



Outotec

Sustainable energy products
Simulation based design for recycling

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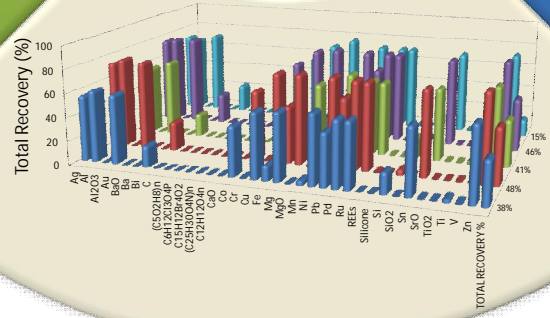
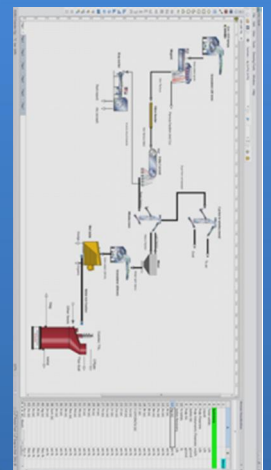
Product Design



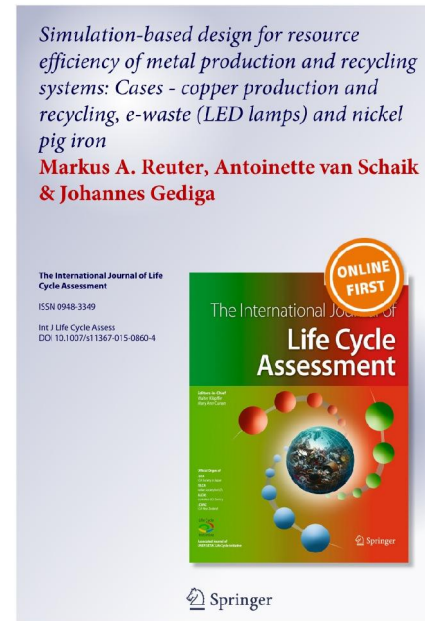
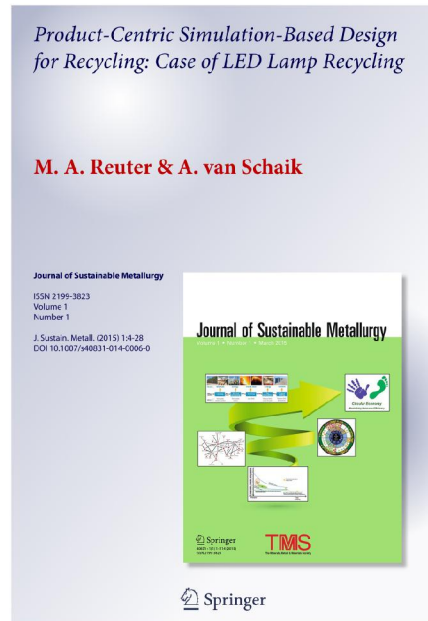
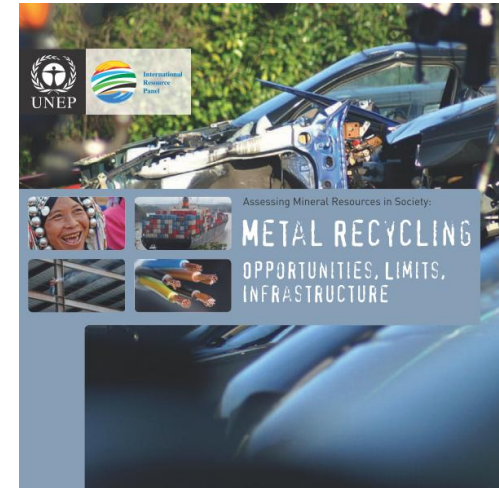
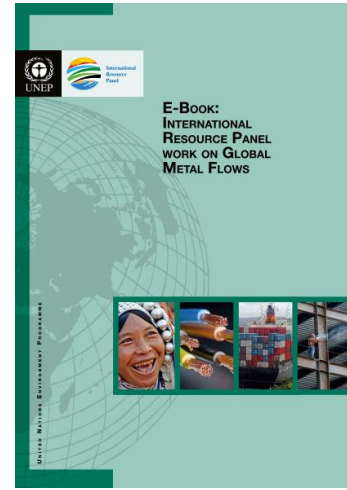
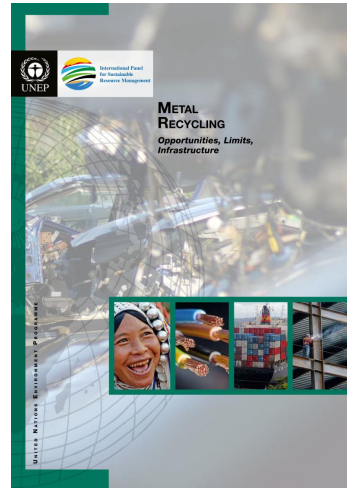
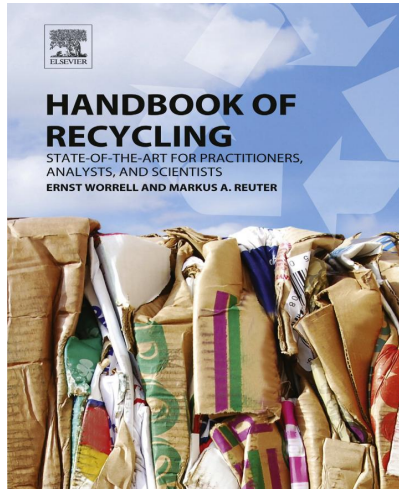
Greenprint



Simulation



Quantified sustainability

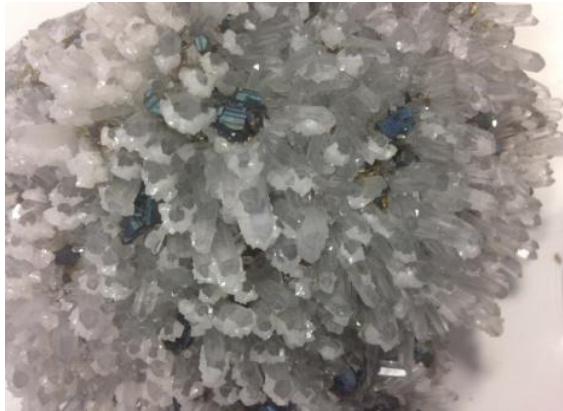


Product Simplicity vis-à-vis Complexity

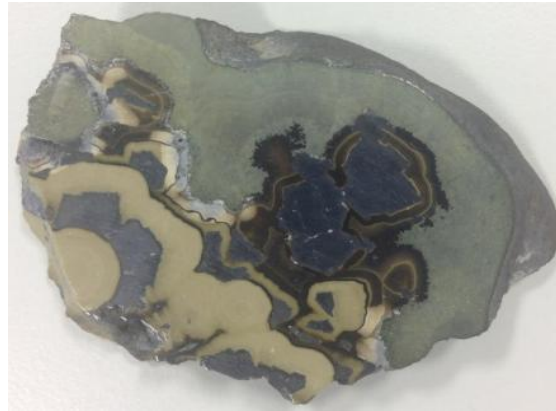
Ag
Al
Al ₂ O ₃
As(2O ₃)
Au
Ba
Bi
Ca(O)
Cu
Cu ₂ O
Dy(Oxide)
Fe
FeOx
Mg
MgO
Mn
MnO
Na
Ni
Pb
Pd
Sb(2O ₃)
Si
SiO ₂
Sn
Sr(O ₂)
Ti
TiO ₂
W
WO ₃
Y(2O ₃)
Zn
Zr/ZrO ₂



Geo Mine & Urban Mine Minerals Complexity...



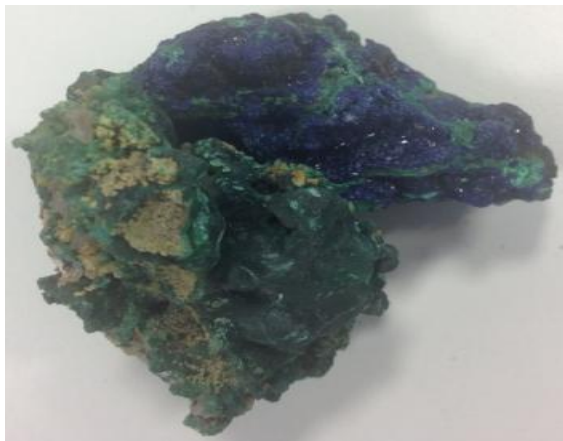
Chalcopyrite, Chalcocite, Bornite



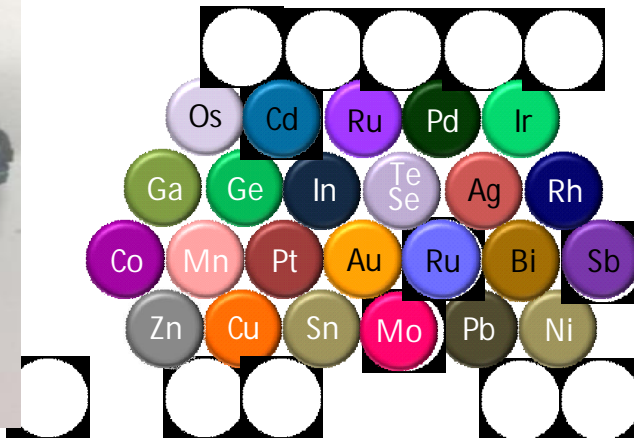
Wurzite, Sphalerite, Galena



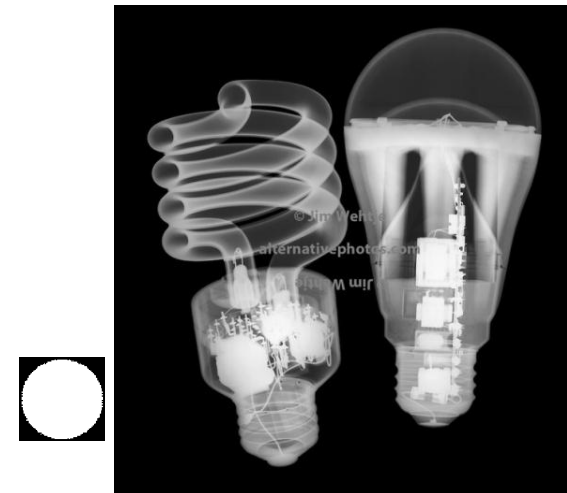
Energy Efficient Lighting



Malachite & Azurite



Some Elements in Minerals



Energy Efficient Lighting

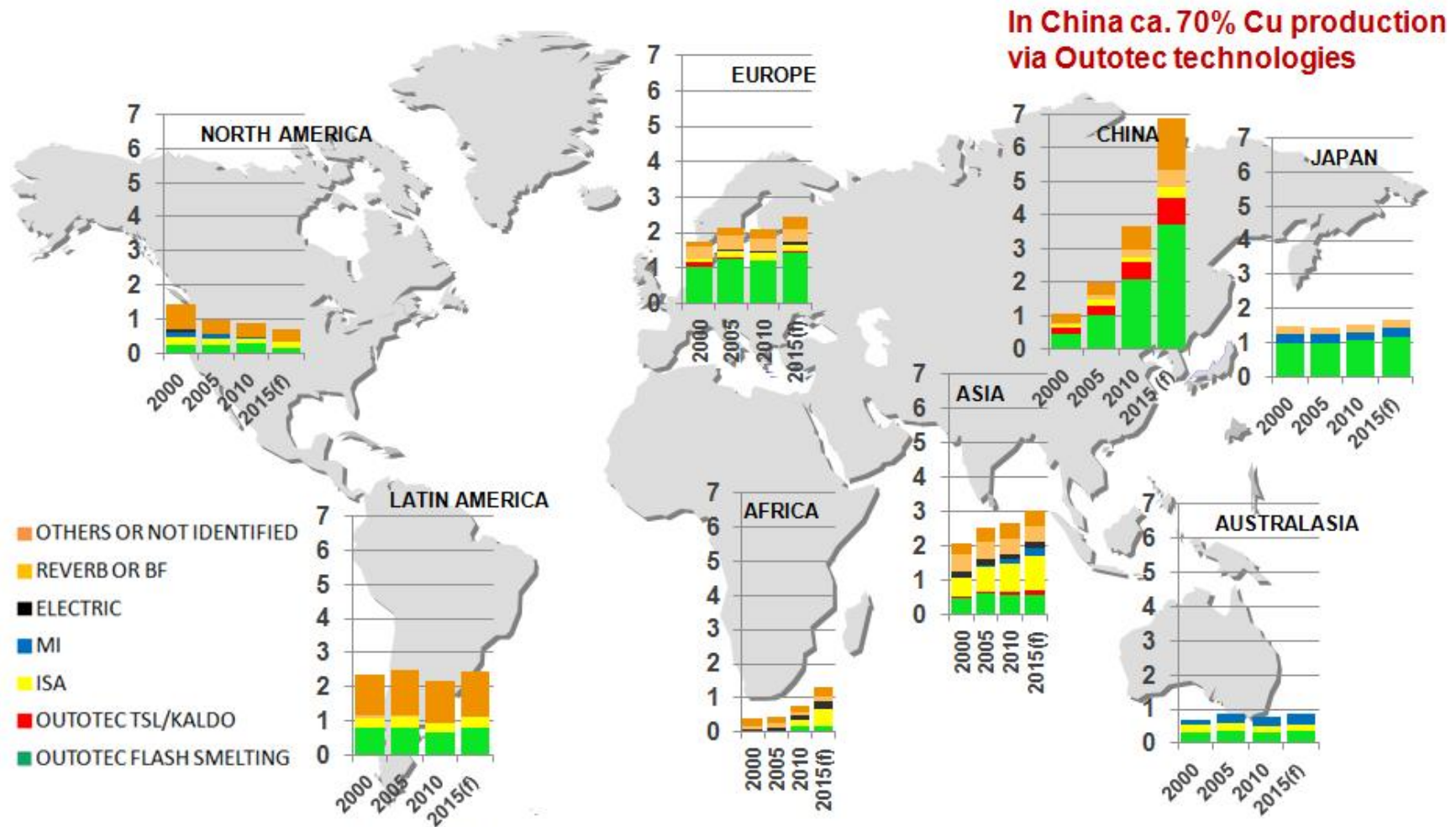
Atacama a couple of days ago (Chuquicamata)

Solar farm, windmill farm – metals from copper used in these



Copper Smelting production (million tonnes)

Outotec 3rd & 12th Globally Most Sustainable Corporation (2014, 2012 & 2014) 

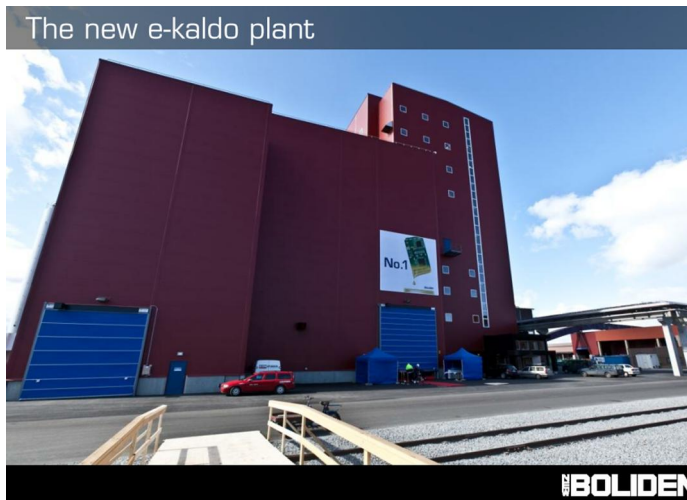


[Sources: ICSG Directory Excel tables - February 2013., Brook Hunt Global Copper production Dec. 2012]

Outotec technology: Metallurgy, recyclates & residues



Dowa (Japan): PCBAs, Cu, residues



The new e-kaldo plant
Boliden Rönnskår (Sweden): Kaldo for eWaste



Recylex (Germany): Lead Battery, Pb residues



JCC Guixi (China): Cu scrap, internal material (slags), residues



GRM – Danyang Smelter (S. Korea): Cu scrap, residues etc.



Young Poong Corporation (S. Korea): Pb/Zn

System Integrated Metal Production

Geological Minerals

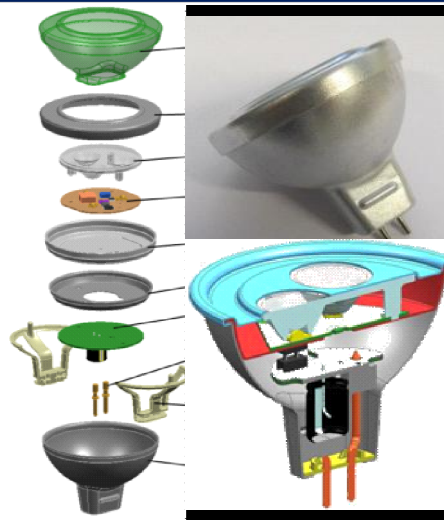
>15 Elements in copper minerals



Geological Linkages

Designer-Minerals

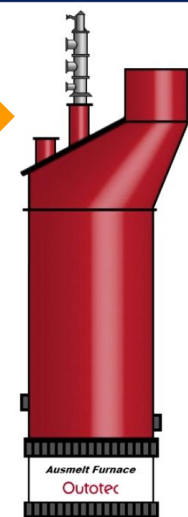
>40 Elements



Designer-Linkages Functional Materials



Complex Recyclates



Metallurgy

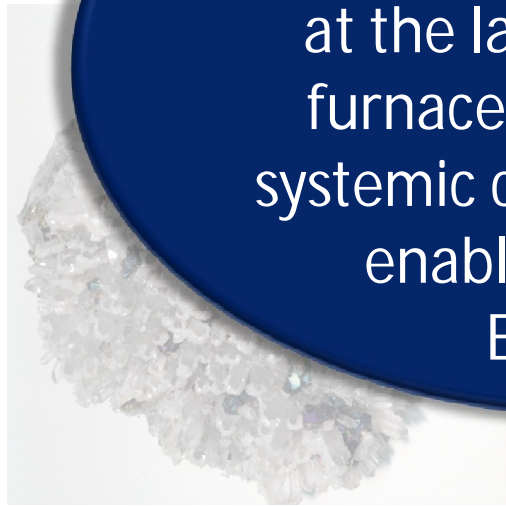
[Source: Handbook of Recycling (2014) : Worrell E & Reuter, M.A. Elsevier]

System Integrated Metal Production

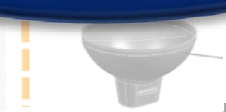
E.g. fundamentally understanding & optimizing the phenomena at the lance tip of a TSL furnace positioned in a systemic context is a key to enabling a Circular Economy

Geol

>15 El



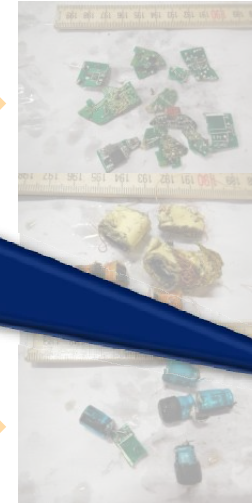
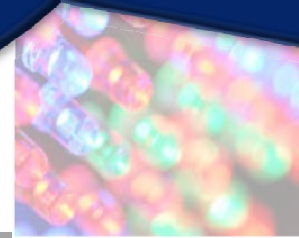
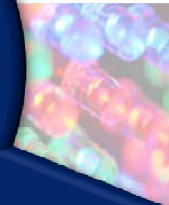
Geological Linkages



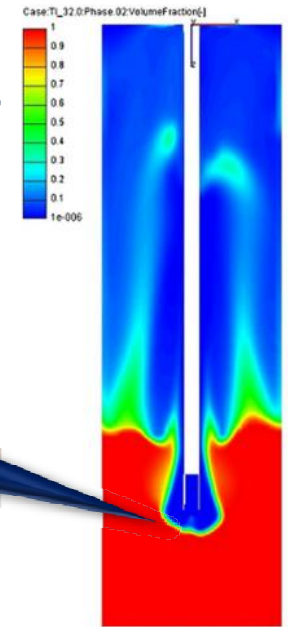
Designer-Linkages
Functional Materials

Designer-Minerals

>40 Elements



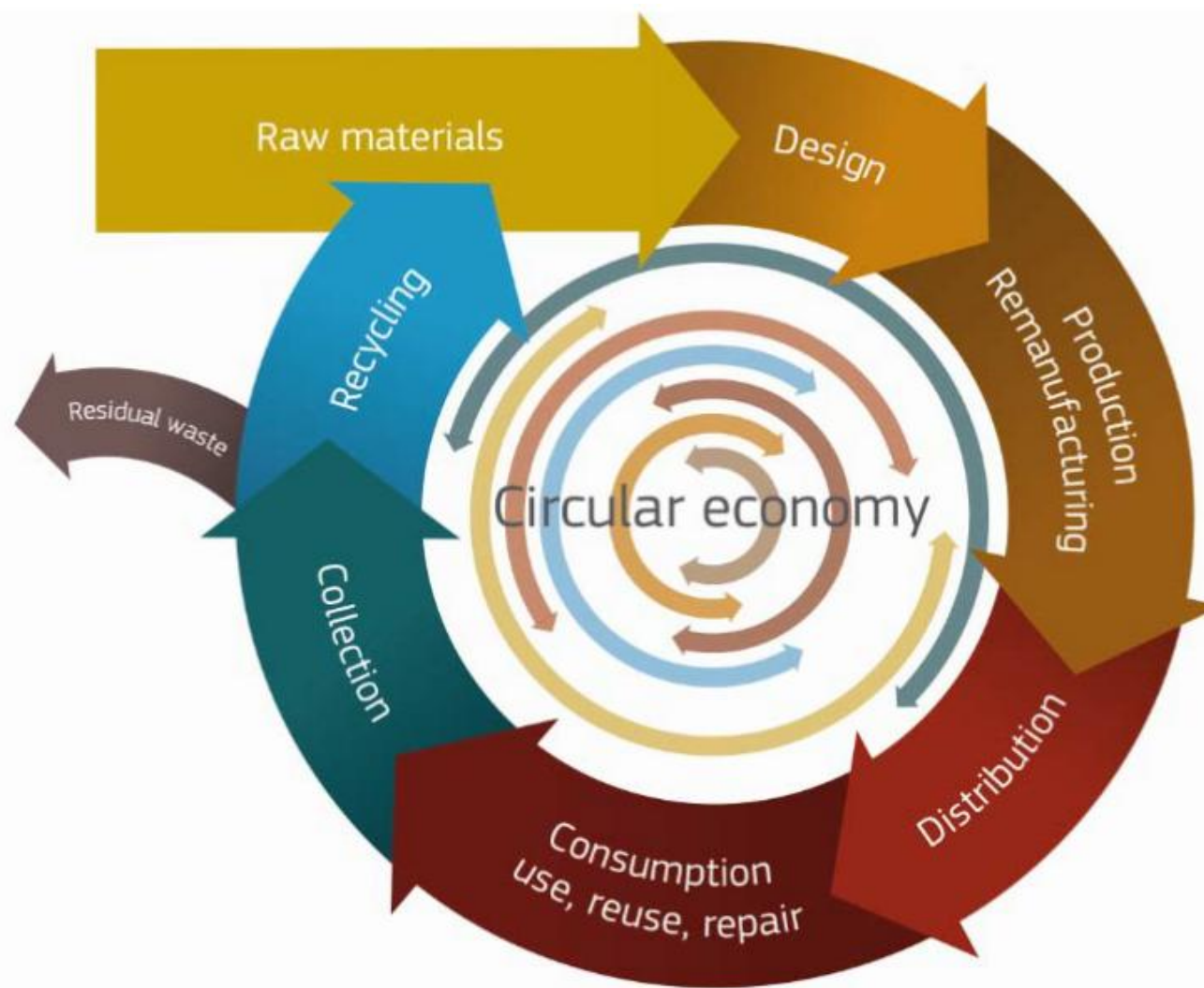
Complex Recyclates



Metallurgy

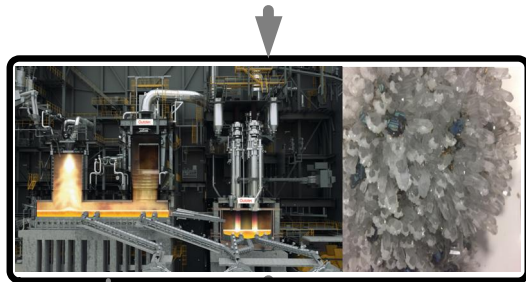
[Source: Handbook of Recycling (2014) : Worrell E & Reuter, M.A. Elsevier]

Circular Economy: Product Centric Recycling



GEOLOGICAL MINE

Geological Minerals



Losses



Product Design

Stocks & Losses

Functional Metal & Material Combinations

Metal & Energy Recovery (Pyro- & hydrometallurgy, Refining)

Thermodynamics Controls

Losses

URBAN MINE

Designer "Minerals" and Functional Materials



Market & Stocks

Losses



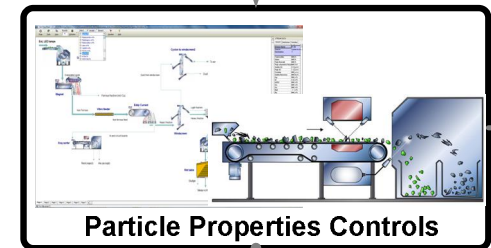
Collection, Dismantling, Shredding

Unaccounted Losses & Theft



Cu, Pb, Zn & their Minor Elements
Enablers of a Circular Economy
&
Internet-of-Things

Physical Separation



Particle Properties Controls

Losses

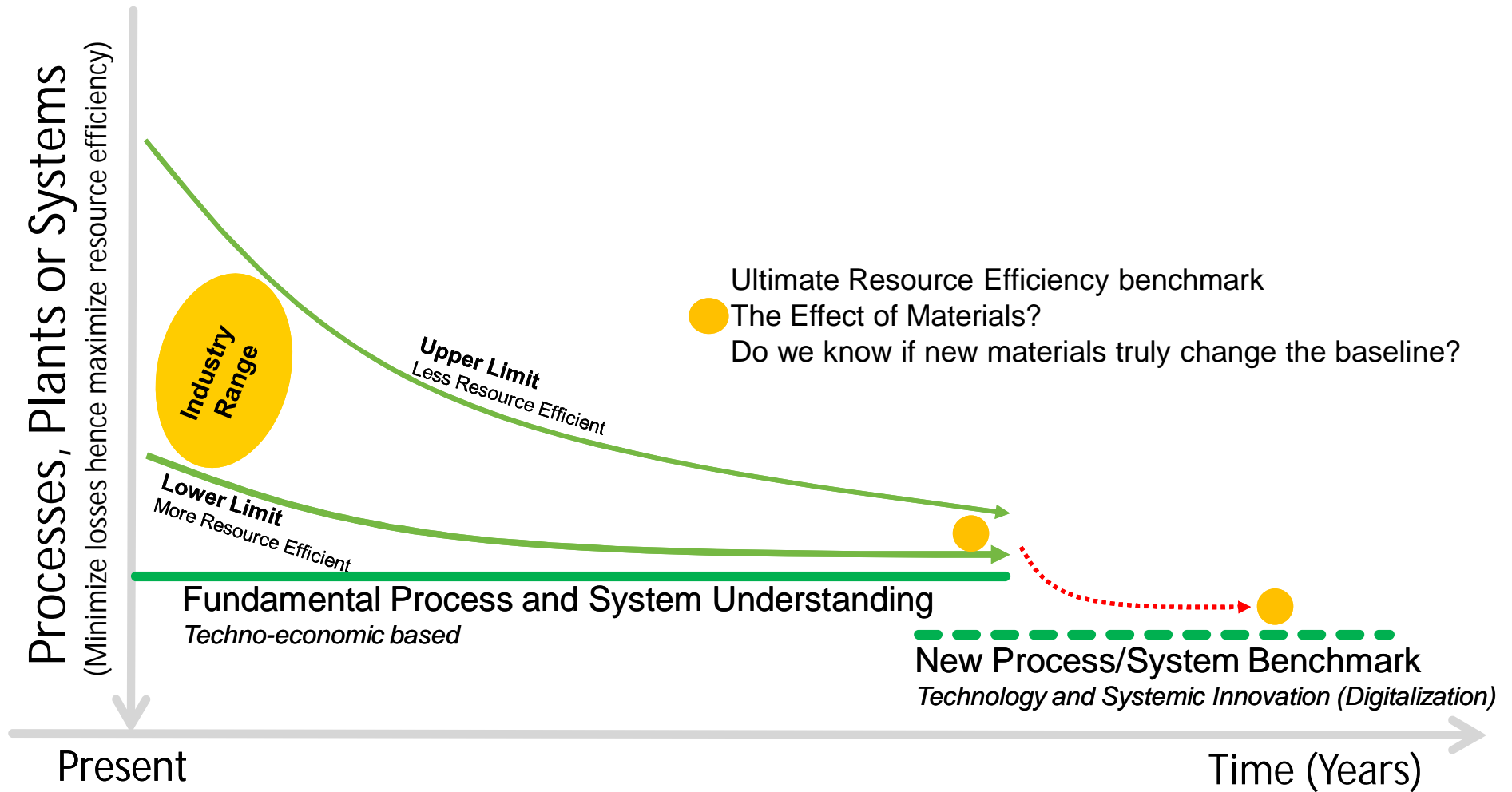
Multi-material Recyclate Grades



Complex Linkages/Connections

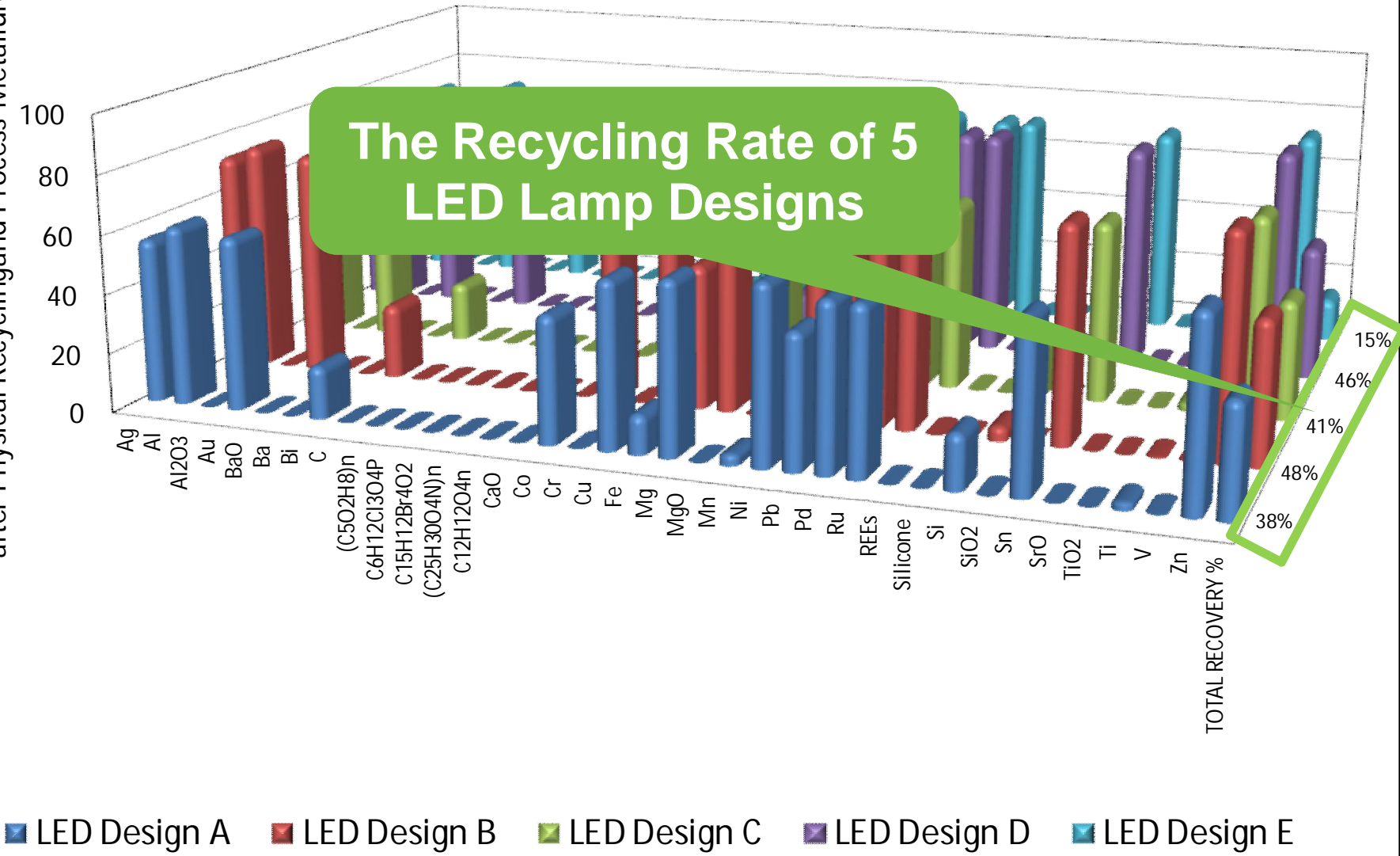
Losses & Stocks

System Integrated Metal Production: Innovative Digitalization



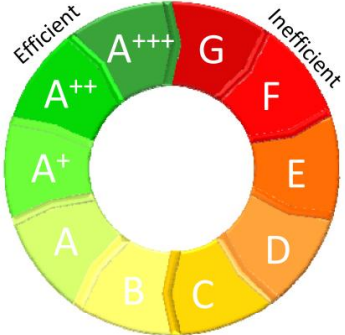
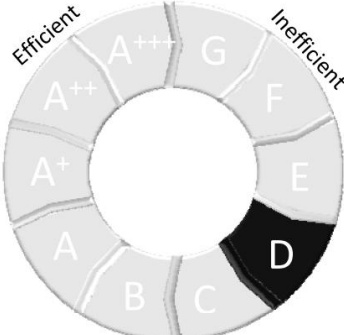
Total Recovery (%)
after Physical Recycling and Process Metallurgy

The Recycling Rate of 5 LED Lamp Designs



■ LED Design A
 ■ LED Design B
 ■ LED Design C
 ■ LED Design D
 ■ LED Design E

Recyclability rating: Inform consumer, taxpayer money spent well by researchers?

Recycling/Resources	LED lamp										
Producer Model	ABC LED Design A										
 <p>© MARAS B.V.</p>	 <p>© MARAS B.V.</p>										
Recycling/recovery rate Total weight based recycling/recovery rate of all materials/elements/compounds in the product after physical sorting and final treatment processing	30-40 %										
Environmental impact score of recycling <ul style="list-style-type: none"> - Recipe end-point indicator (type E - egalitarian weighting) - GWP (Global warming potential) - AP (Acidification potential) - EP (Eutrophication potential) - ODP (Ozone Layer Depletion Potential) 	<table style="width: 100%; border: none;"> <tr> <td style="width: 80%;"></td> <td style="text-align: right;">0.082</td> </tr> <tr> <td></td> <td style="text-align: right;">0.66</td> </tr> <tr> <td></td> <td style="text-align: right;">3.13 e-3</td> </tr> <tr> <td></td> <td style="text-align: right;">1.76 e-4</td> </tr> <tr> <td></td> <td style="text-align: right;">4.55 e-10</td> </tr> </table>		0.082		0.66		3.13 e-3		1.76 e-4		4.55 e-10
	0.082										
	0.66										
	3.13 e-3										
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	4.55 e-10										
	<p style="text-align: right;">© MARAS B.V.</p>										

[M.A. Reuter, A. van Schaik and J. Gediga (2015): Simulation-based design for resource efficiency of metal production and recycling systems, Cases: Copper production and recycling, eWaste (LED Lamps), Nickel pig iron, International Journal of Life Cycle Assessment (In press).]

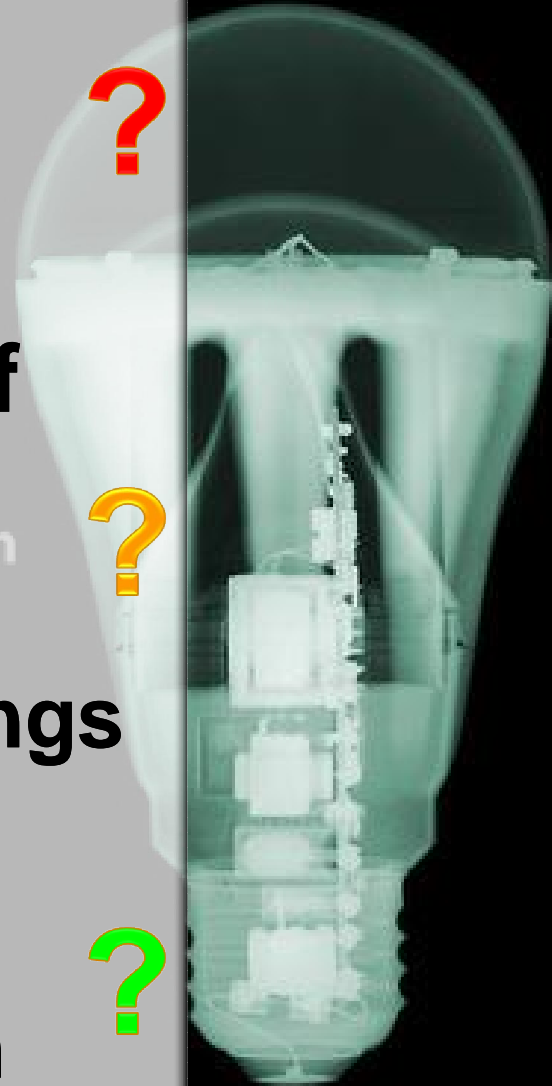


**Beauty of
Simplicity** ?

**The Web of
Energy
Materials** ?

Internet of Things

**System
Innovation** ?



Outotec



Sustainable use of
Earth's natural resources