

Opportunities & Limits of Recycling ...and of a Circular Economy

Markus A. Reuter

[Dr. h.c., D. Eng., Dr. habil., PhD]



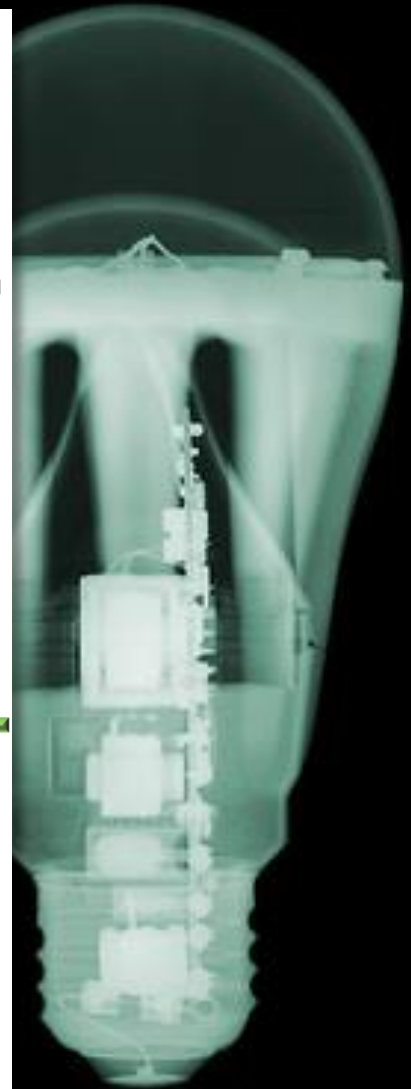
Circular Economy

Product Centric Recycling

Material Centric Recycling

Infrastructure Criticality?

Metal Criticality

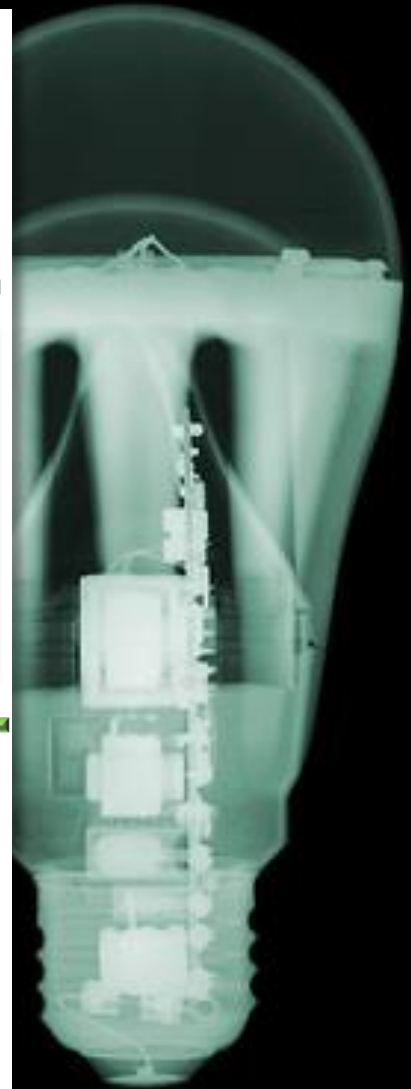




Circular Economy

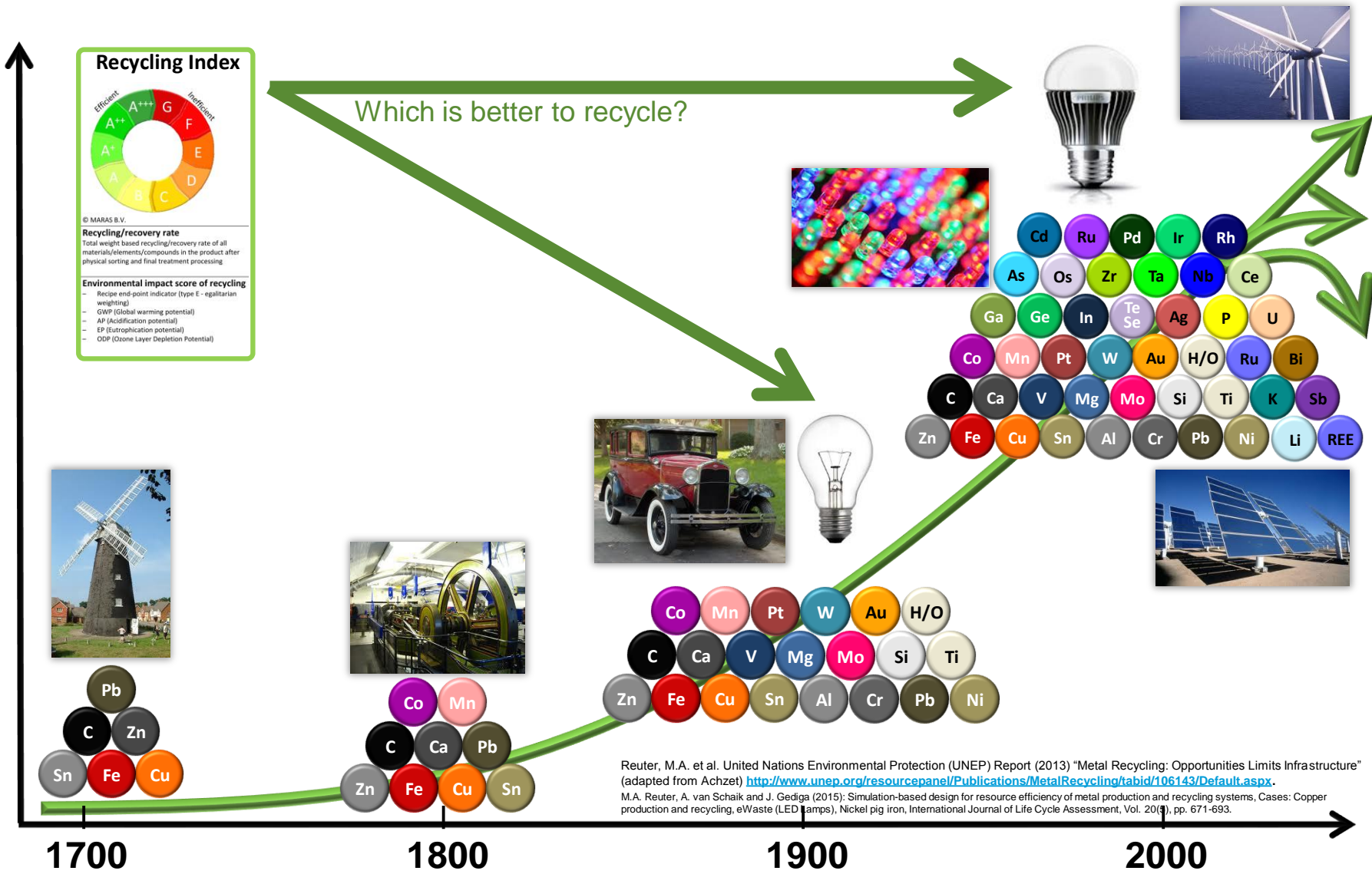
Which of these lamps is better for a circular economy?

**Infrastructure
Criticality?**
Metal Criticality



Metals always a part of society, but complexity?

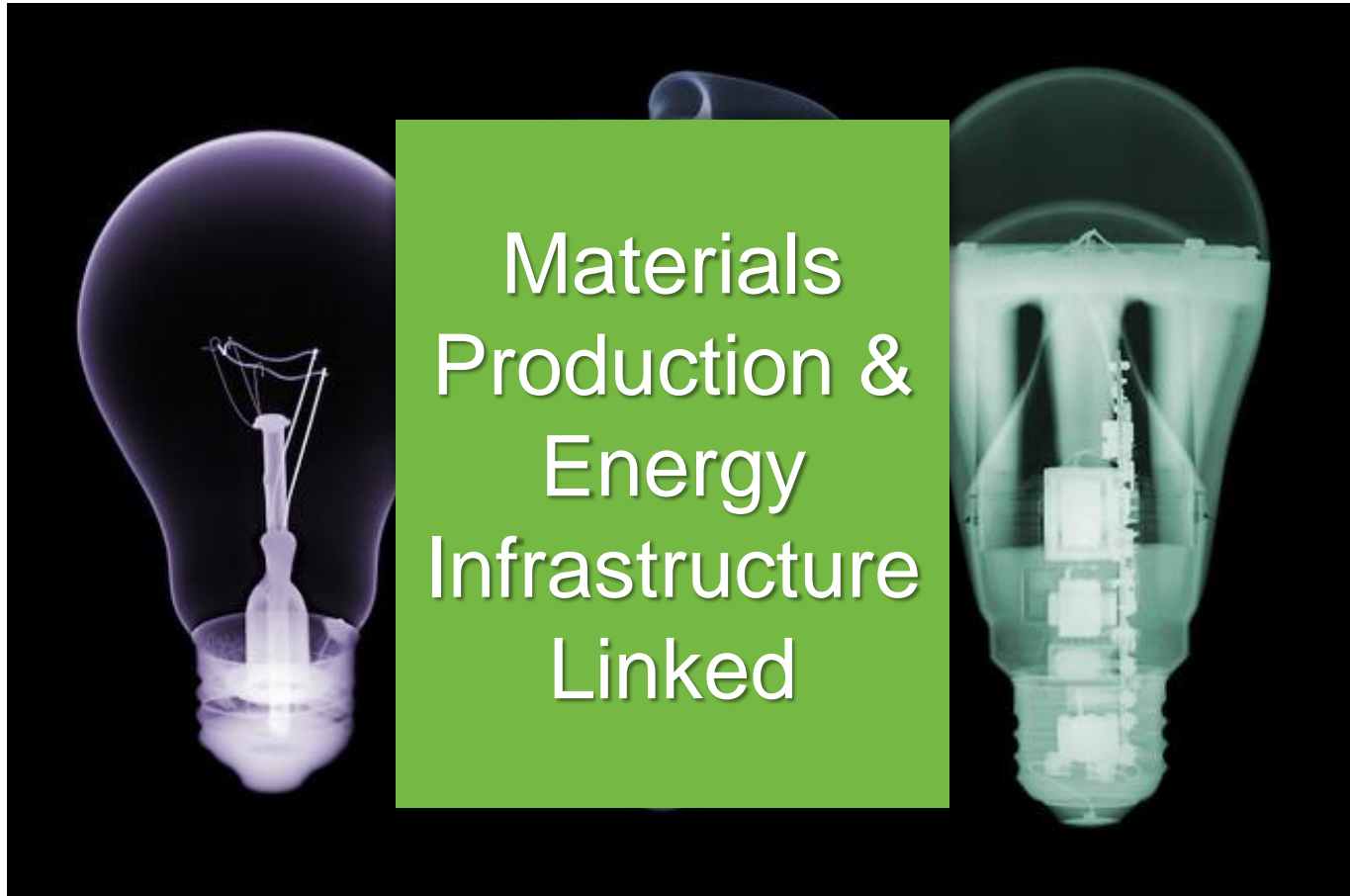
Metal/Element Use Intensity in Products



Reuter, M.A. et al. United Nations Environmental Protection (UNEP) Report (2013) "Metal Recycling: Opportunities Limits Infrastructure" (adapted from Achzet) <http://www.unep.org/resourcepanel/Publications/MetalRecycling/tabid/106143/Default.aspx>.
 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, Vol. 20(9), pp. 671-693.

Circular Economy: Simplicity *vis-à-vis* Complexity

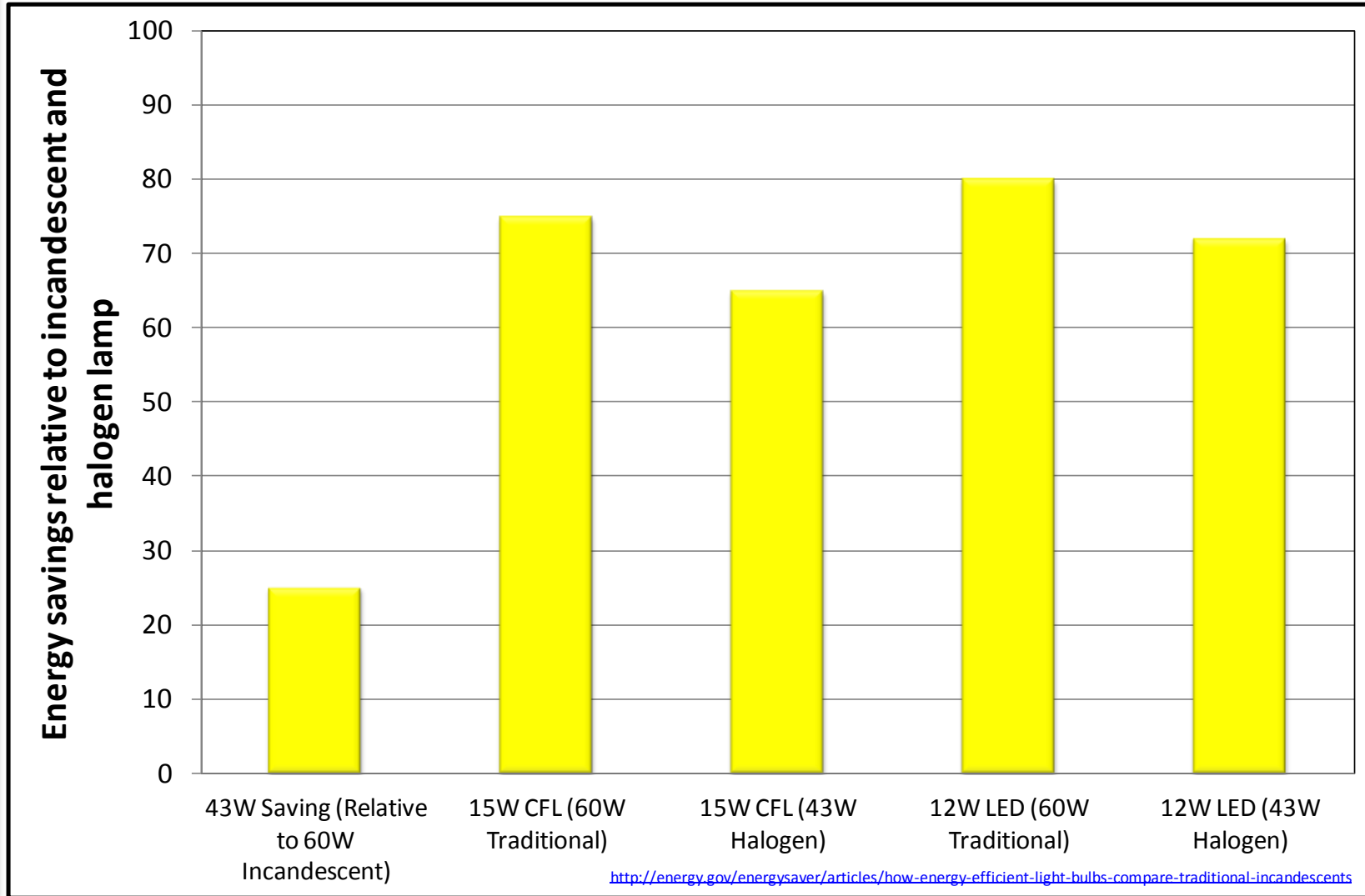
Ag
Al
Al ₂ O ₃
As(2O ₃)
Au
Ba
Bi
Ca(O)
Cu
Cu ₂ O
Dy(Oxide)
Fe
FeO _x
Mg
MgO
Mn
MnO
Na
Ni
Pb
Pd
Sb(2O ₃)
Si
SiO ₂
Sn
Sr(O ₂)
Ti
TiO ₂
W
WO ₃
Y(2O ₃)
Zn
Zr/ZrO ₂



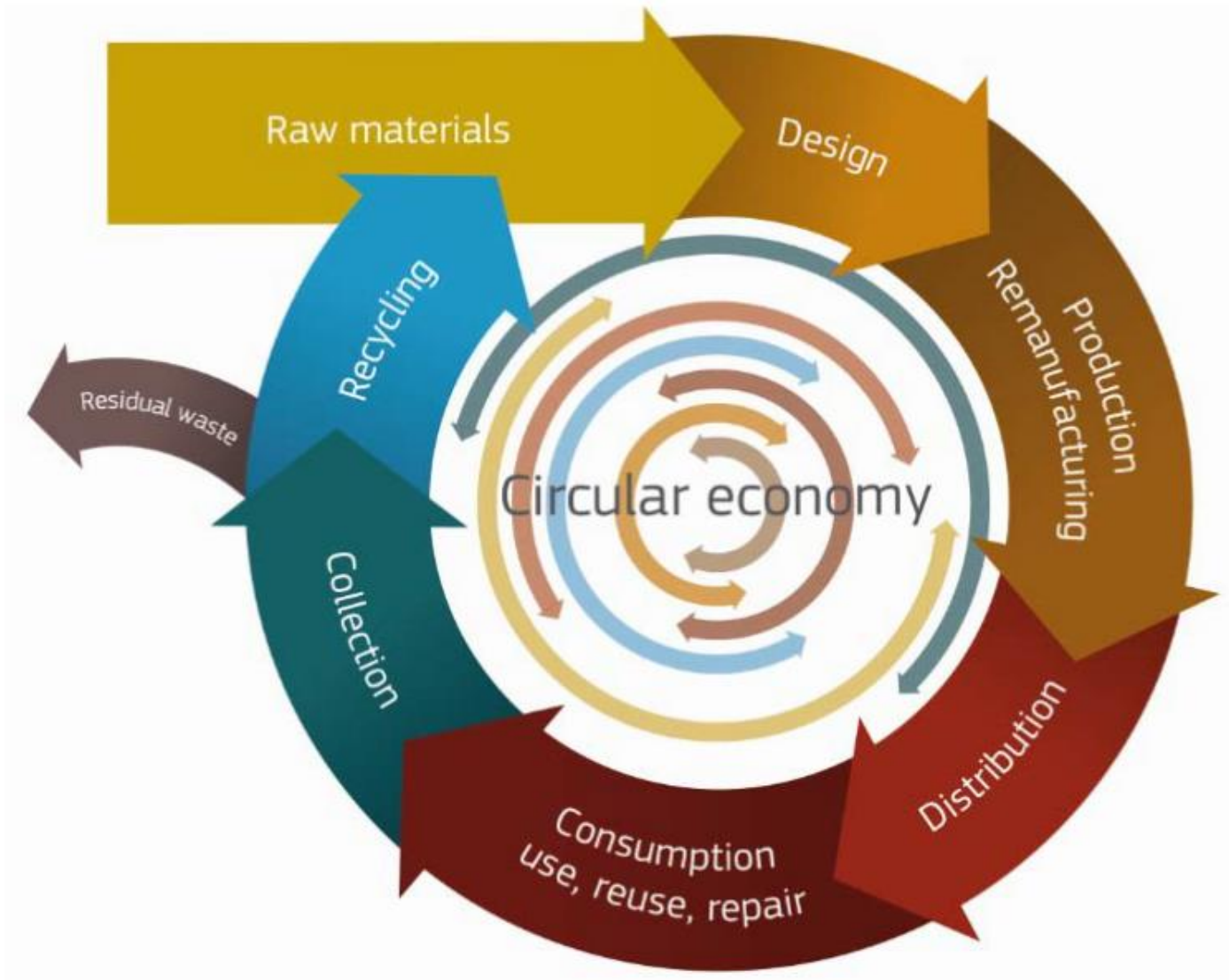
Circular Economy: Simplicity *vis-à-vis* Complexity

From base metals: Optimal link between energy infrastructure and metals

Ag
Al
Al2O3
As(2O3)
Au
Ba
Bi
Ca(O)
Cu
Cu2O
Dy(Oxide)
Fe
FeOx
Mg
MgO
Mn
MnO
Na
Ni
Pb
Pd
Sb(2O3)
Si
SiO2
Sn
Sr(O2)
Ti
TiO2
W
WO3
Y(2O3)
Zn
Zr/ZrO2



Circular Economy: Product Centric Recycling



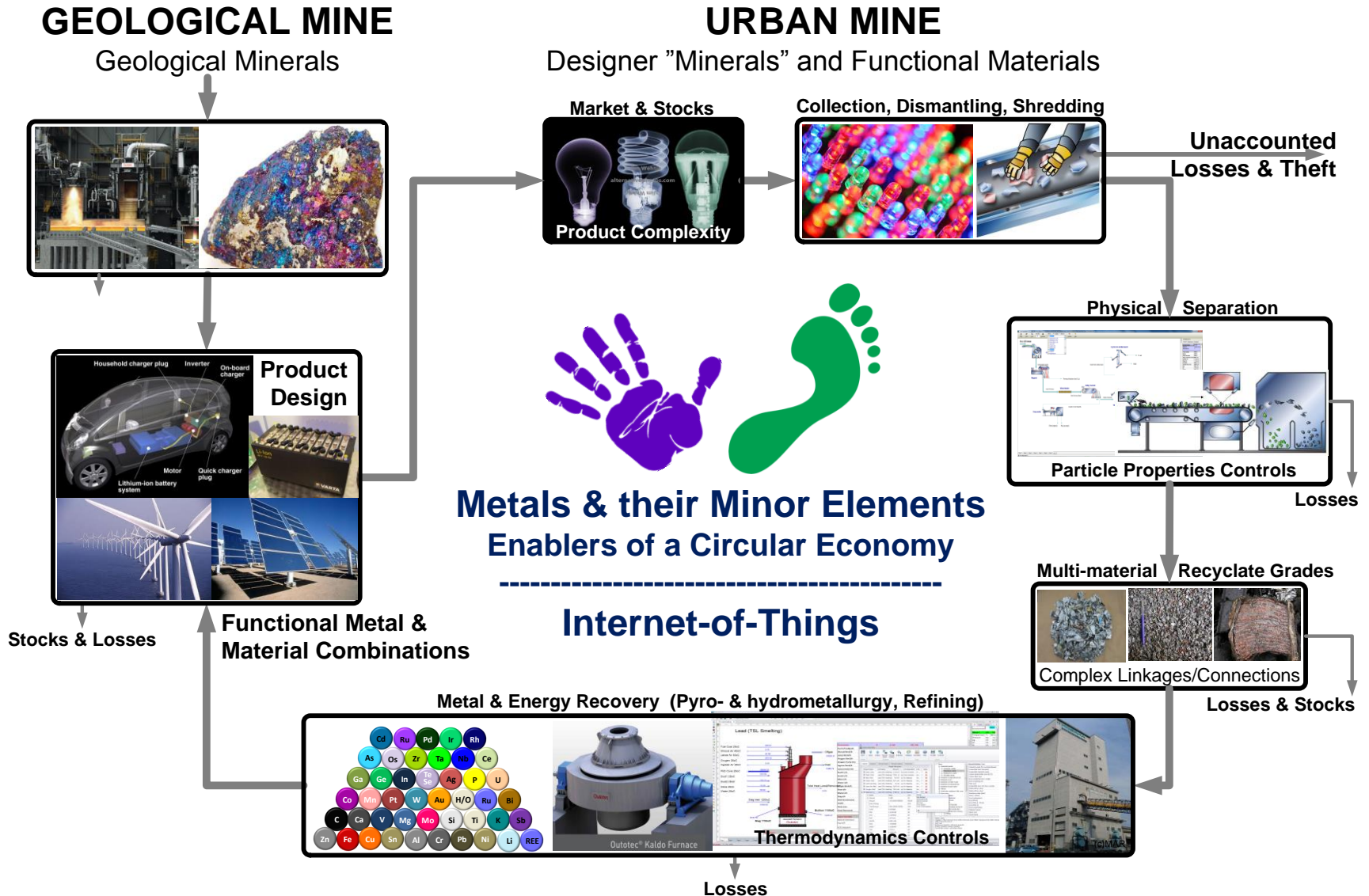
We have choices...



The Circle and Stochasim of Life



Metallurgy Block: Internet of Things (IoT)

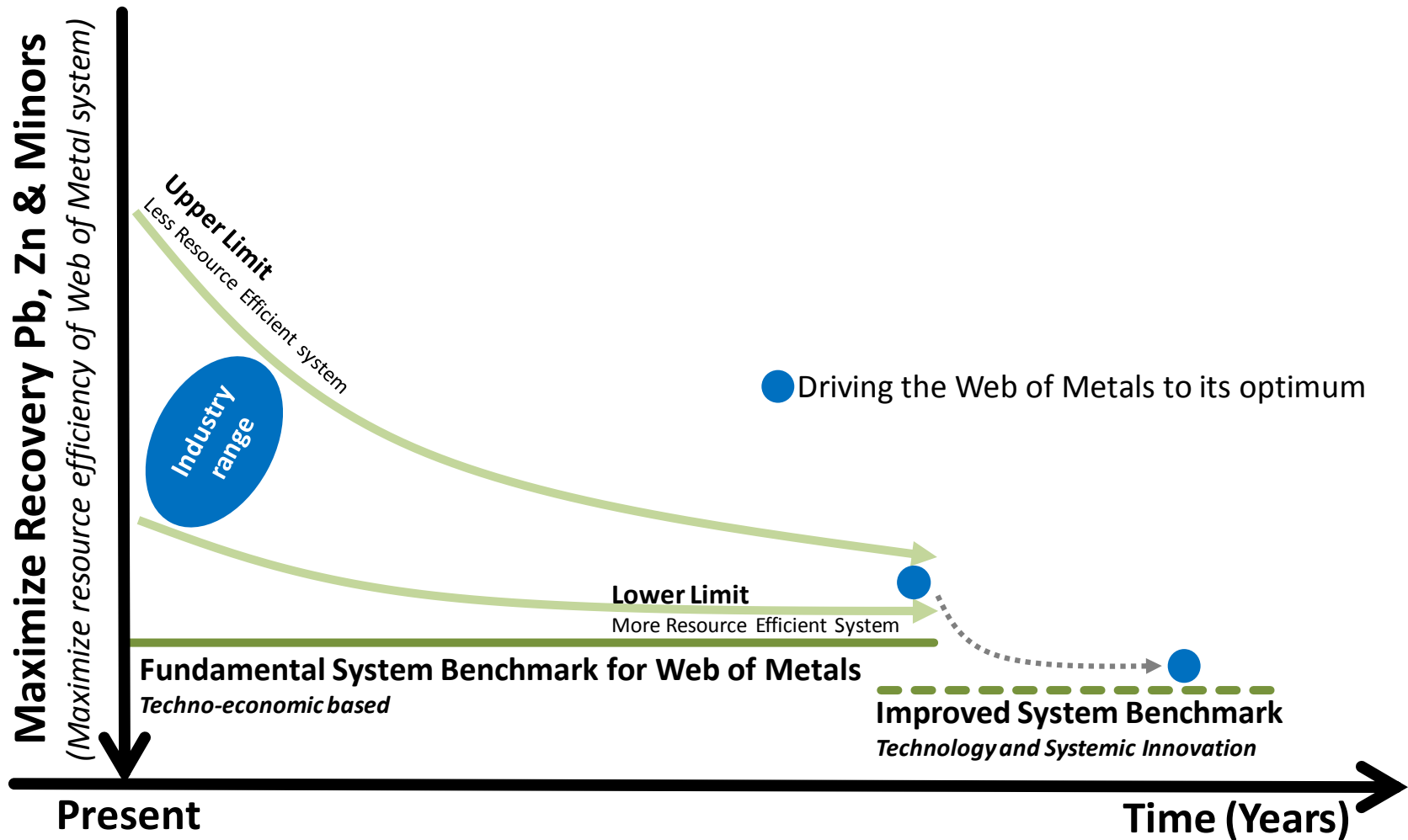


Metallurgy Block: Internet of Things (IoT)



System Integrated Metal Production (SIMP)

Innovative Digitalization of the Internet of Things (IoT)

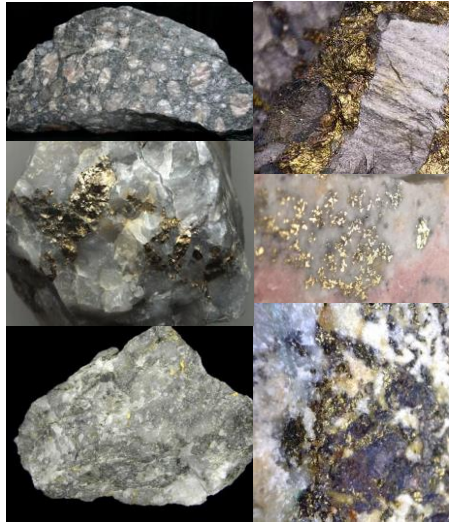


Digitalizing & optimizing metallurgical systems

Mineral/Product centric understanding

Geological Minerals

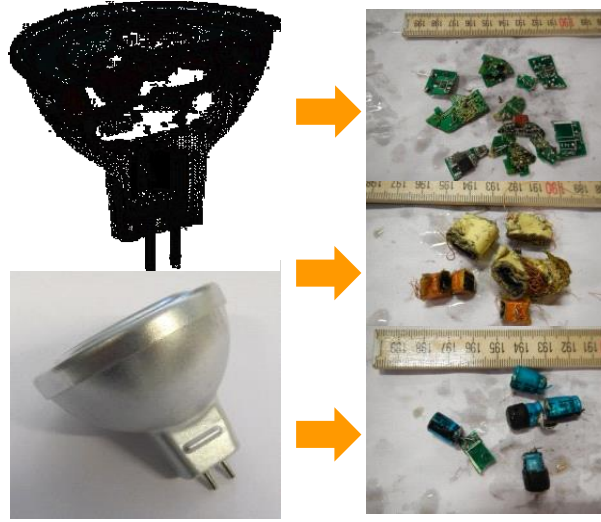
>15 Elements in gold minerals



Geological Linkages

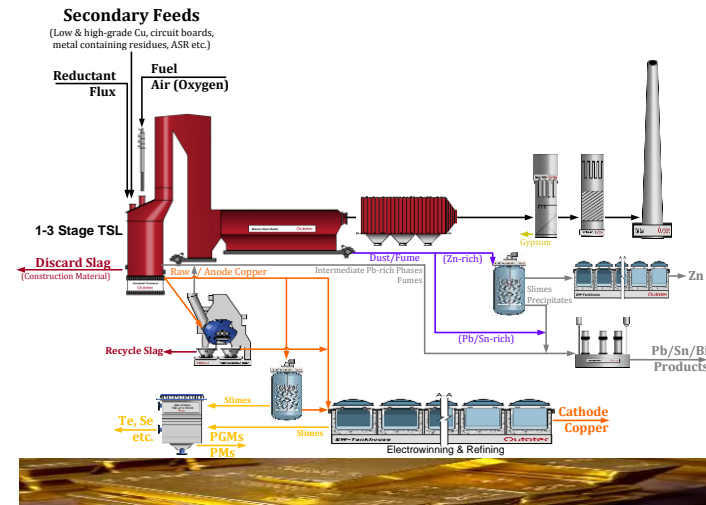
Designer-Minerals

>40 Elements



Designer-Linkages
Functional Materials

Complex
Recyclates

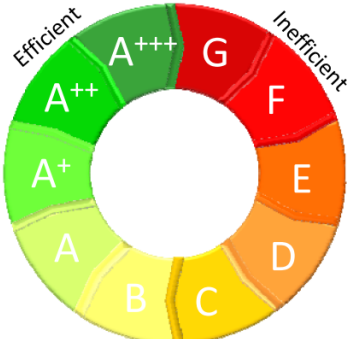
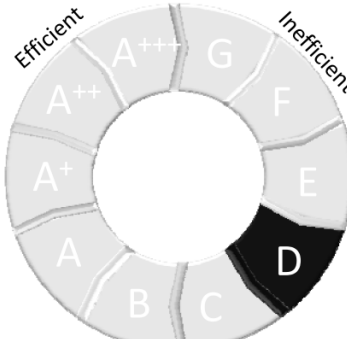


Metallurgical refining infrastructure



Recyclability Index → Enabling resource efficiency

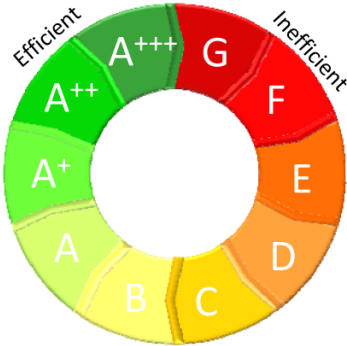
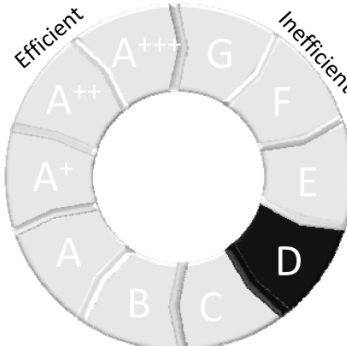
Inform consumer in a simple manner of our industry to show its importance

Recycling/Resources Producer Model	LED lamp 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-collapse: collapse;"> <tr><td style="text-align: right;">0.082</td></tr> <tr><td style="text-align: right;">0.66</td></tr> <tr><td style="text-align: right;">3.13 e-3</td></tr> <tr><td style="text-align: right;">1.76 e-4</td></tr> <tr><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						
1.76 e-4						
4.55 e-10						
	<p style="text-align: right;">© MARAS B.V.</p>					

[Source: 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, Vol. 20(5), pp. 671-693.]

Recyclability Index → Enabling resource efficiency

Inform consumer in a simple manner of our industry to show its importance

Recycling/Resources Producer Model	LED lamp ABC LED Design A
 <p>© MARAS B.V.</p>	 <p>© MARAS B.V.</p>
Recycling/recovery rate	30-40 %
<p style="text-align: center;">So, which is better considering both energy and materials? Quantifying the Circular Economy</p>	

[Source: 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, Vol. 20(5), pp. 671-693.]



Digitalizing

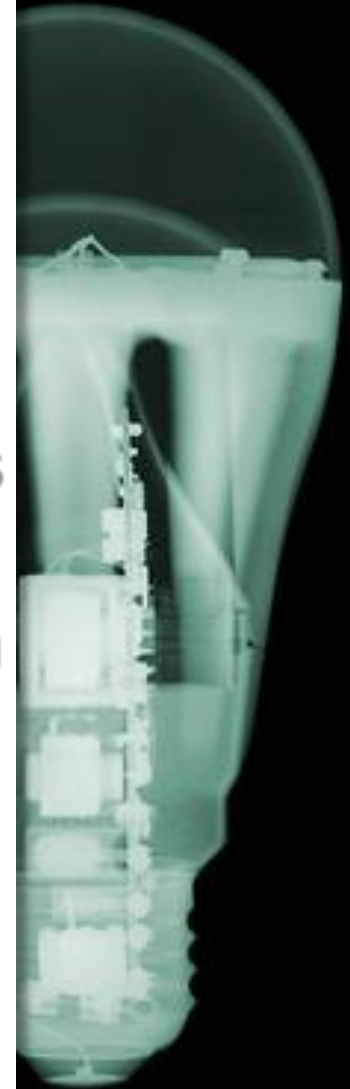
Linking web of
Energy & Materials

Internet of Things

Process metallurgical systems
key to circular economy
De-silo thinking and education

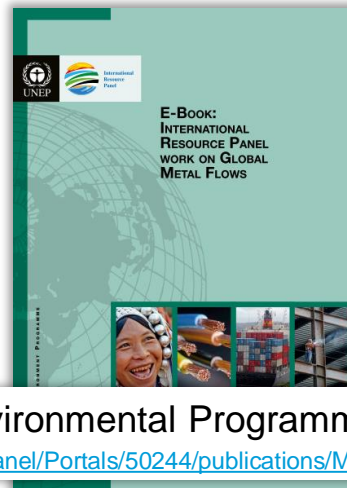
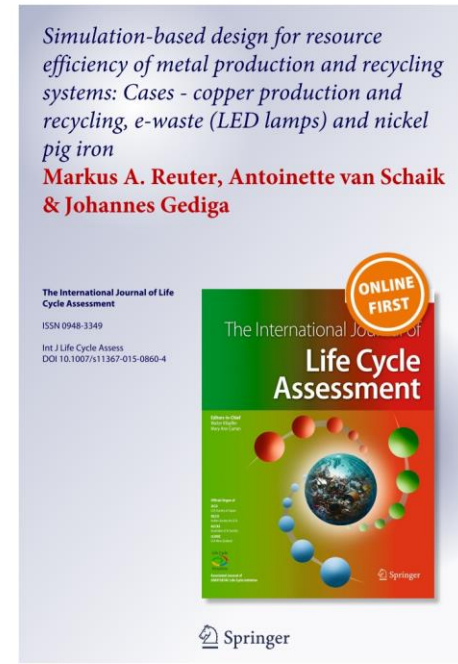
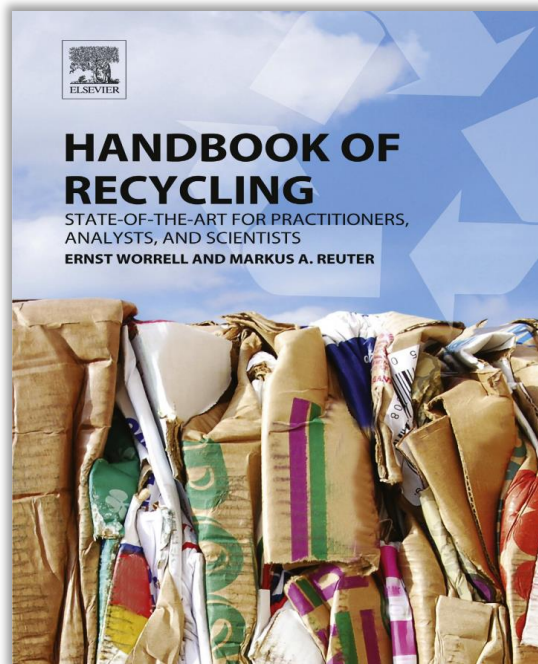
System Innovation

Simulation & Optimization
(linked to big data analysis)
Inform Policy & Consumer



Additional background sheets

Digitalization for Sustainability [2013-2015]



United Nations Environmental Programme - M.A. Reuter: Lead Author

http://www.unep.org/resourcepanel/Portals/50244/publications/Metal_Recycling-Full_Report_150dpi_130919.pdf

System Integrated Metal Production: Innovative Digitalization



Markus Reuter

[Dr. h.c., D.Eng., Dr. habil., PhD]

Background: <http://scholar.google.co.uk/citations?user=5cLC8VEAAAAJ&hl=en&oi=ao>
<http://fi.linkedin.com/pub/markus-reuter/11/195/90>
https://www.researchgate.net/profile/Markus_Reuter3?ev=prf_high
<http://www.researcherid.com/rid/D-2839-2015>



• Industry

- *Director Technology Management*: Technology Management, Outotec, Finland (2010→)
- *Chief Executive Technologist*: Ausmelt-Outotec, Australia (2006-2010 - taken over by Outotec 2010)
- *Leader furnace control group*: Mintek, South Africa (1994-1996)
- *Process Metallurgist*: Anglo American Corporation, South Africa (1984-1985)

• Academic

- *Dr. h.c.*: Honorary Doctorate University of Liège (2015: Belgium)
- *D. Eng. & PhD*: University of Stellenbosch (1991 & 2006: South Africa)
- *Dr. habil.*: RWTH Aachen (1995: Germany)
- *Adjunct Professor*: Aalto University Helsinki (2012→)
- *Guest Professor*: Central South University Changsha, PR China (2012→)
- *Professor and Professorial Fellow*: University Melbourne, Australia (2005→)
- *Professor & emeritus*: TU Delft, Netherlands (1996-2012)
- *Adjunct Professor*: Stellenbosch, South Africa (1999-2007)

• Publications, Interests etc.

- *Lead author*: UNEP report Metal Recycling: Opportunities, Limits, Infrastructure (2013)
 - http://www.unep.org/resourcepanel/Portals/50244/publications/Metal_Recycling-Full_Report_150dpi_130919.pdf
 - <http://www.ubraintv.com/watch.php?id=842>
- *Co-Editor and contributor*: Handbook of Recycling (Elsevier 2014) (International Solid Waste Association 1st Prize-2014)
- 2016 EPD Distinguished Lecture Award, TMS
- *Main author*: The Metrics of Material and Metal Ecology (Elsevier 2005)
- >400 Publications: Book / Chapters in Encyclopedias / Journal / Conference / Patents
- *Expertise*: Process metallurgy & Minerals Processing / Recycling / Design for Recycling & Sustainability, Process control / Simulation