# “Recycling of highly functional and strategically important metals from WEEE – Current status and future perspectives”

Vera Susanne Rotter & Sabine Flamme


12th International Electronics Recycling Congress IERC 2013
**January 16 – 18, 2013, Salzburg, Austria**


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# Recycling of highly functional and strategically important metals from WEEE

– Current status and future perspectives

- Recycling “critical metals” – an imperative?
- Status of (metal) recovery for WEEE
- Product-centered recycling strategies for WEEE
- Future strategies for multi-element recycling
- Outlook

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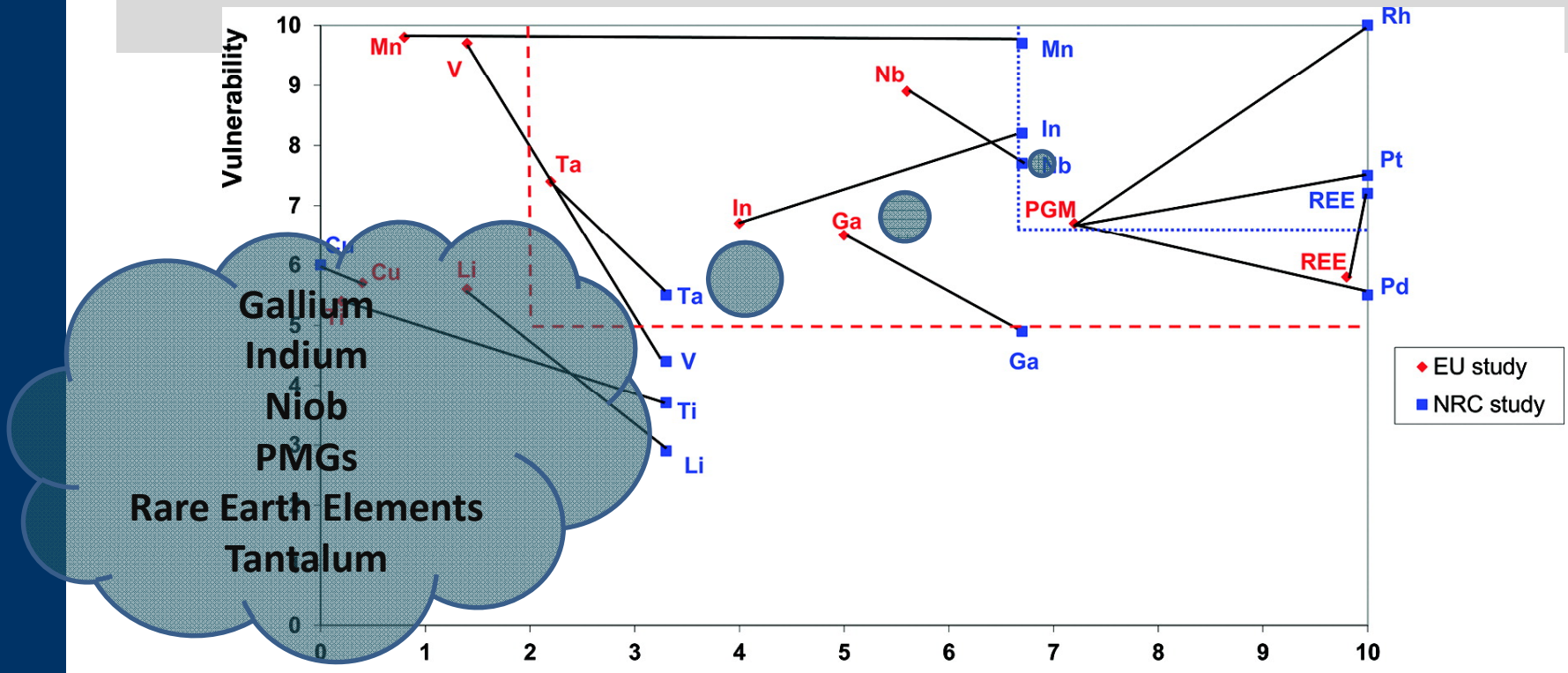
# Critical Metals

National Research Council (NRC), Committee on Critical Mineral Impacts on the US Economy. Minerals, Critical Minerals, and the U.S. Economy; The National Academies Press: Washington, DC, 2008.

European Commission. *The Raw Material Initiative – Meeting our Critical Needs for Growth and Jobs in Europe*; Staff Working Document SEC(2008)2741 {COM(2008) 699}; Brussels, Belgium, 2008.




**Source** Lorenz Erdmann and Thomas E. Graedel **Criticality of Non-Fuel Minerals: A Review of Major Approaches and Analyses**
*Environmental Science & Technology* **2011** *45* (18), 7620-7630

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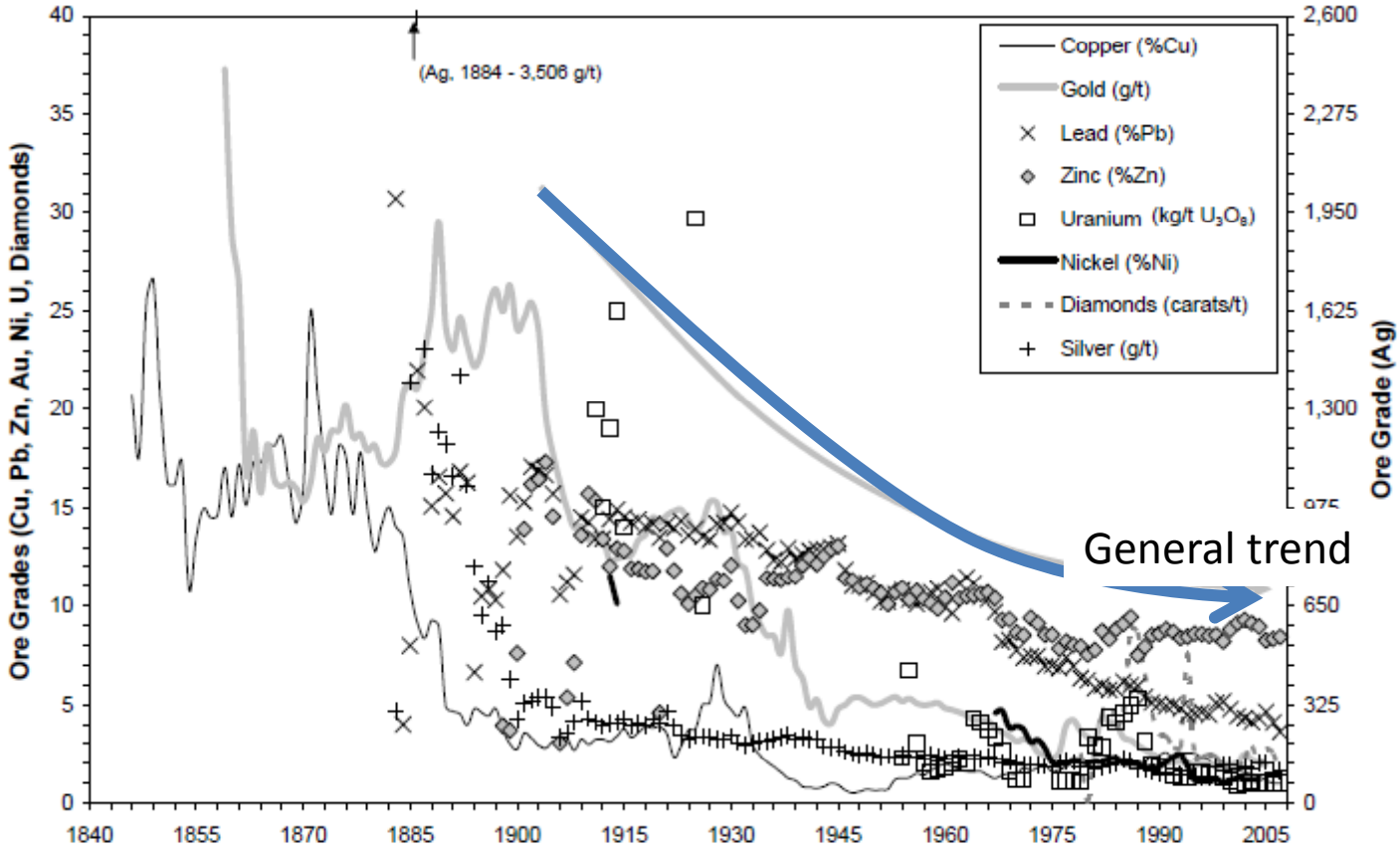
# Critical Metals

## Reduction of primary ore grades




Combined Average Ore Grades in Australia Over Time for Base and Precious Metals

Source: G.M. Mudd, Sustainability of Mining in Australia, Research Report No. RR5, Monash Univ., 2007.

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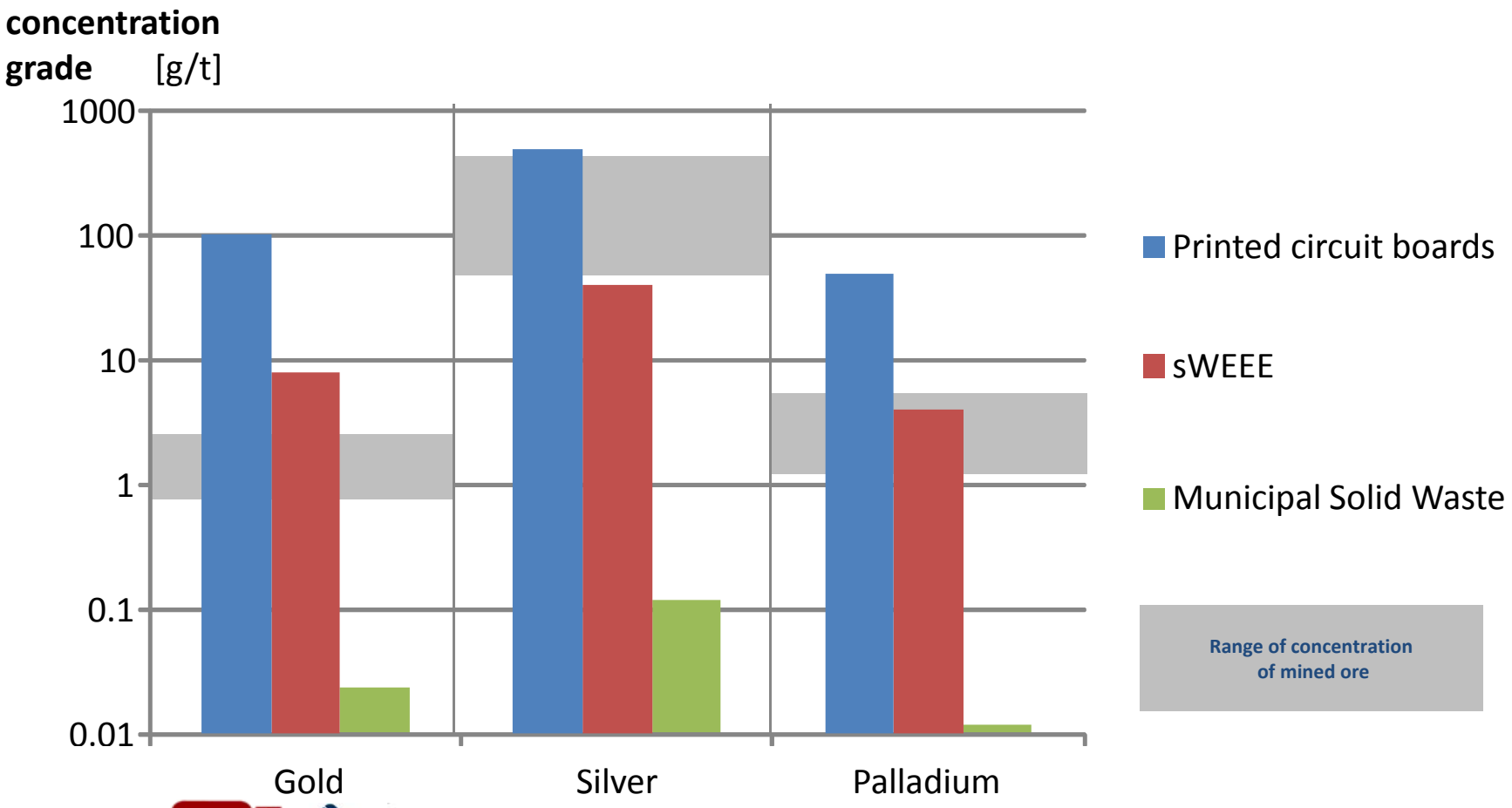
# Critical Metals

Quality of “urban ores”

Strategic relevant metals are concentrated in components and get dissipated through waste management

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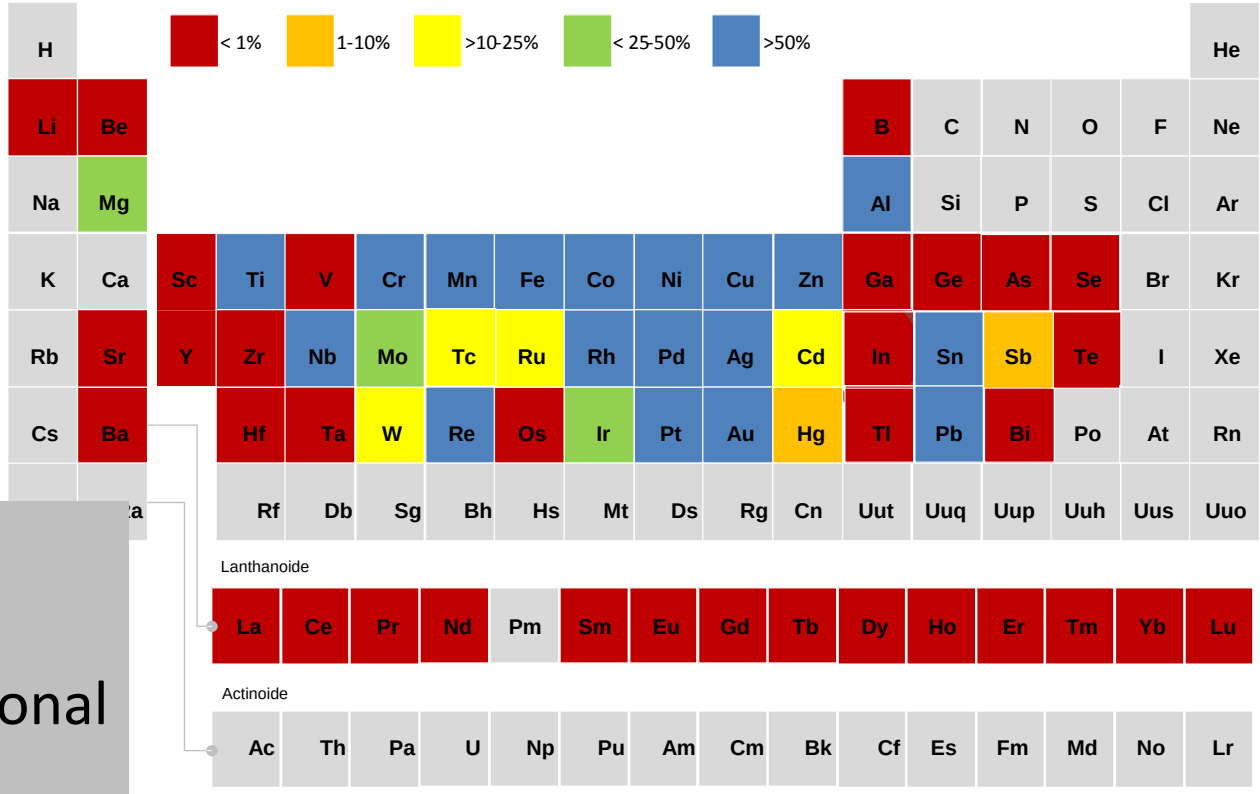
# Critical Metals

The Recycling of Metals: A Status Report. Second report of the Global Metal Flows group of the UNEP's International Panel on Sustainable Resource Management.




The periodic table of global average end-of-life functional recycling (EOL-RR) for 59 metals.

Source:
Graedel, T. E., Allwood, J.; Birat, J.-P.; Buchert, M.; Hagelüken, C.; Reck , B. K.; Sibley, S. F. and Sonnemann G. What Do We Know About Metal Recycling Rates?. Journal of Industrial Ecology, 15 (3), 2011 pp 355–366,

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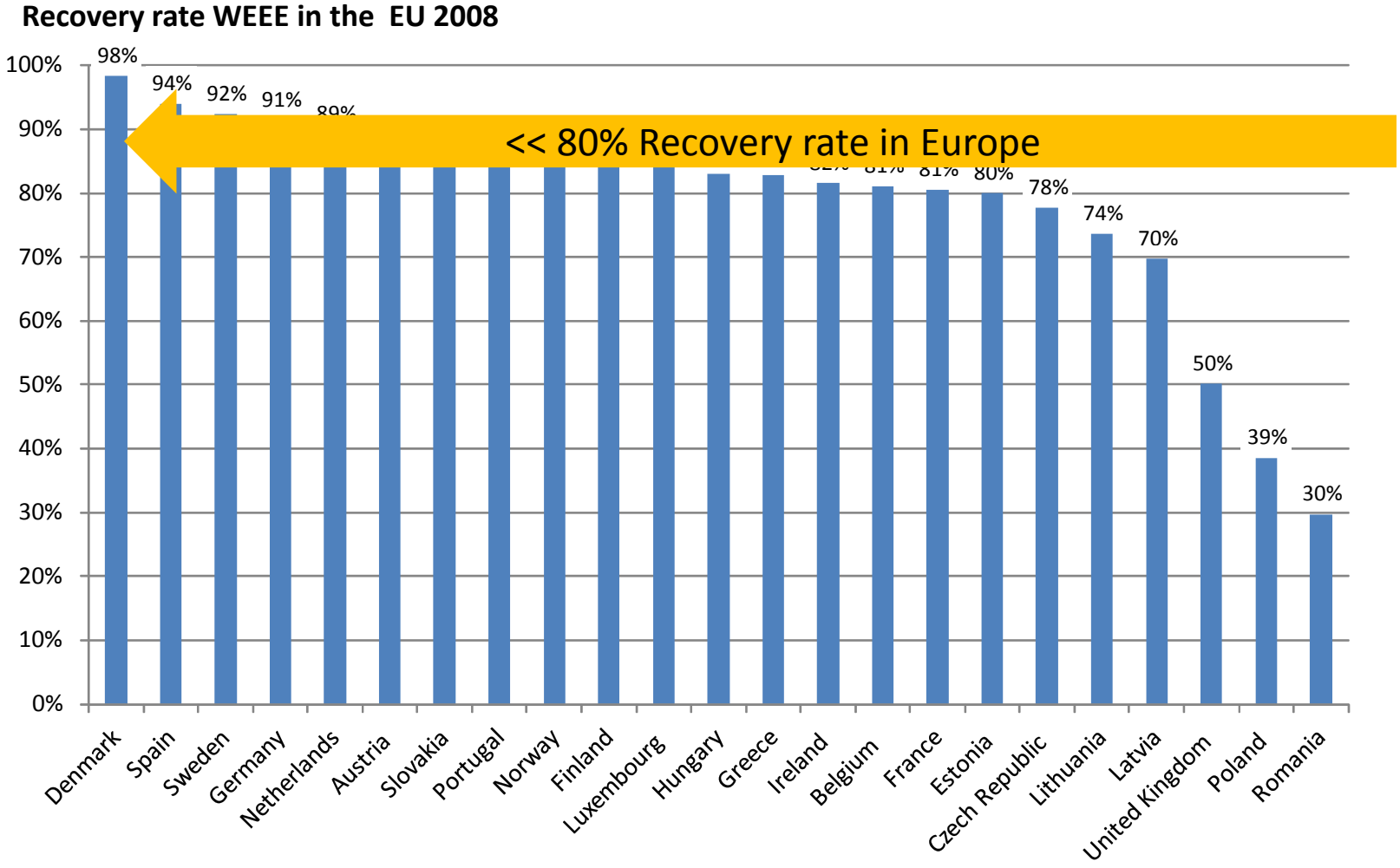
# WEEE Recycling in Europe




Data Eurostat
http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/key_waste_streams/waste_electrical_electronic_equipment_weee

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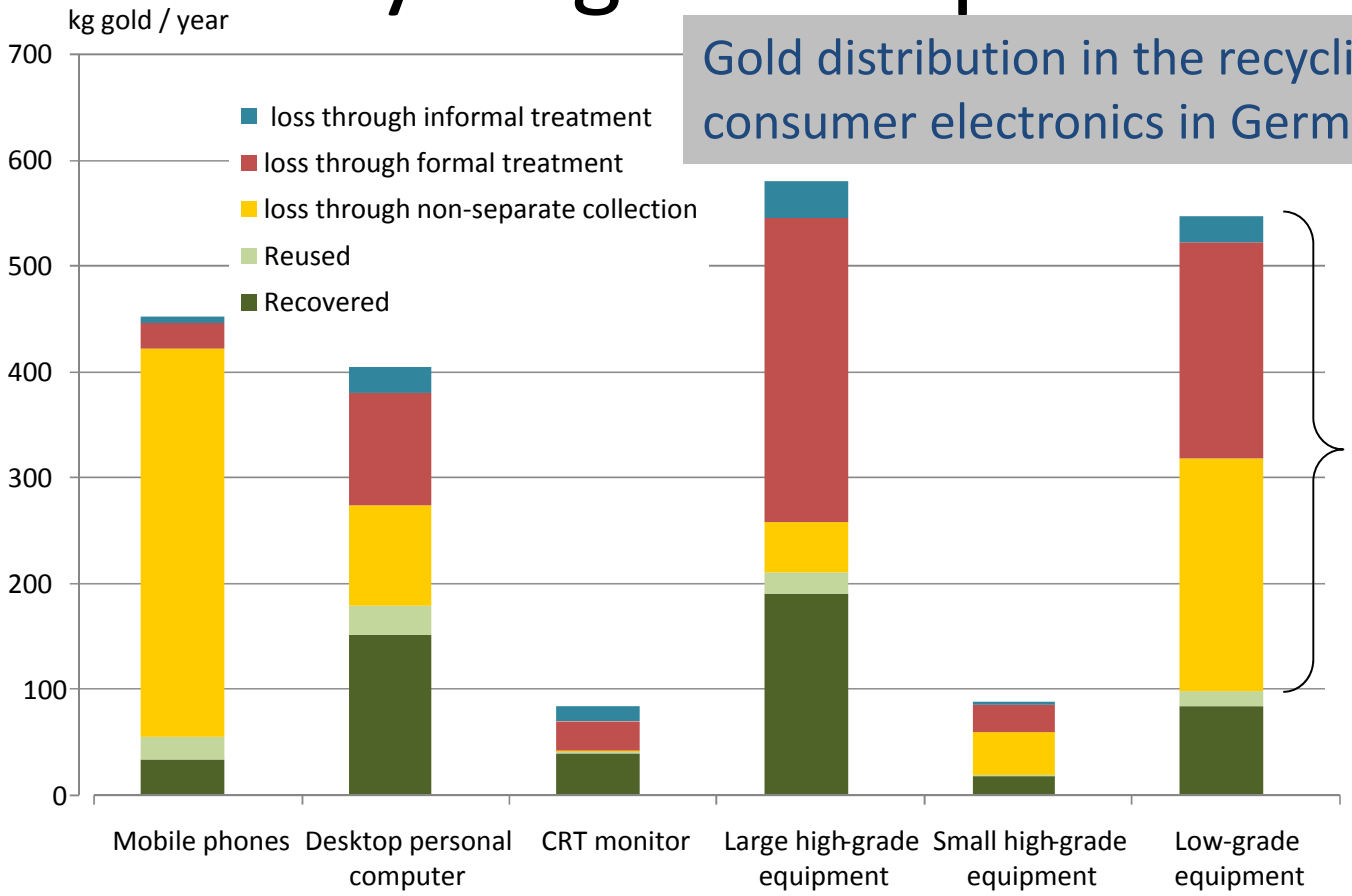
# WEEE Recycling in Europe




## Gold distribution in the recycling of post-consumer electronics in Germany in 2007

1. Trace elements have lower recovery rates
2. Formal treatment and pre-processing contribute hugely to the losses of gold

| | | | | | | |
|---|---|---|---|---|---|---|
| Gold potential (kg) | 451 | 404 | 84 | 580 | 88 | 546 |
| Gold losses (%) | 88% | 56% | 51% | 64% | 79% | 82% |
| Waste generation (t) | 1300 | 13110 | 136978 | 48787 | 1431 | 197998 |

Chancerel, P., 2009 Substance flow analysis of the recycling of small waste electrical and electronic equipment. Dissertation an der TU Berlin

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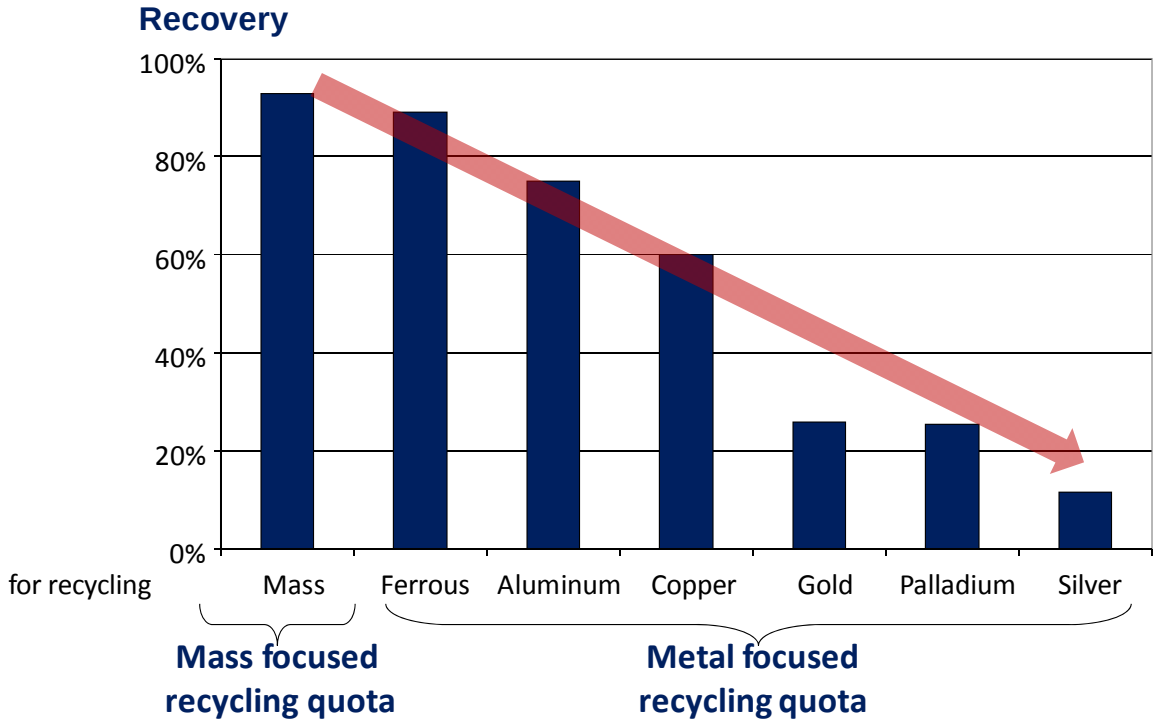
# WEEE Recycling in Europe

**Metal specific recovery rates at the pre-processing level**




Material Flow Analysis in a full scale WEEE processing plant 2007 Germany

Chancerel, P.; Meskers, C.; Hagelueken, C.; Rotter, V. S.
Assessment of metal flows during pre-processing of waste electrical and electronic equipment focusing on precious metals. Journal of Industrial Ecology Volume 13, Issue 5, October 2009, Pages: 791-810

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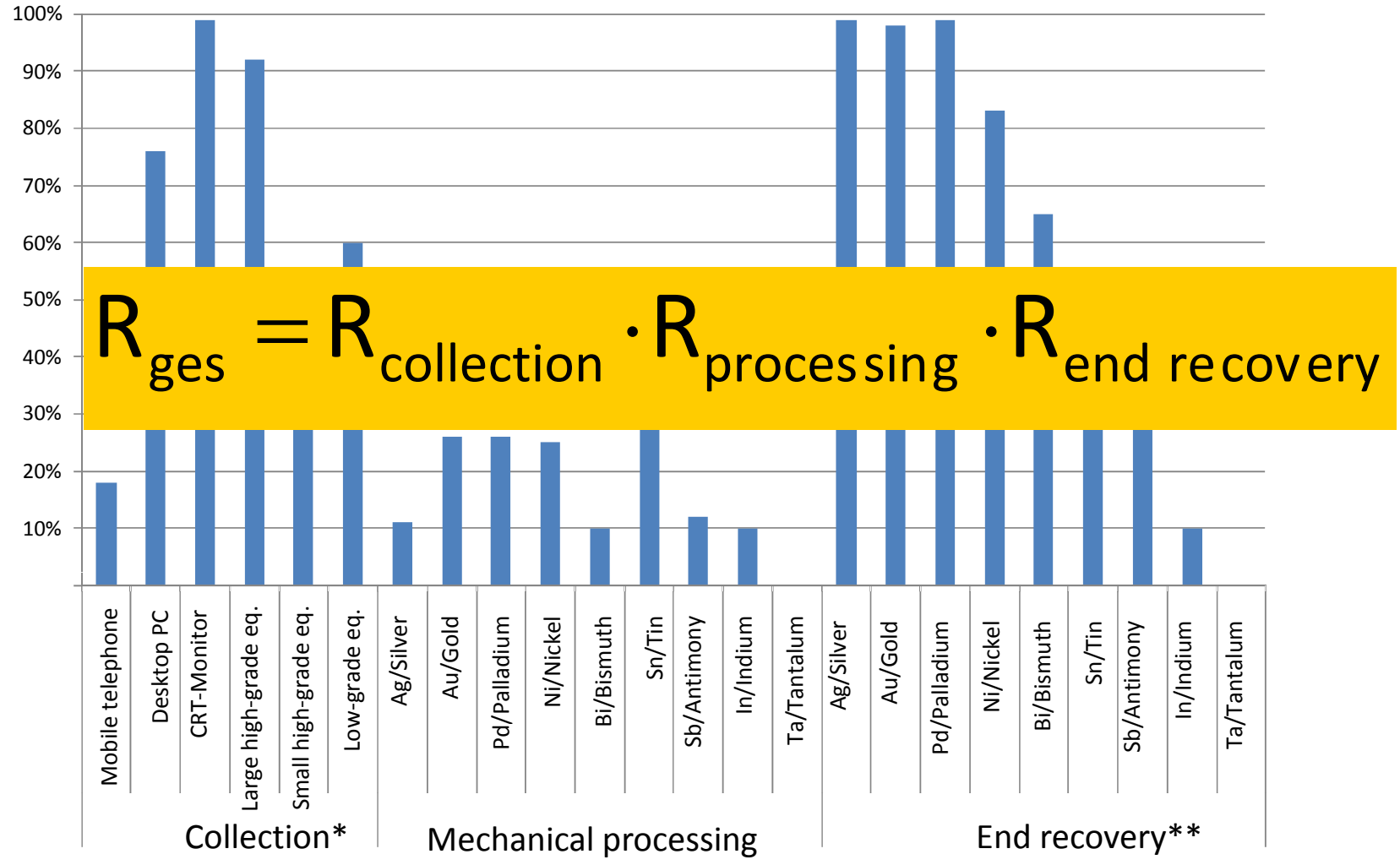
# WEEE Recycling in Europe

**Recovery rates**




$$R_{ges} = R_{collection} \cdot R_{processing} \cdot R_{end\ recovery}$$

* according to Chancerel 2010

** according to Deubzer, 2007

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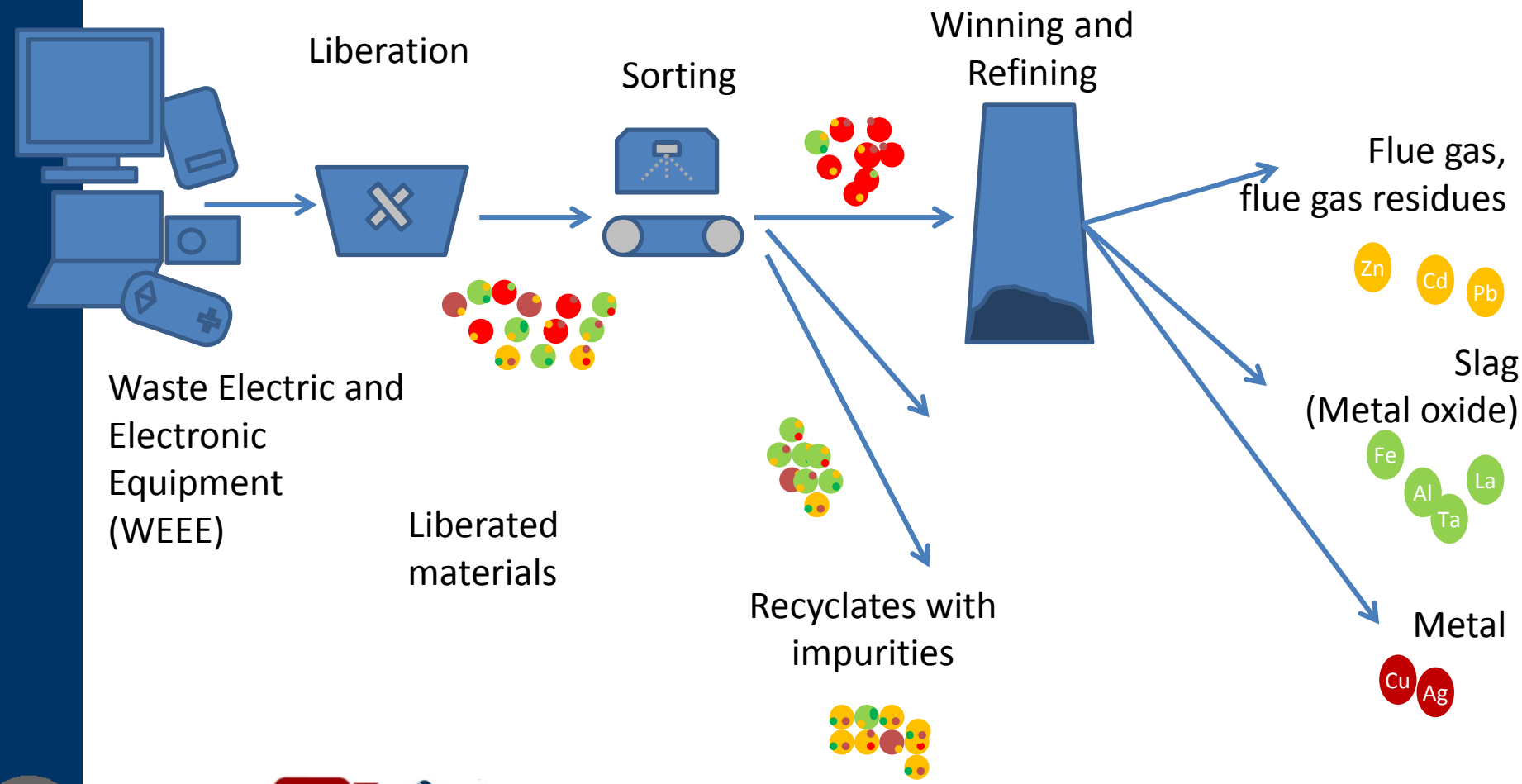
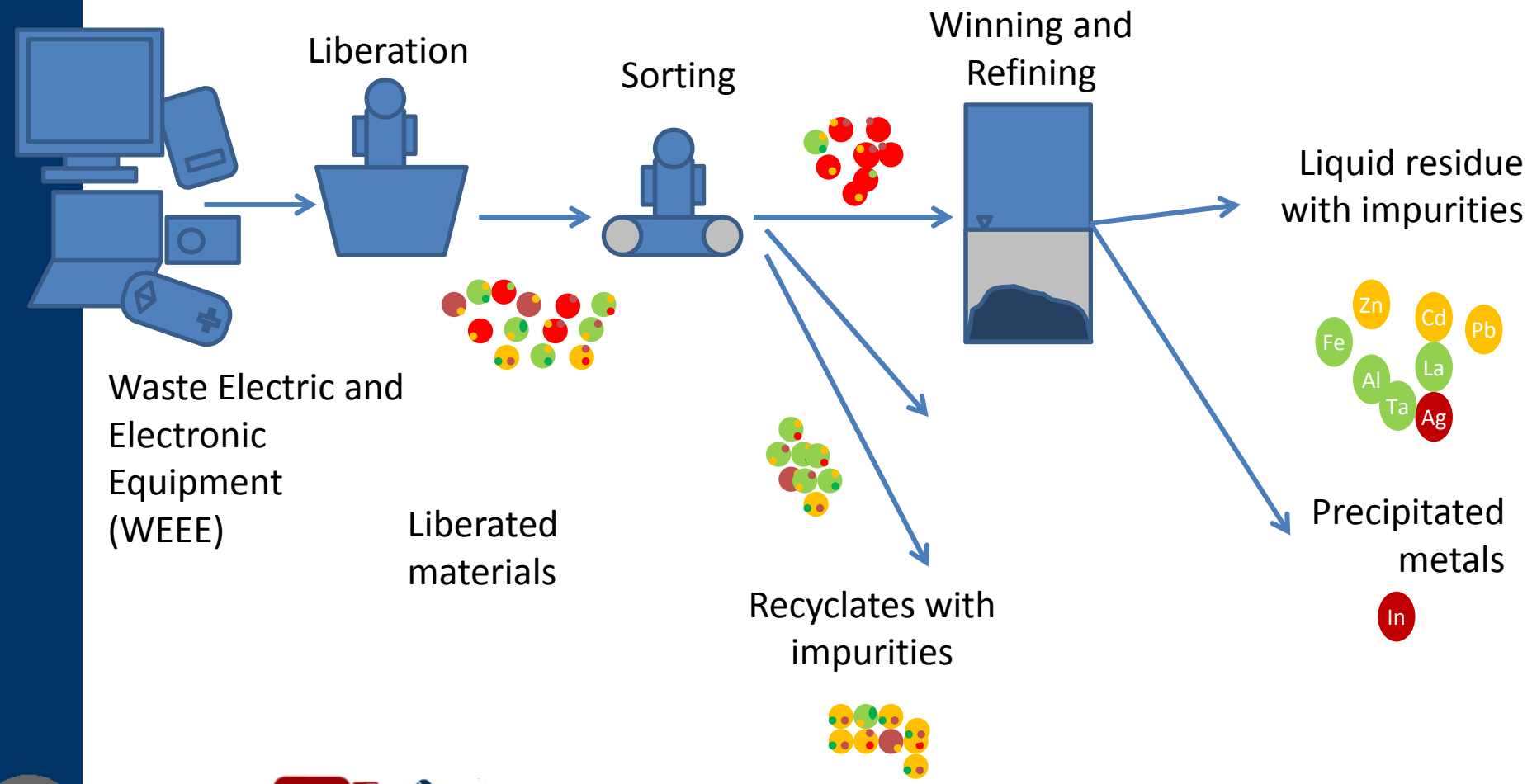
# Closing Material Loops in the Extended Value Chain



# Closing Material Loops in the Extended Value Chain



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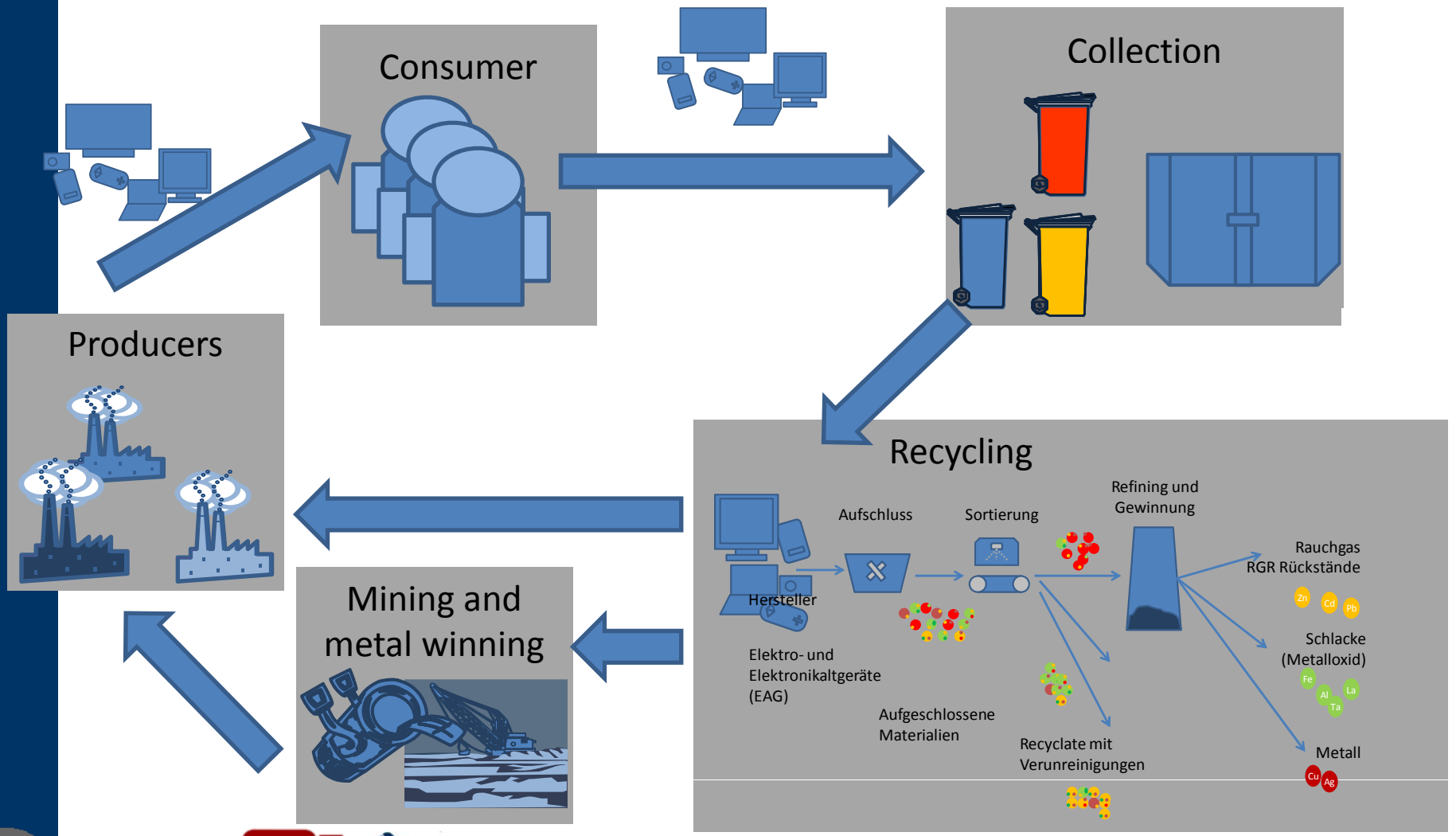
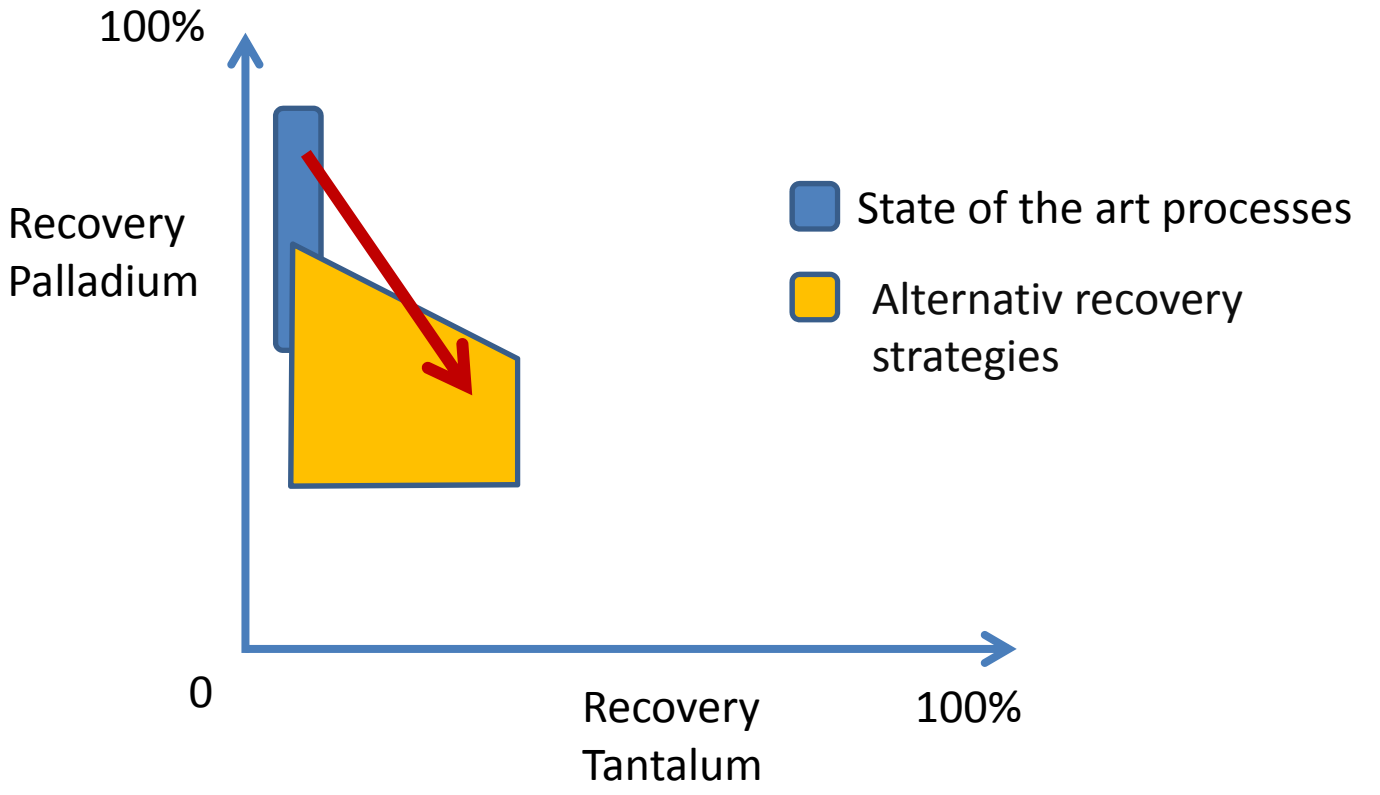


# Closing Material Loops in the Extended Value Chain

Closing loops requires multi-criteria decission making

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# UPgrade

Integrierte Ansätze zur Rückgewinnung von Spurenmetallen und zur Verbesserung der Wertschöpfung aus Elektro- und Elektronikaltgeräten

Improved valorization and integrated recovery of trace metals in Waste Electronic and Electric Equipment (WEEE)


http://www.upgrade.tu-berlin.de/

**Project duration: Aug 2012-Jul 2015**

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

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# UPgrade Consortium

Project partners

Associated partners

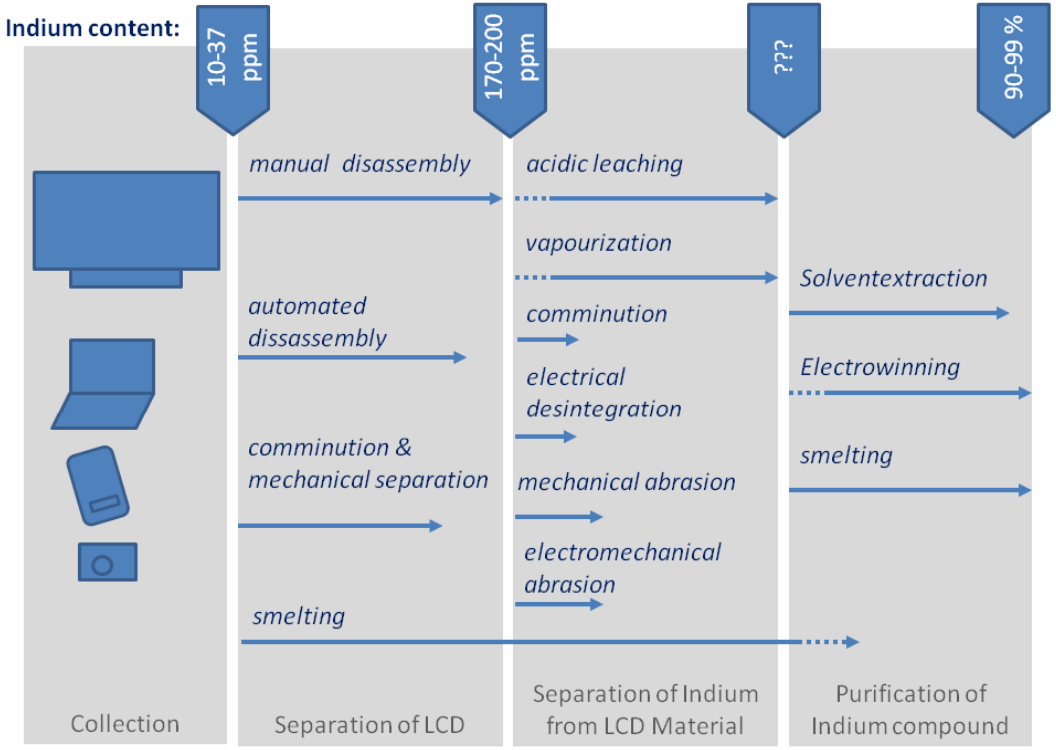
Scientific coordination

# UPgrade approach

1) Recycling-oriented product characterization
2) Experimental Substance Flow Analysis for selected product groups in state-of-the-art processing plants
3) Design of new separation technologies
4) Process and systems modeling for a better decision support
5) Design-for recycling recommendations

**Target Metals:**

Antimony,
Gallium, Germanium,
Indium, Cobalt,
Tantalum,
Tin
Rare Earth Elements

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# Recycling-oriented characterization

Heterogeneity of products is one of the key features relative to recycling strategies

*Heterogeneity* describes the fact that within one lot, units are not strictly identical to each other

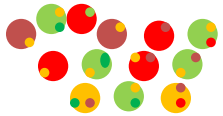
Example: waste electric and electronic equipment

Constitutional heterogeneity:

the unit is a single constituent element

Distributional heterogeneity:

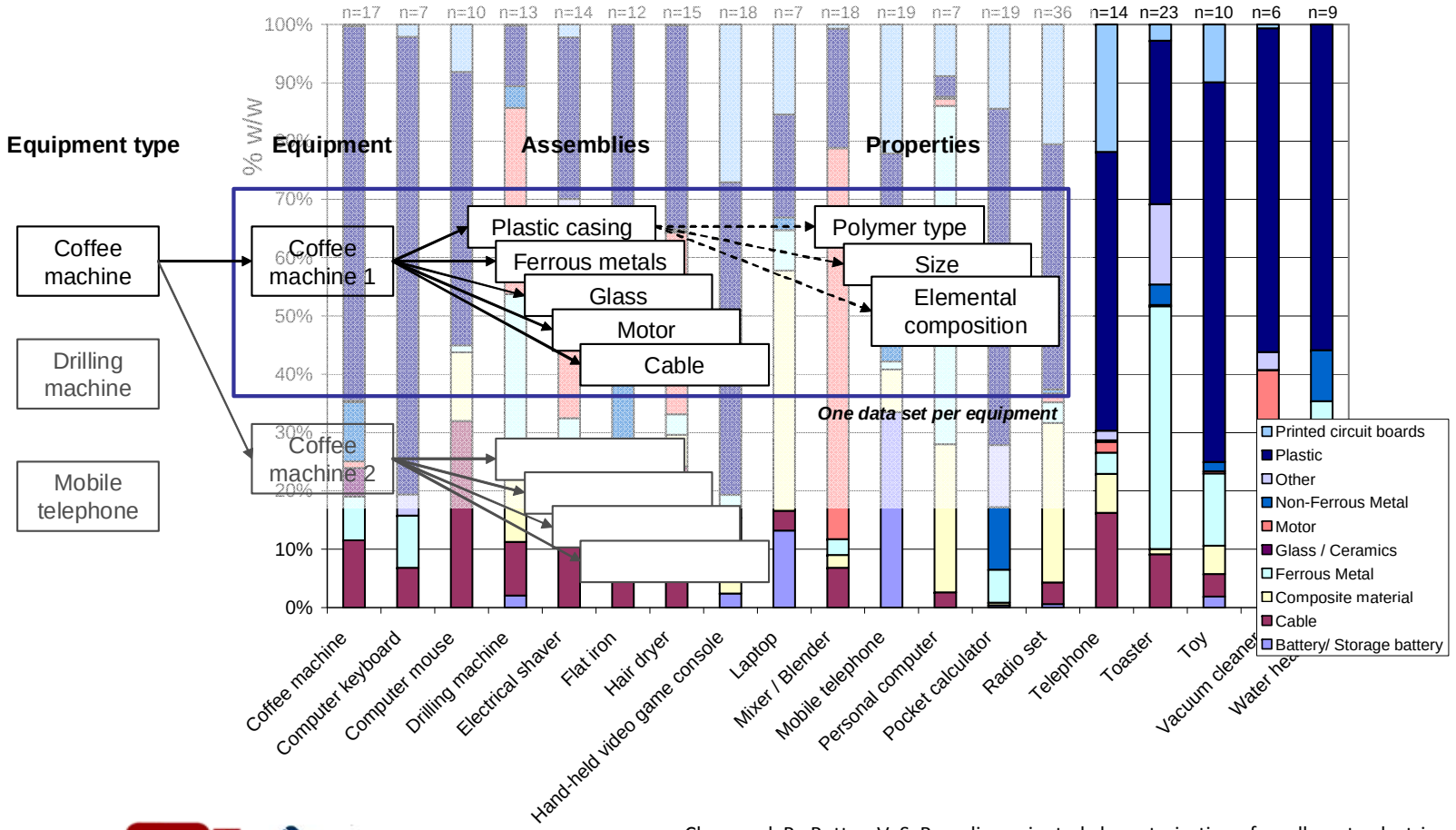
the unit is a group of neighboring constituent elements



Gy, P., 1998. Sampling for analytical purposes. John Wiley & Sons Ltd, West Sussex, United Kingdom.

# Recycling-oriented characterization

Recycling oriented characterization requires a product centered and hierarchical approach



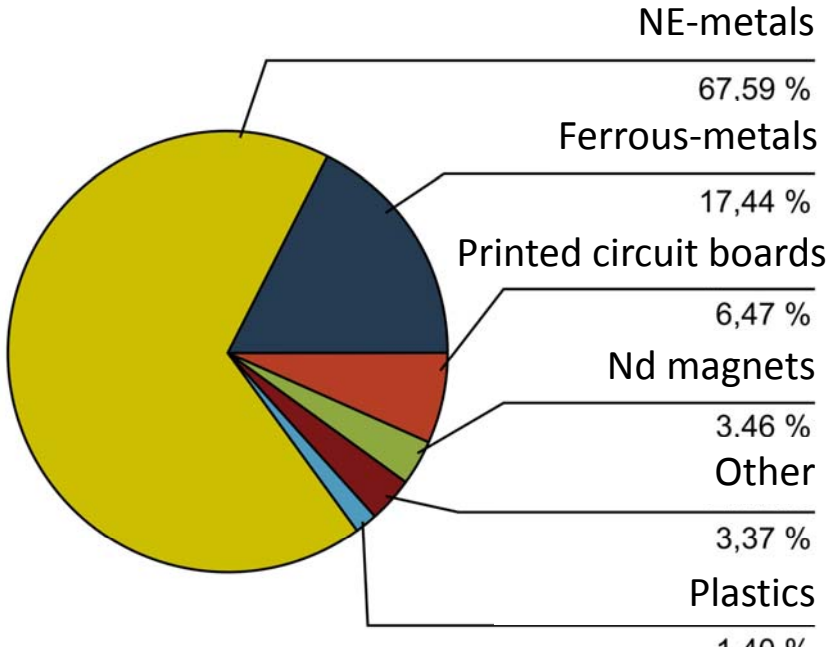

Chancerel, P.; Rotter, V. S. Recycling-oriented characterization of small waste electric and electronic equipment. accepted manuscript: Waste Management (2009) in print

# Recycling-oriented characterization

Recycling oriented characterization requires a product centered and hierarchical approach

*PCB on a hard disk (left) and opened casing with linear and with Linear- und spindle motors (right); marked in red*

*Material composition of hard drive disks from PCs*

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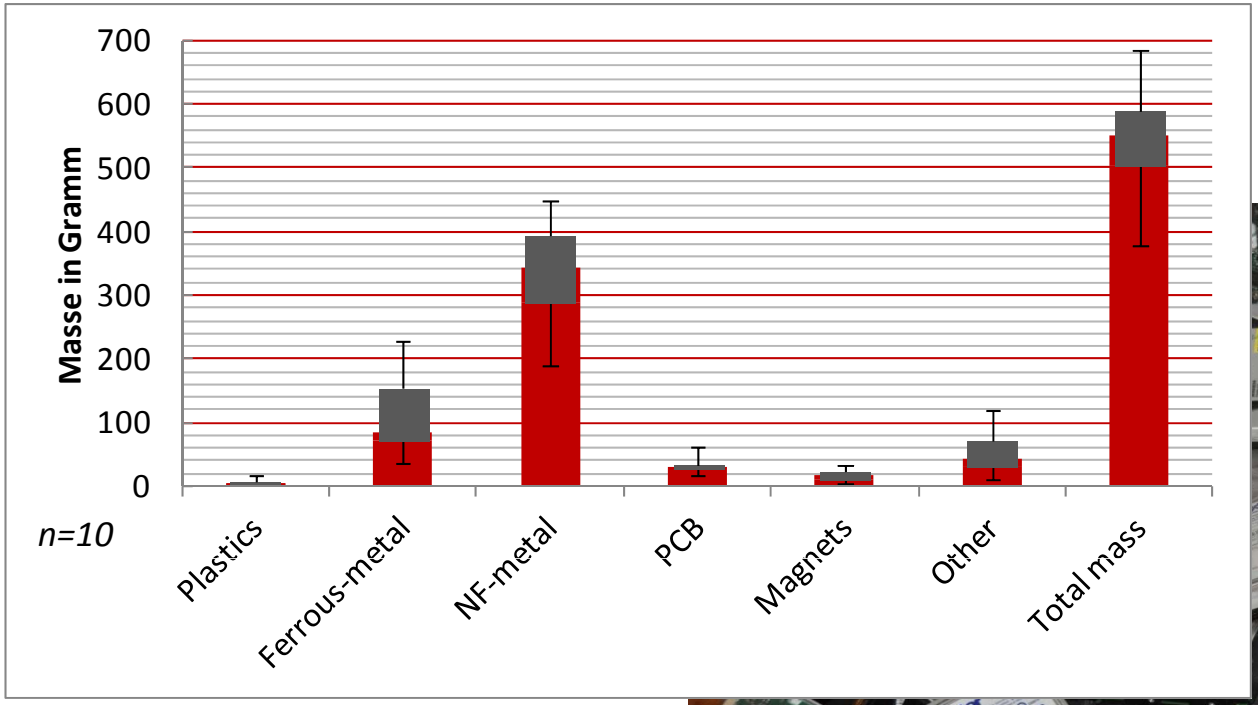
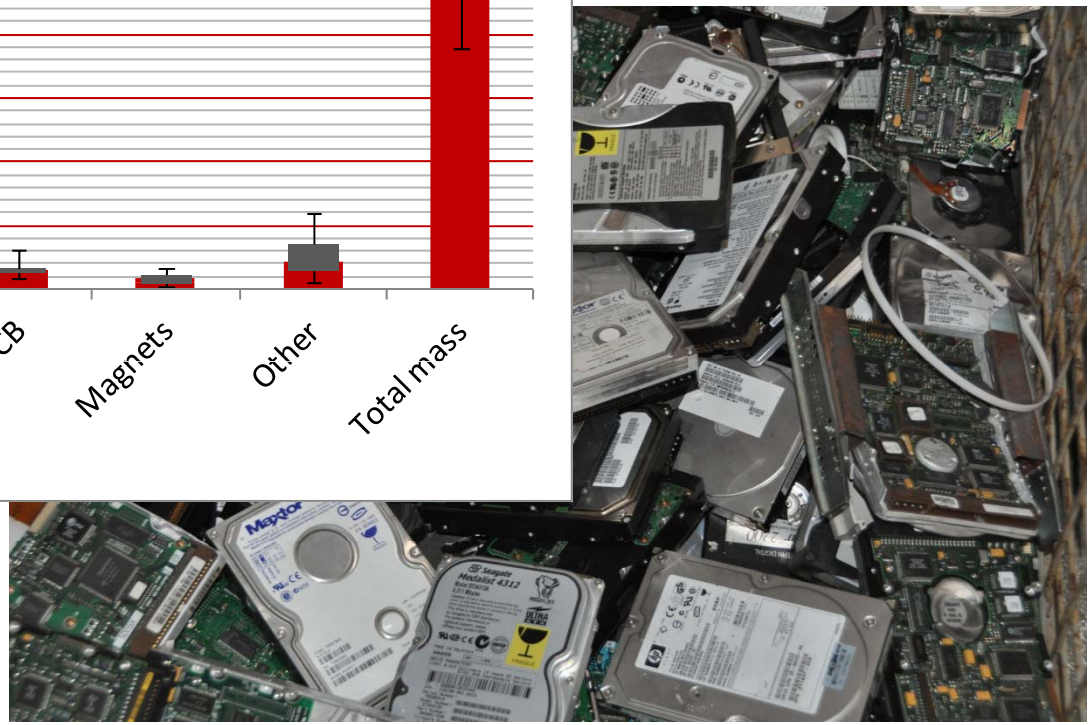
# Recycling-oriented characterization

Recycling oriented characterization addresses distributional heterogeneity

*Variation of absolute weight of components in hard drives disk*



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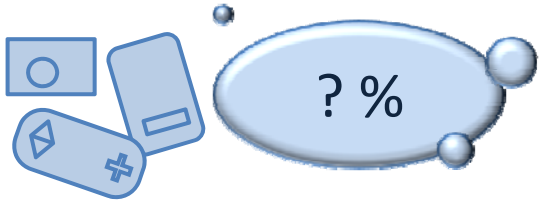
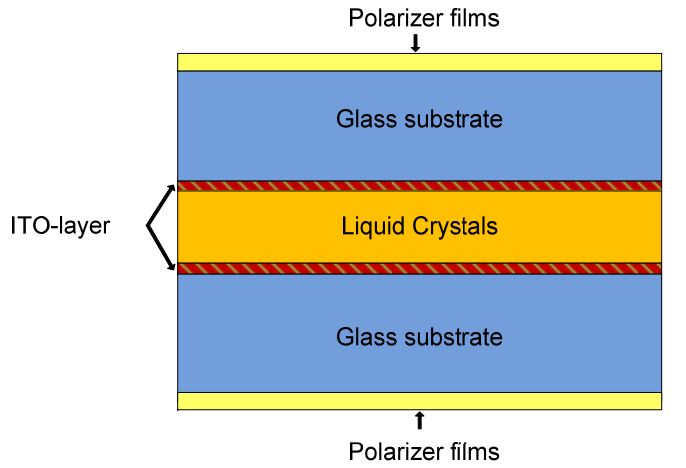
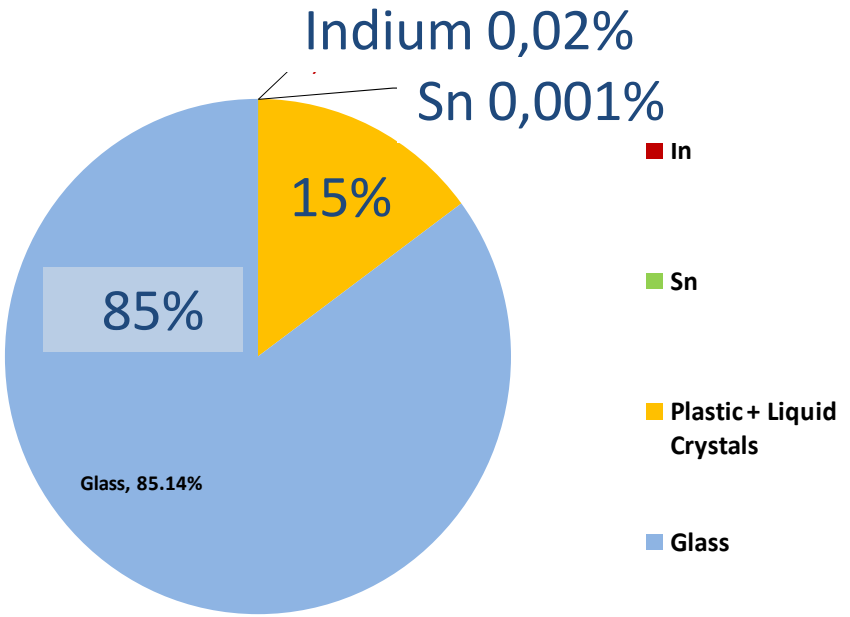
# Recycling-oriented characterization


## LCD Panels




**Status: Disposal, stock piling**

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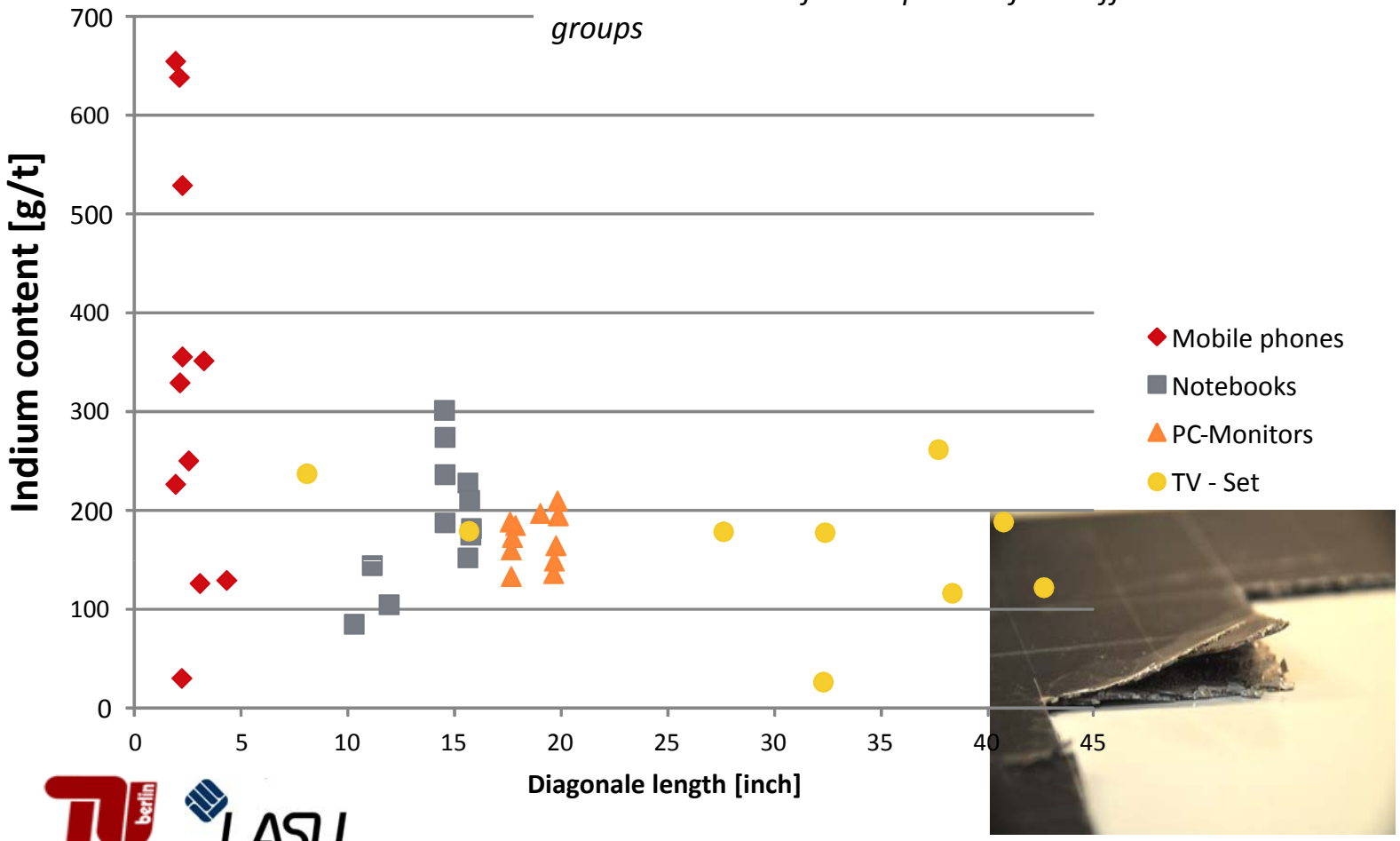
# Recycling-oriented characterization

Recycling oriented characterization considers process relevant properties

*Indium content of LCD panels for defferent device groups*



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Multi-element metal recycling

# Strategies for a multi element metal recycling

## Metal specific recycling strategies

| | Fe | Al | Mg | Cu | Ag | Au | Pd | Ru | Sb | Ga | Ge | In | Co | REE | Ta | Be | Te |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Improved collection | 1) | 1) | 1) | 1) | | | | | | | | | | | | | |
| Alloy specific sorting | | | | | | | | | | | | | | | | | |
| improved and adapted liberation technologies | | | | | | | | | | | | | | | | | |
| identification and separation of metal containing components | | | | | | | | | | | | | | | | | |
| new mechanical, chemical and thermal separation and concentration technologies for concentration metal | | | | | | | | | | | | | | | | | |
| Innovation for end recovery processes for end-refining metals and metal products | | | | | | | | | | | | | | | | | |
| Substitution | | | | | | | | | | | | | | | | | |

1) even after mixed waste disposal metals can be recovered in other waste treatment facilities

Color code

| | |
|---|---|
| | Not relevant |
| | Available technology, high recovery rates |
| | Partially existing but improvements required |
| | Not existing, R&D required |

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# Strategies for a multi element metal recycling

| Recycling strategies | Limitations |
|---|---|
| better collection systems, | Strong economic limitations |
| alloy specific sorting technologies | however liberation i.e. attachment to other materials in complex products may render in some cases this not feasible |
| improved and adapted liberation technologies | DfR and DfS very important for this, but functionality of components may make liberation impossible |
| identification and separation of metal containing components | complex products with complex material linkages may make this superfluous |
| new mechanical, chemical and thermal separation and concentration technologies for concentration metal | in some cases necessary but the Metal-Wheel shows a large coverage of metallurgy |
| additional end recovery processes for end-refining metals and metal products | this is limited by thermodynamics therefore physical separation important to ensure the limitations of thermodynamics is considered |

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# Conclusions

1. The shown examples illustrate, that high metal potentials of minor metals do not imply a technical and economical feasible recycling.
2. A knowledge base about stocks and flow of minor metals is essential for prospective planning of a circular economy
3. The actual knowledge base for WEEE does not comply with the information demand from the recycling industry
4. Recycling of minor metals from complex products like WEEE is only possible if materials can be liberated and concentrated in a “recovery compatible composition”

# Contact

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