</td>
</tr>
<tr>
<td>Cable</td>
<td>1.1%</td>
</tr>
<tr>
<td>Chipboard</td>
<td>2.9%</td>
</tr>
<tr>
<td>Concrete</td>
<td>31.7%</td>
</tr>
<tr>
<td>Copper</td>
<td>1.3%</td>
</tr>
<tr>
<td>Cotton with phenolic binder</td>
<td>0.7%</td>
</tr>
<tr>
<td>Electronic Components</td>
<td>0.5%</td>
</tr>
<tr>
<td>EPDM</td>
<td>3.1%</td>
</tr>
<tr>
<td>Glass</td>
<td>2.7%</td>
</tr>
<tr>
<td>Cast iron</td>
<td>1.8%</td>
</tr>
<tr>
<td>Polyacryl (PA)</td>
<td>0.02%</td>
</tr>
<tr>
<td>PMMA</td>
<td>0.004%</td>
</tr>
<tr>
<td>Polypropylen (PP)</td>
<td>0.2%</td>
</tr>
<tr>
<td>PP 20% mineral filler</td>
<td>0.6%</td>
</tr>
<tr>
<td>PP 40% mineral filler</td>
<td>11.2%</td>
</tr>
<tr>
<td>Polystyrene (PS)</td>
<td>0.3%</td>
</tr>
<tr>
<td>Steel</td>
<td>33.9%</td>
</tr>
<tr>
<td>Other materials</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

**Stakeholder Consultation, Feasibility study, JRC contract number: 391238**

Brussels, 2nd of June 2016
Bill of materials

Recommendations

• Compare BoM with available material specific recycling rates and EoL scenario for best fit
• Use new data; make own teardowns
• If possible and required, break-down of complex assemblies into materials (e.g. motors, hard-disk drives …) or of materials into chemical elements (e.g. alloys, ceramics, glass, …)
• Use sufficient data for representative average of product type
• Assign “new” materials (e.g. magnesium frame) to material list according to final fractions
## Relevant materials and components for testing

<table>
<thead>
<tr>
<th>Material or component</th>
<th>Product group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoplastics</td>
<td>Laptop/WM</td>
</tr>
<tr>
<td>Non-ferrous metals: aluminium and copper</td>
<td>Laptop/WM</td>
</tr>
<tr>
<td>Ferrous-metals</td>
<td>Laptop/WM</td>
</tr>
<tr>
<td>Printed circuit boards (PGMS, PMs)</td>
<td>Laptop/WM</td>
</tr>
<tr>
<td>Drives</td>
<td>Laptop</td>
</tr>
<tr>
<td>Hard Disk</td>
<td>Laptop</td>
</tr>
<tr>
<td>LCD Panel (Indium)</td>
<td>Laptop</td>
</tr>
<tr>
<td>Lithium-Ion batteries (Cobalt)</td>
<td>Laptop</td>
</tr>
<tr>
<td>Mineral fraction: glass, concrete and other mineral materials</td>
<td>Washing machine</td>
</tr>
</tbody>
</table>
Questions/Feedback?
Testing of methodology
Data extraction, calculation of recyclability

Section 3, p. 51
4: Data collection

Input WEEE

Total mass

WEEE treatment processes

Fractions recycled

Plast. Ferr. Met. Non Ferr. Met. ...
X Y Z

Fractions used for OMR and ER

Fractions disposed

Measured and reported in WF-RepTool for each operator

Perrine Chancerel, Max Marwede
### 4: Calculated material specific recycling and recovery rates (RRR) from WF-RepTool: Laptops

<table>
<thead>
<tr>
<th>Fractions and corresponding materials</th>
<th>Recycling rate</th>
<th>Recovery rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Std dev</td>
</tr>
<tr>
<td>Plastics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermo-plastics</td>
<td>92%</td>
<td>9%</td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium</td>
<td>98%</td>
<td>1%</td>
</tr>
<tr>
<td>Copper</td>
<td>98%</td>
<td>1%</td>
</tr>
<tr>
<td>Ferrous metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>98%</td>
<td>1%</td>
</tr>
<tr>
<td>Cast iron</td>
<td>98%</td>
<td>1%</td>
</tr>
<tr>
<td>Printed circuit boards</td>
<td>Extraction rate:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>94%</td>
<td>6%</td>
</tr>
<tr>
<td>Drives</td>
<td>82%</td>
<td>n/a</td>
</tr>
<tr>
<td>Hard-disks</td>
<td>92%</td>
<td>n/a</td>
</tr>
<tr>
<td>LCD panels</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Eco-systèmes, 3 operators selected
4: Calculated material specific RRR from WF-RepTool: Washing machines

<table>
<thead>
<tr>
<th>Fractions and corresponding materials</th>
<th>Recycling rate</th>
<th>Recovery rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Std dev</td>
</tr>
<tr>
<td>Glass, concrete and other mineral materials</td>
<td>73%</td>
<td>18%</td>
</tr>
<tr>
<td>Plastic</td>
<td>Thermoplastics</td>
<td>62%</td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td>Aluminium</td>
<td>96%</td>
</tr>
<tr>
<td>Copper</td>
<td>96%</td>
<td>6%</td>
</tr>
<tr>
<td>Steel</td>
<td>96%</td>
<td>6%</td>
</tr>
<tr>
<td>Cast iron</td>
<td>96%</td>
<td>6%</td>
</tr>
<tr>
<td>Printed circuit boards</td>
<td>Extraction rate:</td>
<td>43%</td>
</tr>
</tbody>
</table>

Eco-systèmes, 3 operators selected
4. Comments on the calculated material-specific rates

• **Thermoplastics**: No differentiation of the RRR per resin

• **Ferrous and non-ferrous metals** found in different output fractions of interim technologies (sorted iron fractions, as well as complex fractions like cables or electric motors, etc.). Aggregation of the recycled quantities of ferrous and non-ferrous metals of all metal-containing fractions

• **Printed circuit boards**: extraction rate of PCB in the interim technologies

• The RRR for **drives and hard-disks** are based on the average "packages" created and periodically updated by Eco-systèmes in WF-RepTool

• The **LCD panel** is only the glass sandwich containing the liquid crystals, excluding the PMMA diffuser. The stored fraction are excluded from the calculation of WEEE recycling and recovery rates reported to public authorities.

• **Mineral fraction, glass** and **concrete** have the same recycling destinations and the same RRR

• Extraction rate of **batteries** from Laptops not quantifiable
4: Calculated material-specific RRR of PCBs

<table>
<thead>
<tr>
<th>Normalized to 100%</th>
<th>R</th>
<th>OMR</th>
<th>ER</th>
<th>LD</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laptop</td>
<td>25%</td>
<td>59%</td>
<td>16%</td>
<td>0.003%</td>
<td>100%</td>
</tr>
<tr>
<td>WM</td>
<td>22%</td>
<td>63%</td>
<td>16%</td>
<td>0.001%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Based on data provided by Aurubis

- 22-25 % recycled (> 90 % of material value)
- Uncertainties in RRR and material composition
- Process specificities depend on specific copper smelter (results cannot be simply transferred)
- Assumptions influencing the calculated rates
  - 90-98 % recycling of Cu and precious metals (here 95 %)
  - Potential disposal of spice metals and hazardous/toxic materials in further treatment (outside Cu smelter)
  - No account of O and H
  - Exact determination of share of C from plastics used as reducing agent or as fuel substitute not possible
4: Calculated material-specific RRR of CRMs

Cobalt from batteries
• Found mainly in LiCoO₂ cathode of Li-Ion battery, also in NMC cathode of Li-Ion and in NiCd and NiMH batteries
• Cobalt recycling rate at Umicore > 90 %

Indium for flat panel display appliances
• Technically feasible, but not economically → R&D
➢ So far no recovery (storage)
Questions/Feedback?
5: Calculation of the recyclability and recoverability rates

<table>
<thead>
<tr>
<th>Materials and components</th>
<th>Share according to BOM</th>
<th>Recycling rate</th>
<th>Recovery rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrous material</td>
<td>11%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Aluminium material</td>
<td>4%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Copper cable and material</td>
<td>0.4%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Plastic</td>
<td>38%</td>
<td>89% for thermoplastics n/a for other plastics</td>
<td>94% for thermoplastics n/a for other plastics</td>
</tr>
<tr>
<td>Printed circuit board</td>
<td>16%</td>
<td>96%* x 26%* = 25%</td>
<td>96%* x 100%* = 96%</td>
</tr>
<tr>
<td>Battery</td>
<td>11%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>LCD panels</td>
<td>8%</td>
<td>Not considered in the calculation because of storage/new technologies under development</td>
<td></td>
</tr>
<tr>
<td>Drives</td>
<td>8%</td>
<td>82%</td>
<td>82%</td>
</tr>
<tr>
<td>Hard Disk</td>
<td>4%</td>
<td>92%</td>
<td>92%</td>
</tr>
</tbody>
</table>

* Extraction rate  
** Recycling rate
5: Calculation of the recyclability and recoverability rates

<table>
<thead>
<tr>
<th>Materials and components</th>
<th>Share</th>
<th>Recycling rate</th>
<th>Recovery rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acryl-Butadien-Styrol (ABS)</td>
<td>1.7%</td>
<td>70%</td>
<td>81%</td>
</tr>
<tr>
<td>Aluminium</td>
<td>3.2%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Brass</td>
<td>0.1%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Cable</td>
<td>1.1%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Chipboard</td>
<td>2.9%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Concrete</td>
<td>31.7%</td>
<td>74%</td>
<td>74%</td>
</tr>
<tr>
<td>Copper</td>
<td>1.3%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Cotton with phenolic binder</td>
<td>0.7%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Electronic Components</td>
<td>0.5%</td>
<td>42%* x 22%** = 9%</td>
<td>42%* x 100%** = 42%</td>
</tr>
<tr>
<td>EPDM</td>
<td>3.1%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Glass</td>
<td>2.7%</td>
<td>74%</td>
<td>74%</td>
</tr>
<tr>
<td>Cast iron</td>
<td>1.8%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Polyacryl (PA)</td>
<td>0.02%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>PMMA</td>
<td>0.004%</td>
<td>70%</td>
<td>81%</td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>0.2%</td>
<td>70%</td>
<td>81%</td>
</tr>
<tr>
<td>PP 20% mineral filler</td>
<td>0.6%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>PP 40% mineral filler</td>
<td>11.2%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Polystyrene (PS)</td>
<td>0.3%</td>
<td>70%</td>
<td>81%</td>
</tr>
<tr>
<td>Steel</td>
<td>33.9%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Other materials</td>
<td>3.0%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Open questions
Selection of the number of operators

<table>
<thead>
<tr>
<th>Materials</th>
<th>Average</th>
<th>Std dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 op.</td>
<td>5 op.</td>
<td>3 op.</td>
<td>5 op.</td>
<td></td>
</tr>
<tr>
<td>Glass, concrete and other mineral materials</td>
<td>73%</td>
<td>18%</td>
<td>56%</td>
<td>100%</td>
</tr>
<tr>
<td>Thermoplastics</td>
<td>62%</td>
<td>30%</td>
<td>35%</td>
<td>100%</td>
</tr>
<tr>
<td>Aluminium</td>
<td>96%</td>
<td>6%</td>
<td>86%</td>
<td>100%</td>
</tr>
<tr>
<td>Copper</td>
<td>96%</td>
<td>6%</td>
<td>86%</td>
<td>100%</td>
</tr>
<tr>
<td>Steel</td>
<td>96%</td>
<td>6%</td>
<td>86%</td>
<td>100%</td>
</tr>
<tr>
<td>Cast iron</td>
<td>96%</td>
<td>6%</td>
<td>86%</td>
<td>100%</td>
</tr>
<tr>
<td>PCB extraction rate</td>
<td></td>
<td></td>
<td>11%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>43%</td>
<td>31%</td>
<td>26%</td>
<td>100%</td>
</tr>
</tbody>
</table>

→ little significant differences between the figures calculated using the rates reported by three and by five operators

- recycling of plastics
- extraction of PCBs

→ premature to fix yet the number of operators! → Need for further work
Open questions
Quantification of uncertainties

Challenges: how to communicate the RRR?

- Providing only one single average RRR per material (e.g. 96% for copper) does not reflect the reality

- Possible approaches are:
  - To assume that the uncertainty is proportional to the standard deviation with an agreed proportionality factor (e.g. 1)
  - To define uncertainty classes, e.g. “high”, “medium” and “low”
  - To base the uncertainty not (only) on the standard deviation, but also (or only) on the range

How to calculate the recyclability and recoverability rates of products?

- use methods for error propagation

- base the calculation on ranges of material-specific RRR and to provide a “conservative”, a “medium” and an “optimistic” recyclability and recoverability rate of the product
Open questions
Data validity - Complexity of WEEE treatment

Challenges

• (Geographic) variation of input
• Variation of outputs (legal requirements, availability of downstream operators, commodity prices etc.)
• Diversity of technical treatment solutions

Recommendations

• No ‘secret recipe’
• Critically check applied methods and results to determine RRR
• Broader data sourcing
• Good documentation
• Plausibility checks (e.g. compare orders of magnitude of the batch analyses and the amounts of final fractions yearly sent to acceptors)
Open questions
Required information about treatment process

2 options:

1. accepting black box approaches in cooperation with the organizations controlling the quality of the data, and/or

2. finding agreements to get access to sensitive information

Here: „black box“ approach because of confidentiality, complexity and variability of process chain, level of detail not necessarily required

- No information on influence of treatment technologies/design on RRR
- Less traceability of fractions, less transparency, less control

Recommendations

• Follow both options!

• Trust in systems controlling the data and find agreements with operators to reveal sensitive information (e.g. NDA)

• Description of final fractions (quality, type etc.)
Questions/Feedback?
Presentation and discussion of specific challenges
Harmonizing interpretations, material-specific data, extension of the scope

Section 5 & 6, p. 85-105
Harmonization of interpretation and definitions

- Classification of the use of a final fraction in “final technologies” as recycling, recovery or disposal across different countries

- Different measurement and reporting of RRR based on Waste framework definitions

    “any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It […] does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations”

    or WEEE-Directive

    “the achievement of the recycling targets shall be calculated […] by dividing the weight of the WEEE that enters the […] recycling […] facility […] by the weight of all separately collected WEEE”

- Data quality across countries (transposition of directive, enforcement, availability …)

    ➔ Use harmonized methodological framework
Harmonization of interpretation and definitions

Products: Example RRR of PCB of Laptop

<table>
<thead>
<tr>
<th>Normalized to 100%</th>
<th>R</th>
<th>OMR</th>
<th>ER</th>
<th>LD</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laptop</td>
<td>25%</td>
<td>59%</td>
<td>16%</td>
<td>0.003%</td>
<td>100%</td>
</tr>
<tr>
<td>Laptop scenario*</td>
<td>66%</td>
<td>18%</td>
<td>16%</td>
<td>0.003%</td>
<td>100%</td>
</tr>
</tbody>
</table>

* With the assumption that all materials (also reducing agents such as Al or Fe), which end up in a product (e.g. slag) count as recycled

Important is the end use of the product (for example not used for backfilling)
Collection of more detailed material-specific data
Plastics, complex parts, ferrous and non-ferrous metals, batteries and critical materials

Challenges

- Higher granularity (e.g. differentiation between plastic resins) rely on step 2, 3, 4 … operators (batch assessment)
- Complexity of the material fractions
- Level of details not yet given
- Confidentiality issues and burden for the operators
- Unstable markets
- Technical and statistical challenges (e.g. variation of fractions produced by step 1 operator, step 2 operator mixes different input fractions)
Collection of more detailed material-specific data
Plastics, complex parts, ferrous and non-ferrous metals, batteries and critical materials

Recommendations

• Improve input and batch analysis as well as downstream traceability
• Cooperate with downstream acceptors to collect available data
• Harmonise reporting
• Batteries: Use reporting data from battery directive
• Critical Raw Materials
  • Include in list of final fractions recycled
  • Calculate substance-based recycling rate
  • Include treatment technologies in EoL scenarios
Extension of the scope
Non-material related design features

Challenges

• Recyclability and recoverability is influenced by material composition of the product, the homogeneity of the components, their identifiability, the connections, the standardisation of all these design-related factors

• Currently, the influence of individual design cannot be derived from reported data

Recommendations

• Accompany the calculated recyclability and recoverability rates with **qualitative assessment**: e.g. extractability and accessibility of pollutants/components (e.g. through a checklist or disassembly trial)

• Test effect of design choices in treatment trials and simulation and prove that product will really end up in that economically running process
Extension of the scope

Collection
• Including collection rates would measure performance of system, and not recyclability of product (category)

Reusability
Challenge
• Current exclusion of reusability in reference values
• Reuse high in waste management hierarchy

Recommendations
• Enable in principle the consideration of reuse in the reference values

Applicability to other products
• RRR targets for batteries, packaging waste, end-of-life vehicles (assess feasibility)
Extension of the scope

Use for further environmental and economic assessments

- MEErP, REAPRo, QWERTY, product environmental footprint
- Contribution to life cycle inventories (more data on treatment chain, destinations, final applications required)
- Compare data to data from process simulation tools
- Economic assessments
  - Add economic factors such as treatment costs, commodity prices (High uncertainty due to time gap between design and recycling and fluctuation of secondary material prices and cost factors)
  - Include semi-quantitative indicators for cost-influencing design factors e.g. disassembly time for sorting fractions
Questions/Feedback?
Presentation and discussion of recommendations
Summary of recommendations and conclusions

Section 7 & 8, p. 106-108
Summary of recommendations

Reporting and WEEE compliance schemes

• Increase granularity of collected data (material-specific recycling and recovery rates): Improve input and batch analysis, downstream traceability for critical materials, batteries, plastic resins, complex parts, batteries, ferrous and non-ferrous metals

• Willingness of the stakeholders (WEEE compliance schemes and operators) to participate depends on incentives and confidentiality issues

• Increase data validity by broad data sourcing, common reporting praxis, good documentation and through plausibility checks by experts
Summary of recommendations

Method and reference values

- Data should consider entire “economically viable” treatment chains for a WEEE flow due to interdependencies between different process steps and operators
- Several alternative EoL scenarios with different associated reference values if
  - they have relevant market shares
  - the differentiation of the EoL scenarios serves the goal of achieving progress towards eco-design and better recycling of the products
  - the user can prove that its products will actually be treated in this scenario
- Recommendations on how to handle “new” materials or components
- The RRR should be periodically updated
Summary of recommendations

Extension of the reference values and work to be done

• Investigate the possibility to collect data on type and quality of the final fractions which uses are classified as recycled or recovered

• Investigation of methods to reflect uncertainties of the calculated material-specific RRR

• Assess possibilities to calculate material-specific recycling rates for critical materials, which due to their low weight share have negligible effect on the recyclability and recoverability rate of a product

• Assess the possibility to integrate re-use as part of recovery in the reference values

• Assess the possibility to use proposed approach for other waste flows such as packaging, batteries or end-of-life vehicles

• Assess possibilities to extend reference values with indicators on economic and environmental performance of recyclability and recoverability
Conclusions

• New opportunities to harmonize the calculation of the recyclability and the recoverability of products
• Study shows that it is feasible to define reference values for materials/components contained in products
• The method is not yet a “turnkey solution” and several areas for which further work is needed were identified
• New opportunities to link product design and recycling, as well as to enhance the dialogue between the stakeholders
• The generation of the reference values and the availability of data on RRR depend on systematic questions like the harmonizing the interpretation of definitions
• The methodology needs to be embedded in the current discussion on the relevance and the ability to implement recyclability and recoverability indicators
Questions/Feedback?
Now that the feasibility for references values has been confirmed…

Discussion on next steps

… the floor is yours…
What are the next steps?

When should they be initiated/finalized?
Who should be involved?

- Setting-up a table of reference values to support recyclability assessment of products?
  - To support product policy work (preparatory / review studies; material efficiency analysis; PEF)? As a platform for producers / recyclers to cooperate? …
  - Who should participate to its elaboration?

- Initiate dialogue with other bodies concerning other product groups (e.g. non ErP; end-of-life vehicles; batteries; packaging)?
  - …
What are the next steps?

When should they be initiated/finalized?
Who should be involved?

- Ensure access to data from WEEE Compliances schemes (and/or operators)?
  - Now? How often?
  - Which compliances schemes? Several?
  - Incentives? Confidentiality? Need first to harmonize reporting practices?

- Explore other sources of data?
  - Now?
  - Who? (e.g. for plastics): (association of) recyclers? Research organisations?

- Define an appropriate number of relevant end-of-life scenarios?
  - When? How often? Who?
What are the next steps?

When should they be initiated/finalized?
Who should be involved?

• Address open questions:
  • Variability of treatments?
  • Address also re-use?
  • Assess possibilities to extend reference values with indicators on economic and environmental performance of recyclability and recoverability?
  • Who?

• Other suggestions…?
Summary

- Concluding remarks and wrap-up

- Next steps:
  - Please send your written feedback ASAP and anyway by June 24th
  - The report will be adjusted and published (during summer)