

# Recycling in het ontwerp

Recyclingsymposium 26 oktober 2016

Dr. ir. Antoinette van Schaik

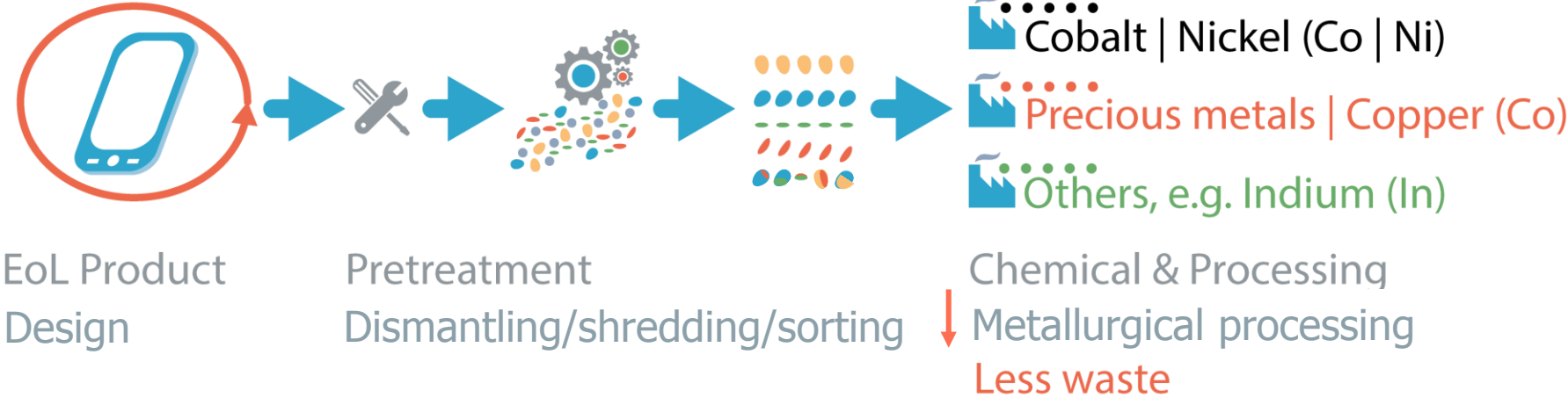
Material Recycling and Sustainability (MARAS) B.V.  
Den Haag

# Circulaire Economie en Recycling (in het Ontwerp)

## Product-Centric View

General initial question

How can we use a product as resource?



# Productcomplexiteit en recycling

Unieke recyclingvingerafdruk per product : mogelijkheden en beperkingen van circulaire economie verschillen per product (groep)

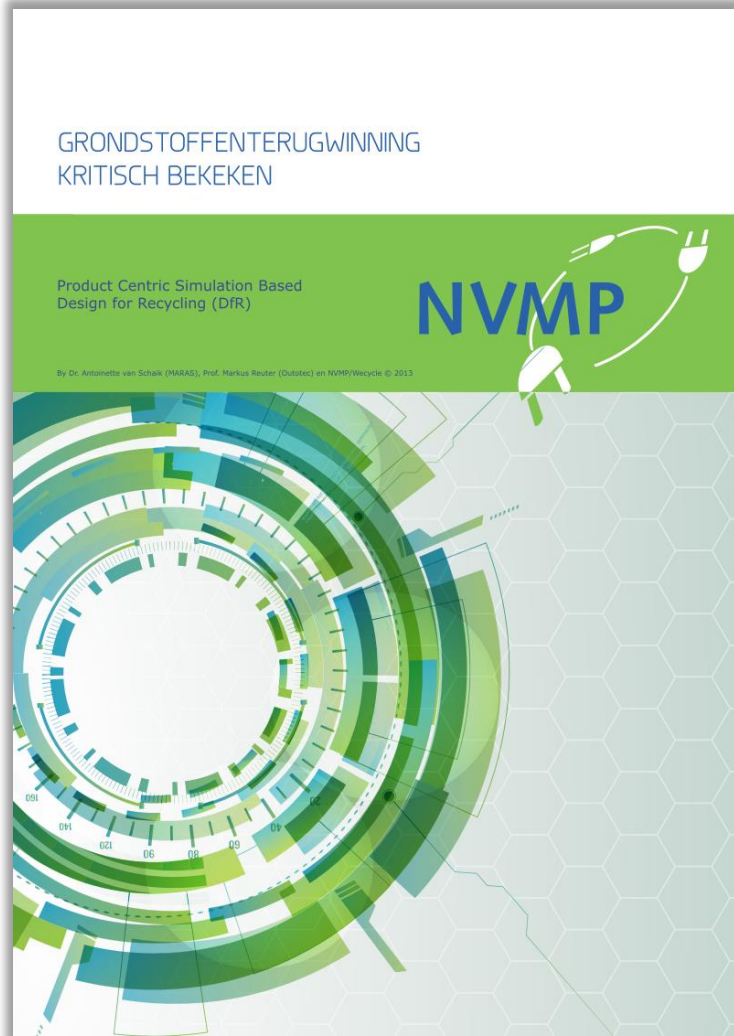


# Recycling, ontwerpen en circulariteit

- **Transparantie en kwantificering van product- en materiaalrecyclingpercentages**
  - Gebruikmakend van **industriële** en **fysica** gebaseerde processimulatietools
  - Kennis van de **recyclingindustrie en -technologie** en mogelijkheden en beperkingen hiervan in relatie tot productontwerp
- **Inzichtelijk maken van consequenties van ontwerp op recyclingmogelijkheden en beperkingen**
  - **Beschikbaarheid van product-/ontwerpdata (BOM/FMD)** in een format compatibel met het detail benodigd om recyclingprestatie te kwantificeren en te optimaliseren
- **Milieu-analyse (levenscyclusanalyse) van einde levensduur**
  - Gebaseerd op **product-specifieke** en **gedetailleerde kwantificering** van recycling/recovery/verliezen, en kwaliteit/verontreinigingen van recyclingstromen en producten

# 10 Design for Recycling Rules & Guidelines

<http://www.nvmp.nl/onderzoek/design-for-recycling.html>



GRONDSTOFFENTERUGWINNING  
KRITISCH BEKEKEN

## Product Centric Simulation Based Design for Recycling (DfR)

By Dr. Antoinette van Schaik (MARAS), Prof. Markus Reuter (Outotec) en NVMP/Wecycle © 2013

### Summary

Metals and materials play a pivotal role in the production of Electric and Electronic Equipment (EEE). Their properties impart unique functions to consumer products. Through mindful product design, closely linked to recycling technology, Design for Recycling (DfR) can contribute to the recovery of metals and materials following a Product Centric Approach. MARAS has performed a study on DfR for NVMP to develop DfR rules taking into account the possibilities and limits of Recycling. This includes recycling technology and physical limits due to functional limits and combinations of materials in a product. Various recyclers have provided their input on design related issues in recycling to develop these rules. MARAS has investigated numerous recyclates to this end as well as understand the relationship between design and recyclate quality. Based on the information gathered in this study combined with the expertise of MARAS, comprehensive simulation based DfR rules and guidelines have been developed. The

Figure 1: Product Centric Recycling: A throughout the recovery chain to extract designed "minerals" i. e. products, of complex geological minerals (Reuter et al., 2013)

1 M.A. Reuter and A. van Schaik (dynamicmodel-based analysis Sustainability)

## Manifesto for the sustainable design of electronics

### Recommendations for product design with efficient use of raw materials

Association NVMP (the Dutch Association for the Disposal of Metaelectro Products) has established that the environmentally-friendly processing of most of our electronic waste in the Netherlands is well-organised and that we are recovering most of the steel, copper, plastic and other commonly-used substances in our e-waste.

At the same time, NVMP has also ascertained that high-quality raw materials that we use in small amounts and in complex compounds, which are essential for the functionality of our modern electronics, are lost during the recycling process.

Those high-quality metals are either rare or their supply is critical because producers are dependent on just a few suppliers or on geopolitical constraints. It is essential that we recover these critical metals from discarded electronic devices in order to guarantee their availability in the future.

However, new recycling techniques are not the solution. After all, those technologies cannot overcome the limitations of metallurgy and the laws of nature that affect the recycling of critical substances. The solution is to adapt the product design so that these materials can be recovered using the best available recycling technology.

Research commissioned by NVMP\* has resulted in a number of workable empirical rules so that the necessary adjustments can be made in the choice of materials and in the construction and design processes. Association NVMP wishes to make the following four recommendations in order to promote and implement the desired new working method in the electronics chain:

#### 1. Define targets that are technically and economically feasible

Given the laws of nature, it is inevitable that metals and materials that are mixed and combined in products are partly lost during the recycling process. Targets that ignore the laws of nature and the maximum that the industry can achieve with metallurgical processes are doomed to failure and can only end in frustration. On the other hand, realistic ambitions that

Incl. input van recyclingindustrie : Coolrec bv; Remondis Electrorecycling GmbH; Alba Service GmbH; Indaver nv; Sims Recycling Solutions; Van Dalen / De Ruiter Schroot bv

# Ontwerp, recyclebaarheid en kwaliteit

(Re)Designs



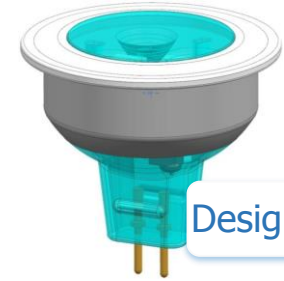
Design A



Design B

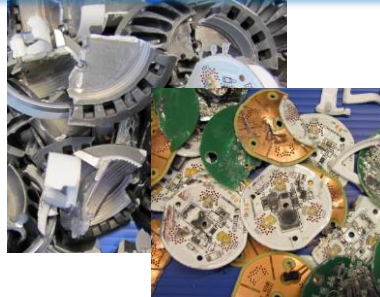


Design C/D



Design E

Samenstelling deeltjes/fragmenten (vrijmaking als functie van ontwerp)



Recyclaatkwaliteit en samenstelling (bepalend voor recovery materialen en milieu-impact)

Ferro fractie



Printplaat fractie



Plastics recyclaat



Al recyclaat



# 'Know how' van ontwerp, shredderen en sorteren

Theorie en praktijk

Shredderproeven/berekenen  
recyclingprestatie

Foto : © Jack Tillmans/ARN



Demontage/ontwerpanalyse



Recyclaatkwaliteit, productontwerp en  
recyclingprestatie



Vrijmaking als gevolg van productontwerp



# Metallurgische 'know-how'



WEEE, eWaste, Cu scrap,  
Residues: Dowa (Japan)



3 Stage lead smelting, Slag cleaning: YTCL (China)



Lead Battery Recycling:  
Recylex (Germany)



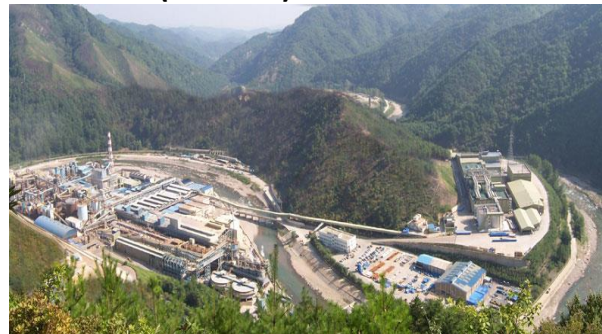
Cu, slimes, eWaste etc.:  
Boliden (Sweden)



Cu-scrap, internal  
residues: Guixi (China)



WEEE, Cu Recycling, Slag  
cleaning: GRM (S. Korea)



Zn-Residue processing: Young Poong  
Corporation (S. Korea)



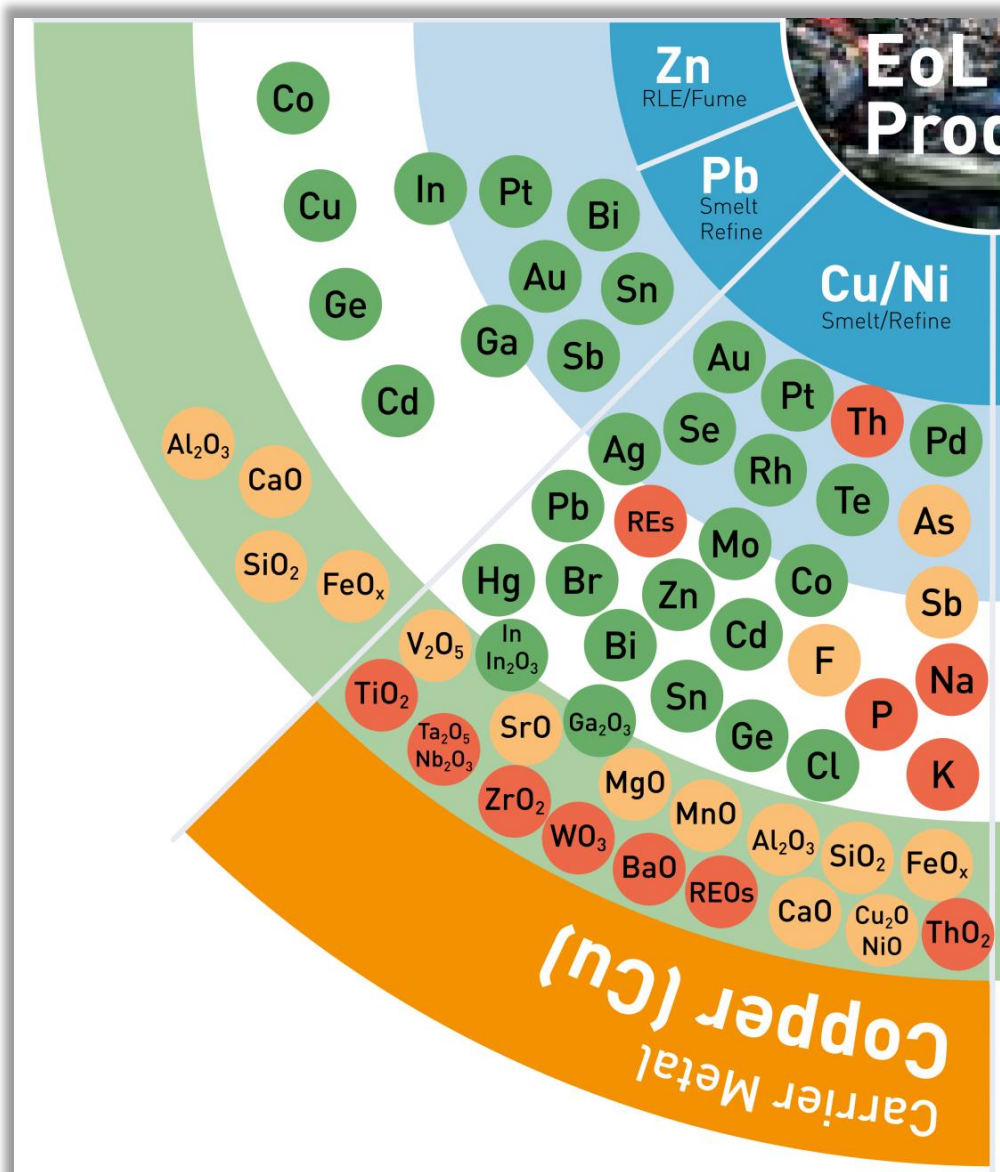
Slag cleaning: Mitsui, Hachinohe  
(Japan)





# 'Metal Wheel' : (in) compatibiliteit van materialen in metallurgie

Quick scan voor recycling in het ontwerp



# Ontwerpdata

Detail en format benodigd voor kwantificatie/optimalisatie van recyclingprestaties

Opbouw van product :  
verbindingen tussen  
materialen/onderdelen



**Exploded views**

Materiaalgebruik &  
materiaalcombinaties



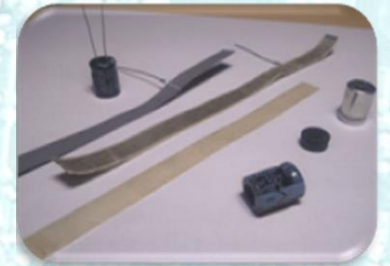
**Bill of Materials (BOM)**

Chemische  
samenstelling van  
materialen/onderdelen



**Full Material Declarations (FMD)**

Chemische samenstelling  
van van componenten



# Recycling assessment op basis van industriële processimulatie tools

Kwantificering van recycling/recovery percentages, recycelaatkwaliteit en dispersie van materialen

The screenshot displays the HSC Sim8 interface with a detailed process flow diagram for recycling. The process starts with 'EoL LED lamps' which are granulated (40 mm) and then processed by a magnet to separate ferrous and non-ferrous fractions. The non-ferrous fraction goes through a vibro feeder and an eddy current separator. The eddy current separator rejects a fraction to a windscreen, which also receives dust from the windscreen. The windscreen separates light and heavy fractions, which go to a mixer. The mixer output goes to a 20mm granulator, then a wet table, and finally an Outotec TSL furnace. The furnace produces offgas, flue dust, slag, and metal. The ferrous fraction from the magnet goes to an X-ray sorter, which separates Al and circuit boards from rest reject and Alu accept.

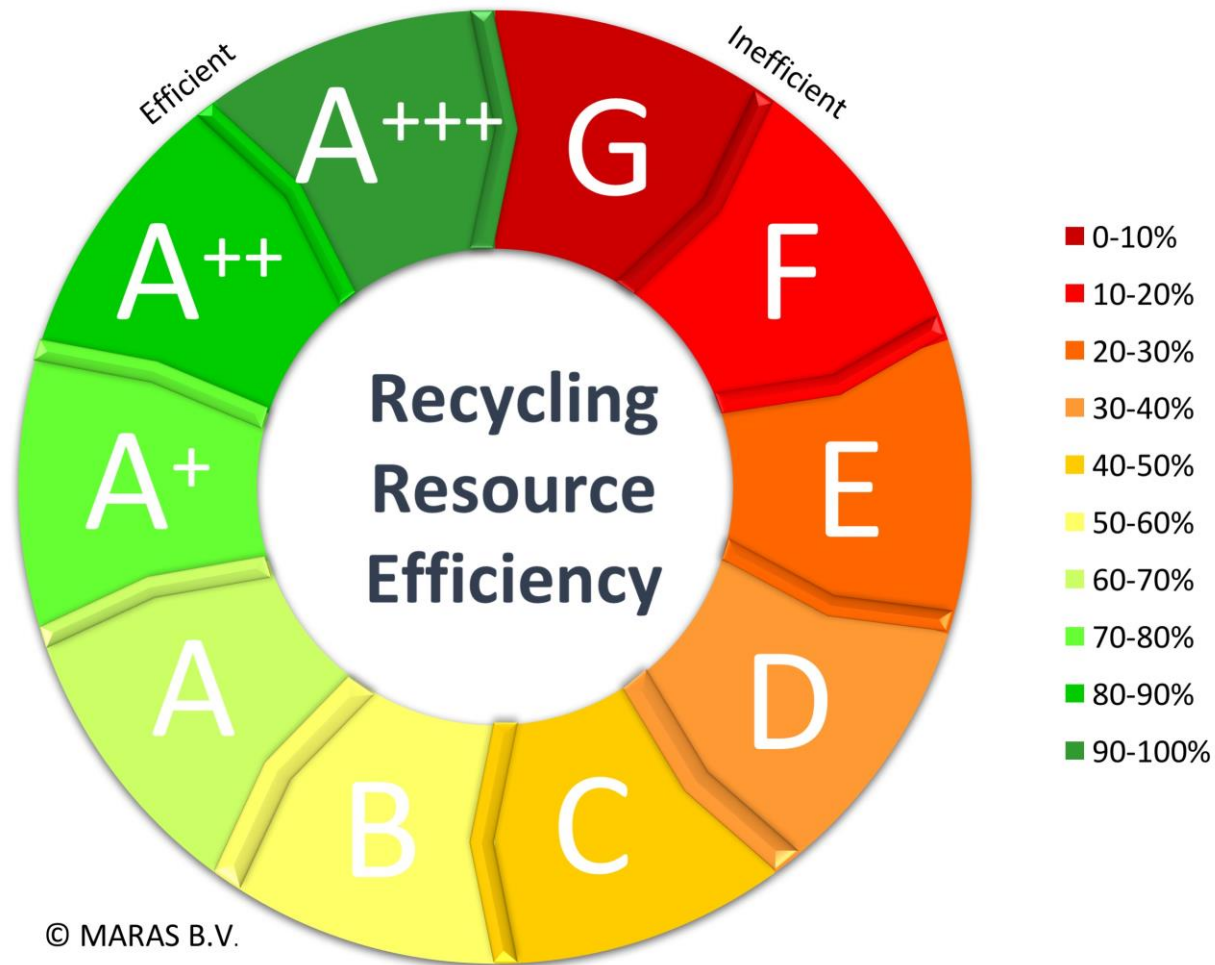
On the right, the 'Stream Visualization' table shows the following data:

	A	B
1		Metal
2		
3	Summary	
4	Total solids	t/h
5	Liquid	t/h
6	Pulp Flowrate	t/h
7	Pulp Volumetric Flowrate	m3/h
8	Solids SG	g/cm3
9	Pulp SG	g/cm3
10	% Solids	%
11	Solids Recovery	t/h
12	Ag (e)	wt-%
13	Al (e)	wt-%
14	As (e)	wt-%
15	Au (e)	wt-%
16	Be (e)	wt-%
17	Bi (e)	wt-%
18	Br (e)	wt-%
19	C (e)	wt-%
20	C12H10xC1x (e)	wt-%
21	Ca (e)	wt-%
22	Cd (e)	wt-%
23	Cl (e)	wt-%
24	Co (e)	wt-%
25	Cr (e)	wt-%
26	Cu (e)	wt-%
27	Fe (e)	wt-%
28	H (e)	wt-%
29	N (e)	wt-%
30	Ni (e)	wt-%
31	O (e)	wt-%
32	Pb (e)	wt-%
33	Pd (e)	wt-%
34	Res (e)	wt-%
35	Sb (e)	wt-%
36	Si (e)	wt-%
37	Sn (e)	wt-%
38	Sum (e)	wt-%
39	Zn (e)	wt-%
40	Ag (e)	Rec-%
41	Al (e)	Rec-%
42	As (e)	Rec-%
43	Au (e)	Rec-%

- Volledige massabalans over demontage, shredderen/sorteren en eindverwerking
- Recycling/recoverypercentages
- Samenstelling/kwaliteit van elke flow
- Dispersie/verdeling materialen

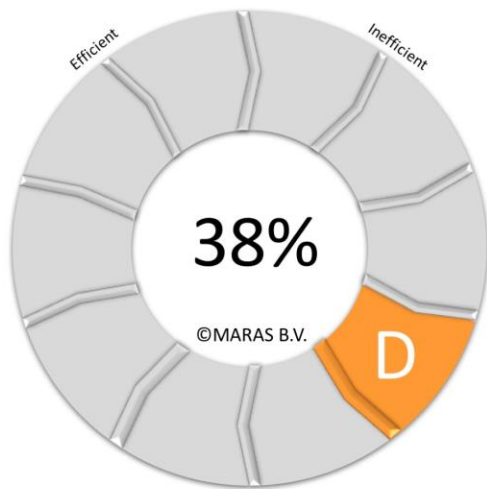
# Recycling Index

Kwantificering en visualisatie van (Product) Recyclingpercentages

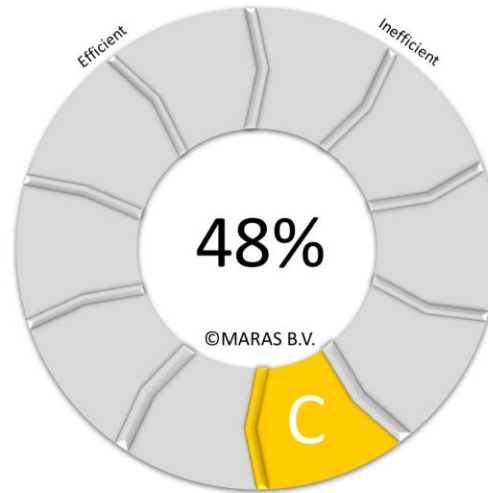


# Recycling Index

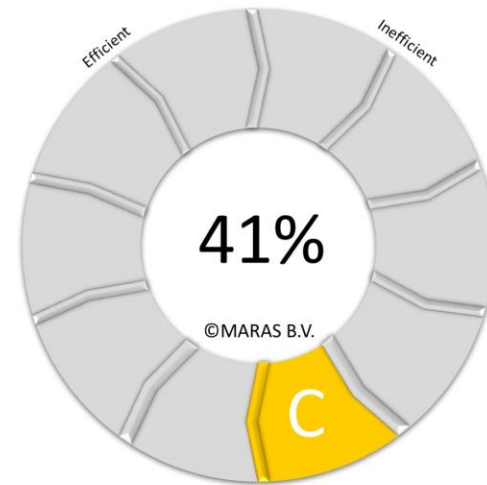
## Kwantificering en visualisatie van (Product) Recyclingpercentages



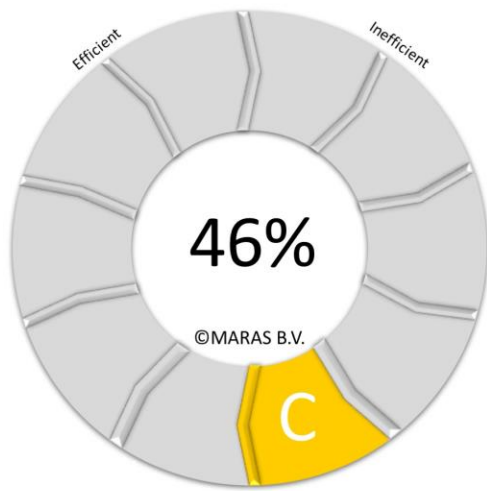
(a)



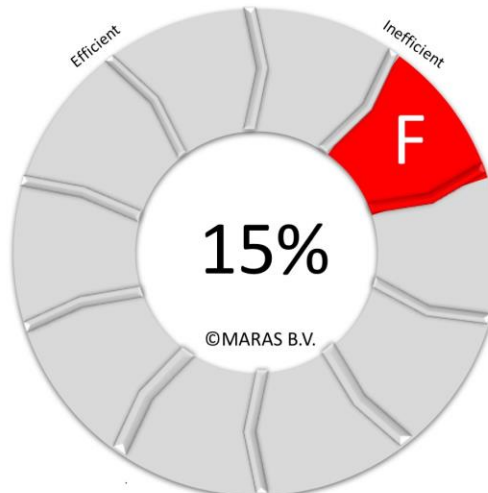
(b)



(c)



(d)

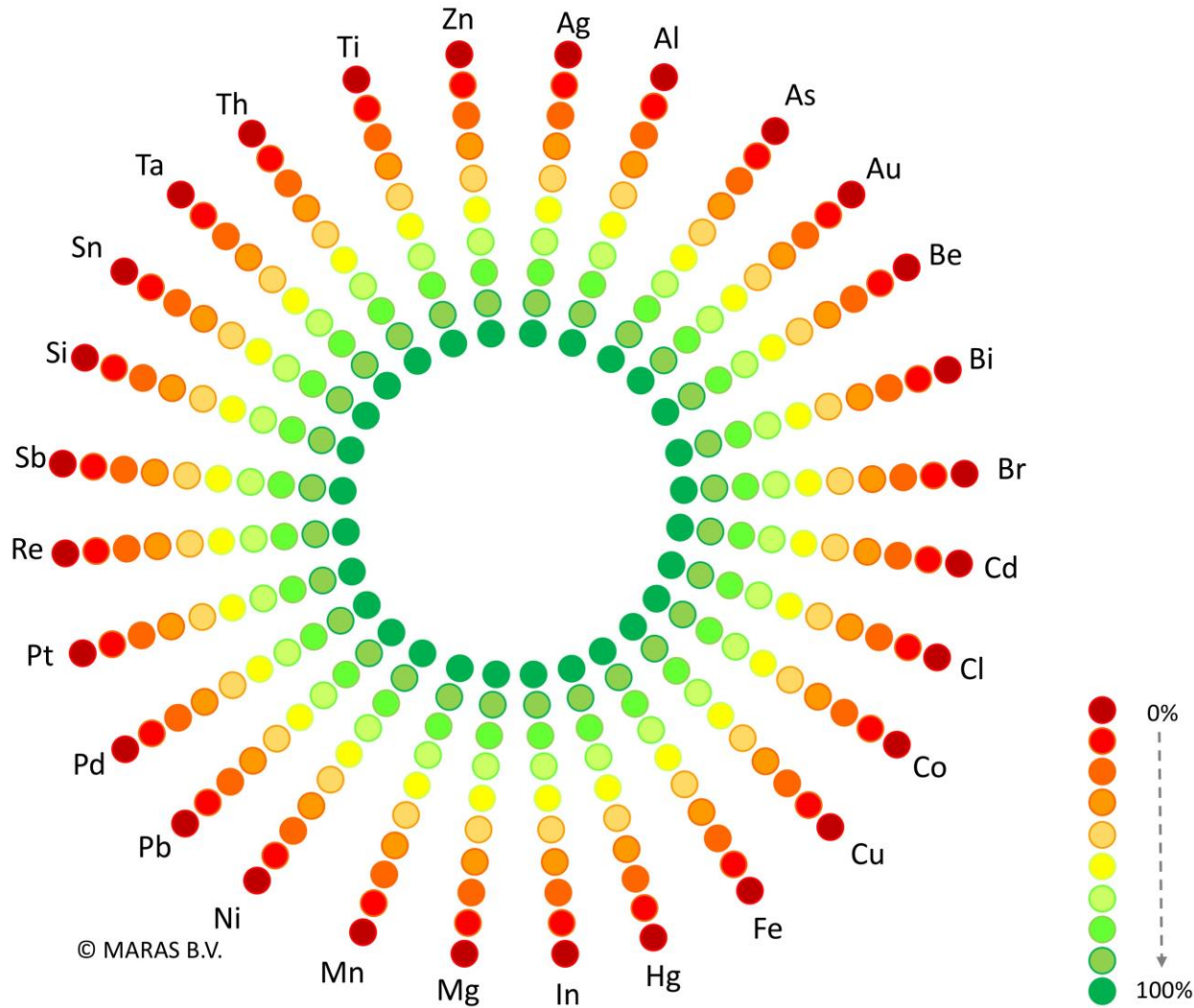


(e)

Voorbeeld :  
(Re) design recycling  
assessment van 5 typen  
LED lampen

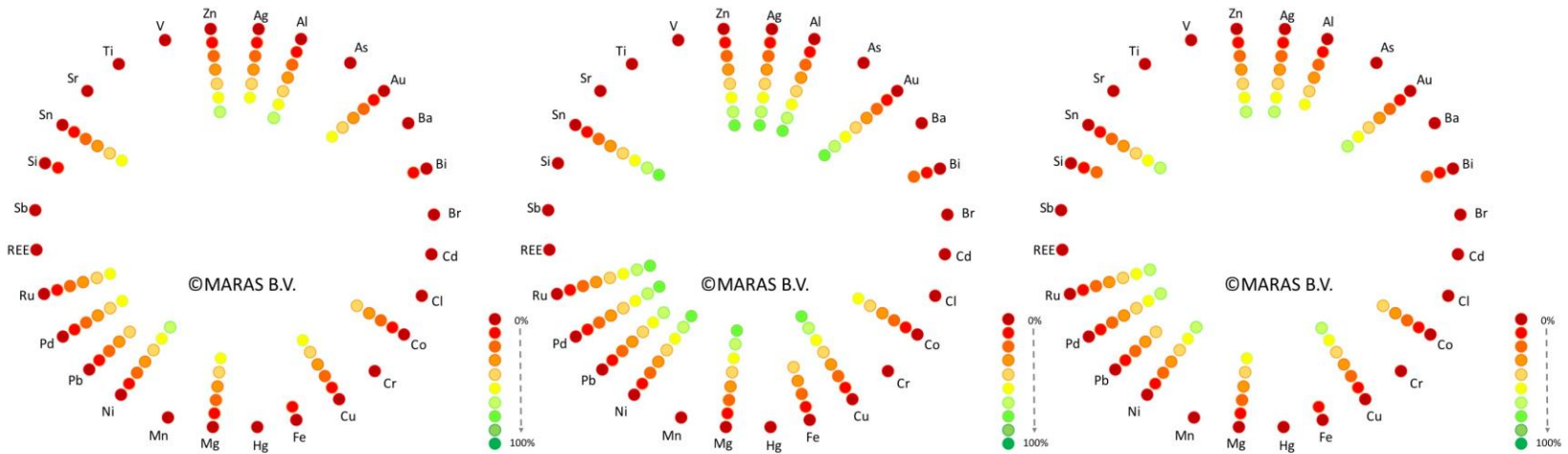
# Recycling Index

Kwantificering en visualisatie van recyclingpercentages van individuele materialen in een product



# Recycling Index

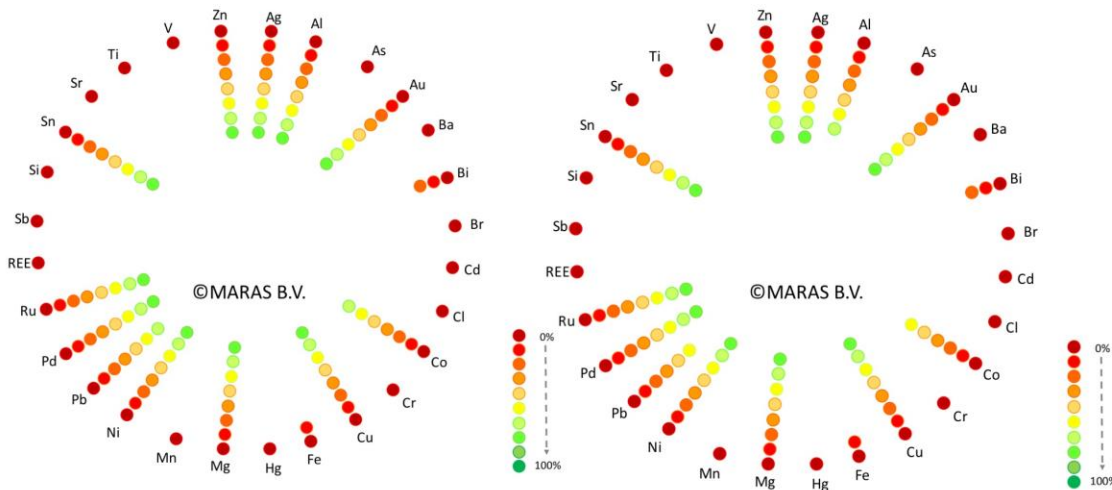
Kwantificering en visualisatie van recyclingpercentages van individuele materialen in een product



(a)

(b)

(c)



(d)

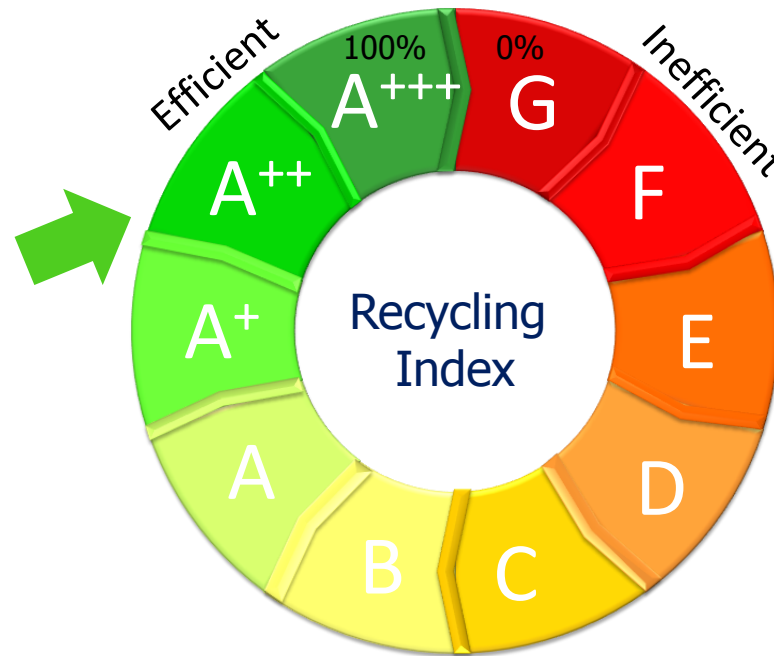
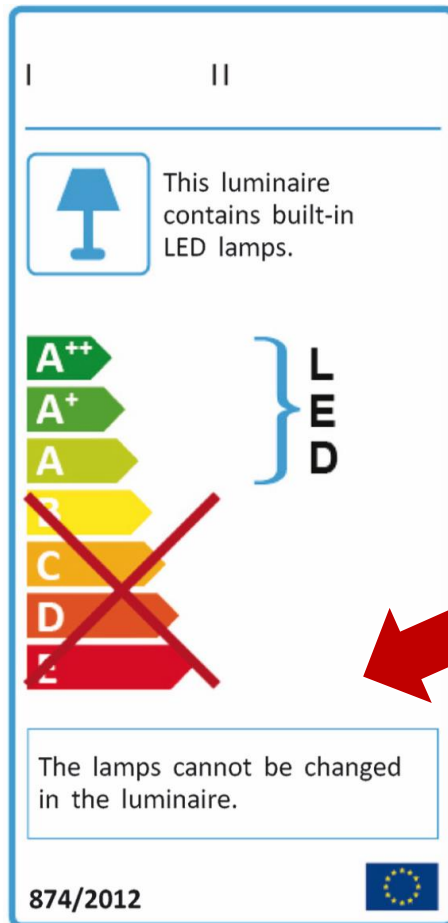
(e)

Voorbeeld :  
Verschillen in  
materiaalrecyclingpercentages  
voor 5 typen LED lampen



# Wat is de werkelijke grondstoffenefficiëntie?

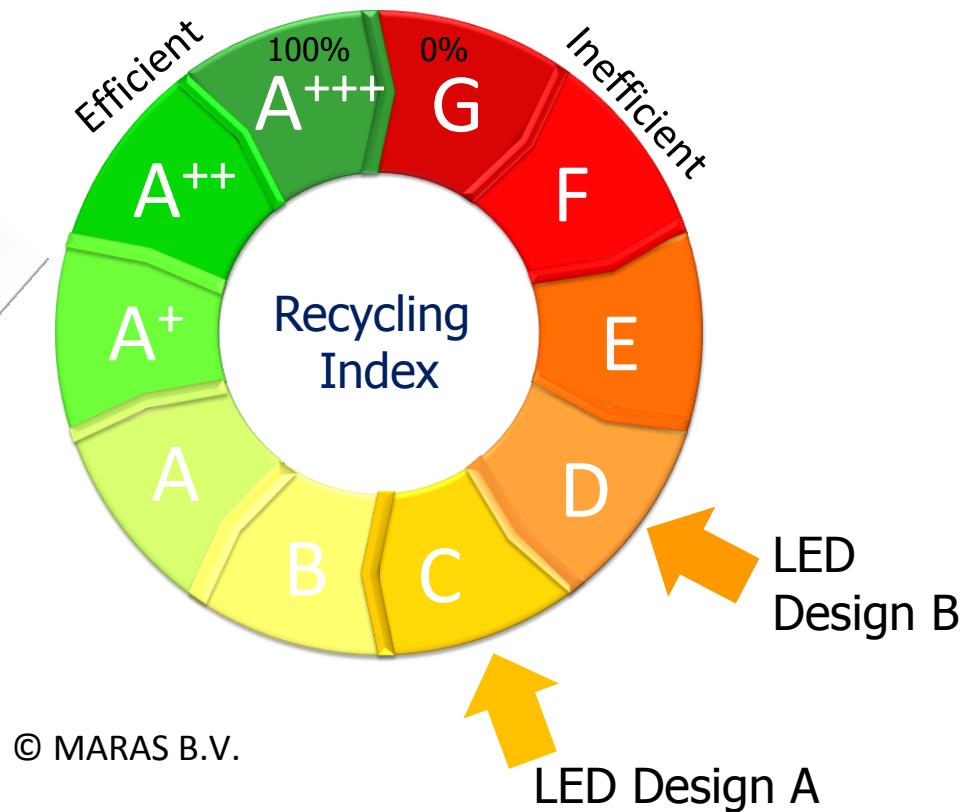
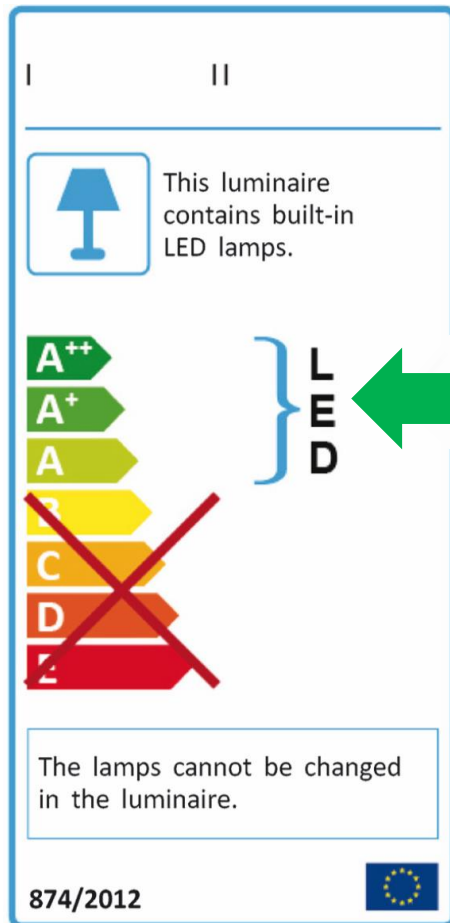
Duurzaam (circulair) ontwerp voor zowel materialen als energie?



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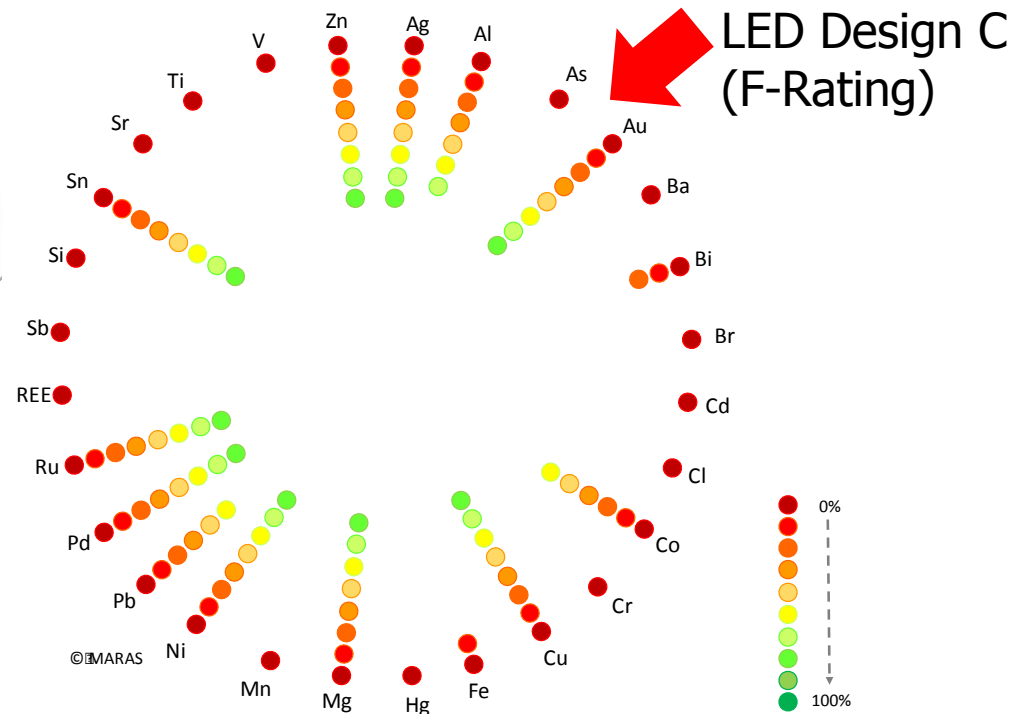
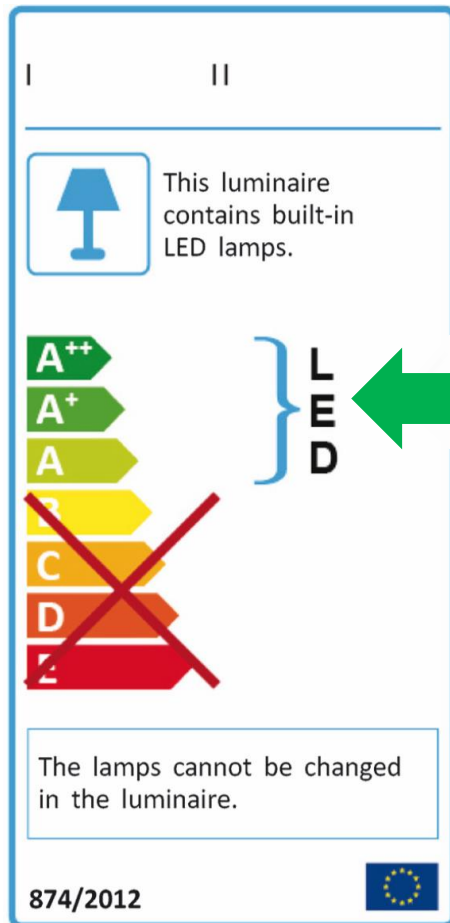
# Informeren consument en wetgever over grenzen van circulaire economie

Duurzaam (circulair) ontwerp voor zowel materialen als energie?



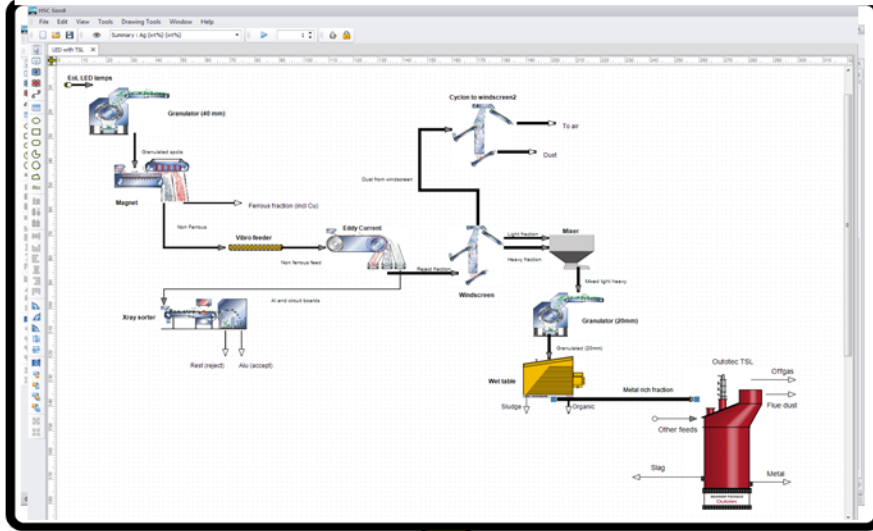
# Informeren consument en wetgever over grenzen van circulaire economie

Duurzaam (circulair) ontwerp voor zowel materialen als energie?



# Recycling en milieu-analyse (LCA)

## Recycling simulation models (HSC)



### BAT, Flow Sheets & Recycling System Maximizing Resource Efficiency – Benchmarks

**\$US / t Product (CAPEX & OPEX)**

**Recyclability Index (based on system simulation of whole cycle)**

Energy: GJ & MWh / t Product (source specific)

Exergy: GJ & MWh / t

kg CO<sub>2</sub> / t Product

kg SO<sub>x</sub> / t Product

g NO<sub>x</sub> / t Product

m<sup>3</sup> Water / t Product (including ions in solution)

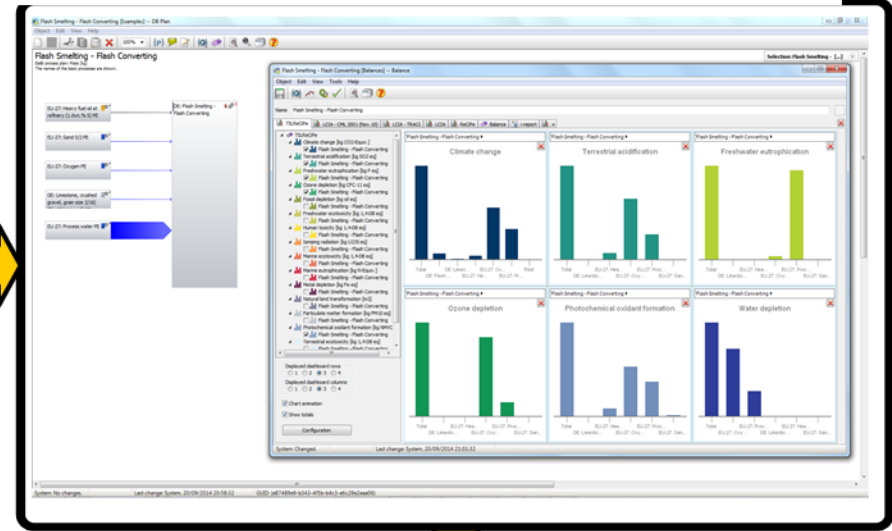
kg Residue / t Product (including composition)

kg Fugitive Emissions / t Product

kg Particulate Emissions / t Product

Etc.

## LCA software (GaBi)



### Environmental Indicators based on BAT Driving Benchmarks of Industry

**ReCiPe (and similar) – Endpoint estimation**

Global Warming Potential (GWP)

Acidification Potential (AP)

Eutrophication Potential (EP)

Human Toxicity Potential (HTP)

Ozone Layer Depletion Potential (ODP)

Photochemical Ozone Creation Potential (POCP)

Aquatic Ecotoxicity Potential (AETP)

Abiotic Depletion (ADP)

Etc...

# 'Lessons learned'

## Kwantificering en transparantie mogelijkheden/limieten recyclebaarheid en ontwerp

- Gebruik van industriële (fysica gebaseerde) processimulatie, quick scan tools en Recycling Indices
- Inzicht in kwantitatieve relatie ontwerp/recycling en pinpointen verbeterpunten en limitaties (incl. trade-offs met andere ontwerpoverwegingen zoals modulariteit, lichtgewicht ontwerp, etc.)

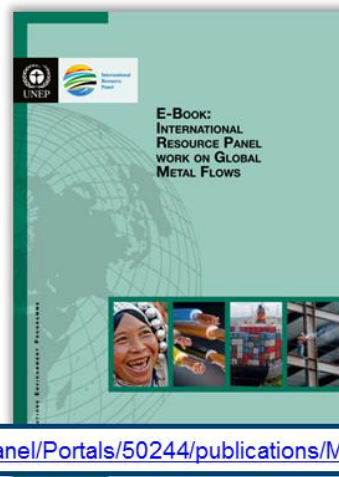
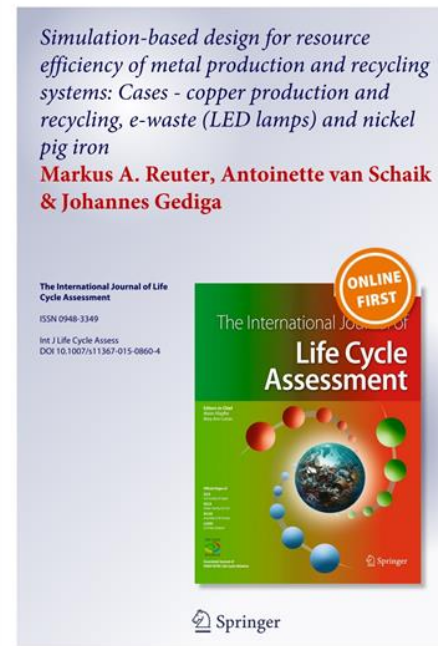
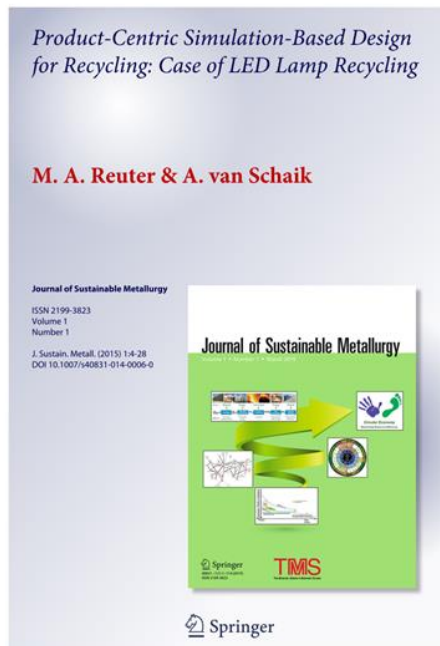
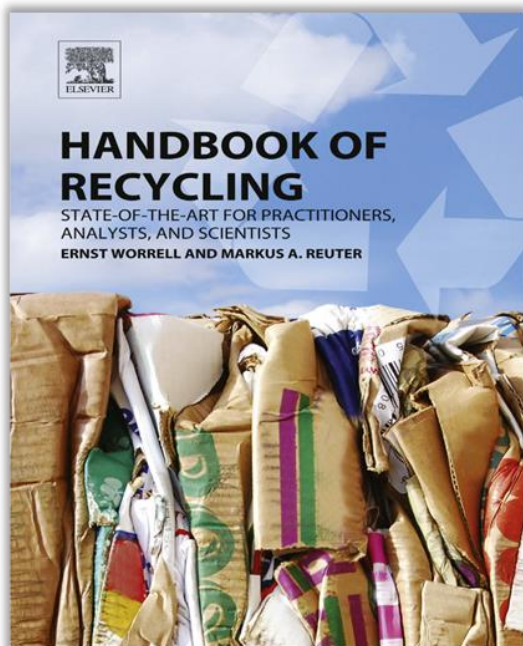
## 'Closing the gap' tussen ontwerp (OEMs) en recycling (recycling-/eindverwerkingsindustrie)

- OEMs : productdata (BOM/FMD) in consistente formats (bruikbaar voor OEMs en recyclers)
- Recyclers/verwerkers : benodigde productinformatie en mogelijkheden en limieten in recycling/verwerking
- Confidentialiteit / Digitalisatie

## Recycling wetgeving/Eco-design richtlijnen/CE pakket/LAP3

- Recyclingpercentages en DfR zijn product-specifiek en hebben een fundamentele limiet : recycling- en Eco-design en LAP3 doelstellingen moeten hierop gebaseerd zijn
- Harmonisatie van rekenmethodes voor recyclingpercentages in CE pakket baseren op product specifieke recyclingpercentages – gemiddelde percentages geven een foutief beeld en zijn contraproductief voor CE binnen Europa
- Gebaseerd op Best Beschikbare Technologie (techno/economisch) en dit stimuleren

# Additional information : Recent publications



[http://www.unep.org/resourcepanel/Portals/50244/publications/Metal\\_Recycling-Full\\_Report\\_150dpi\\_130919.pdf](http://www.unep.org/resourcepanel/Portals/50244/publications/Metal_Recycling-Full_Report_150dpi_130919.pdf)

# Educatie en bewustmaking jonge generatie



# Contact

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