

The (Geo)Metallurgy of the Circular Economy

Markus A. Reuter

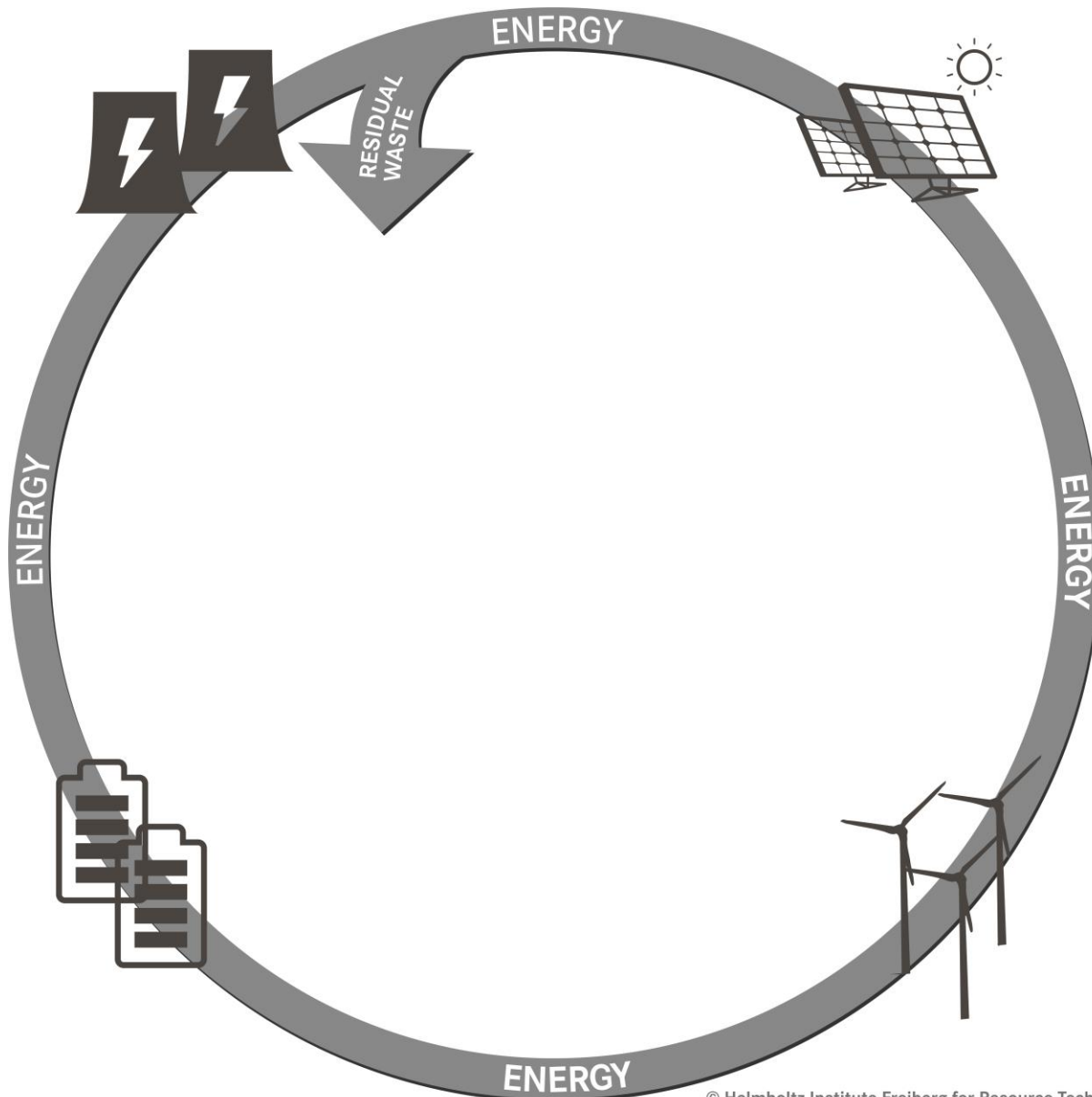
From: M.A. Reuter (2016): Digitalizing the Circular Economy-Circular Economy Engineering defined by the metallurgical Internet of Things- 2016 TMS EPD Distinguished Lecture Award, USA, Metallurgical Transactions B (<http://link.springer.com/article/10.1007/s11663-016-0735-5>).

Prof. Dr. Dr. h.c. Markus A. Reuter

Helmholtz Institute Freiberg for Resource Technology | www.hzdr.de/hif



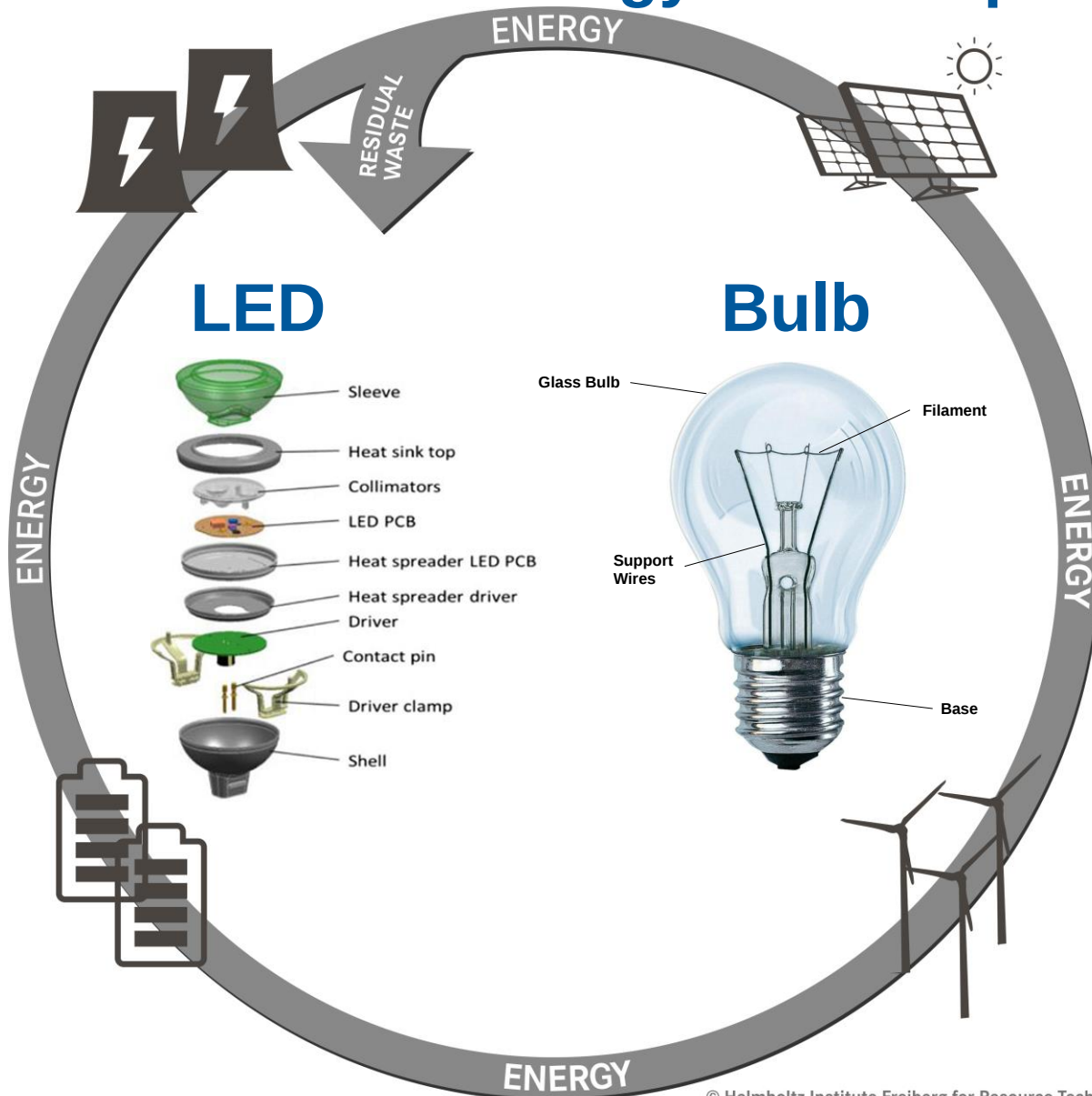
Energy system often considered separately...



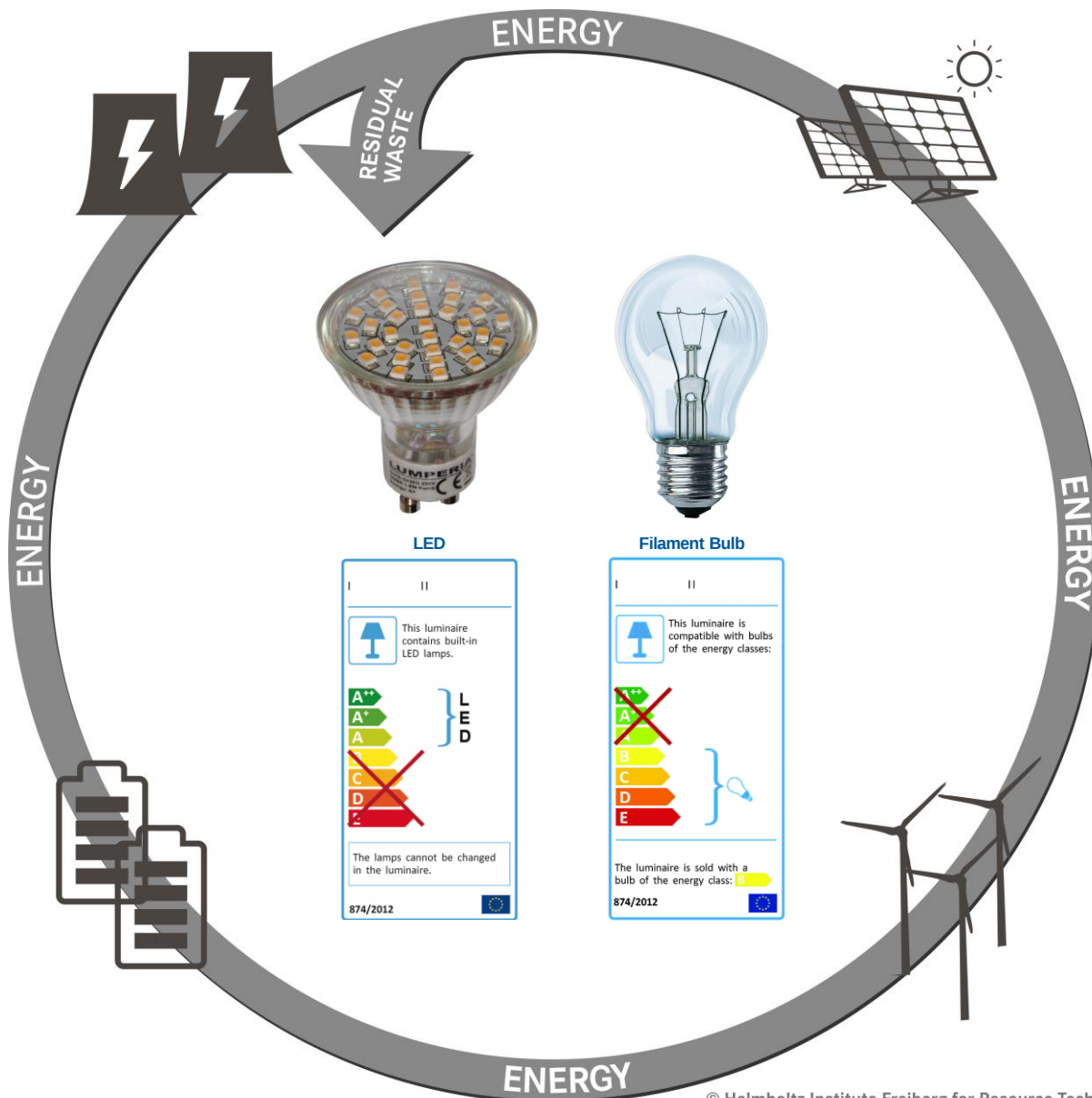
We talk about energy efficiency...



Forgotten is the complexity of renewable energy systems + embodied energy and footprint...



Which is more resource efficient?



How does complexity affect resource efficiency?

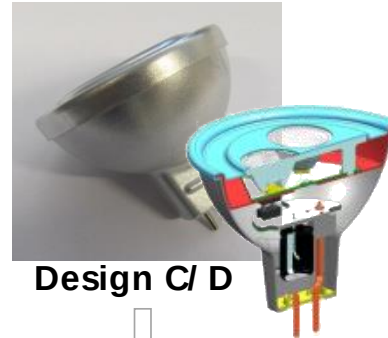
Different LED lamp (Re) Designs



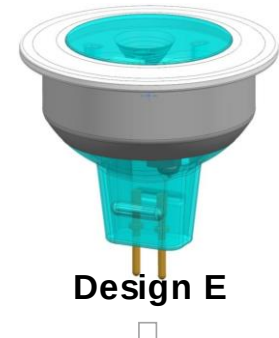
Design A



Design B



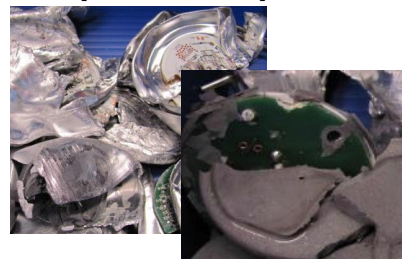
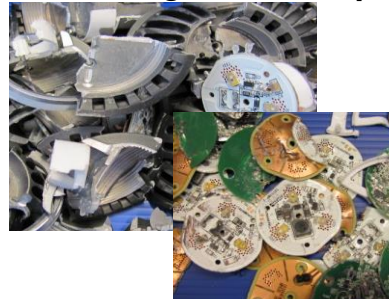
Design C/ D



Design E



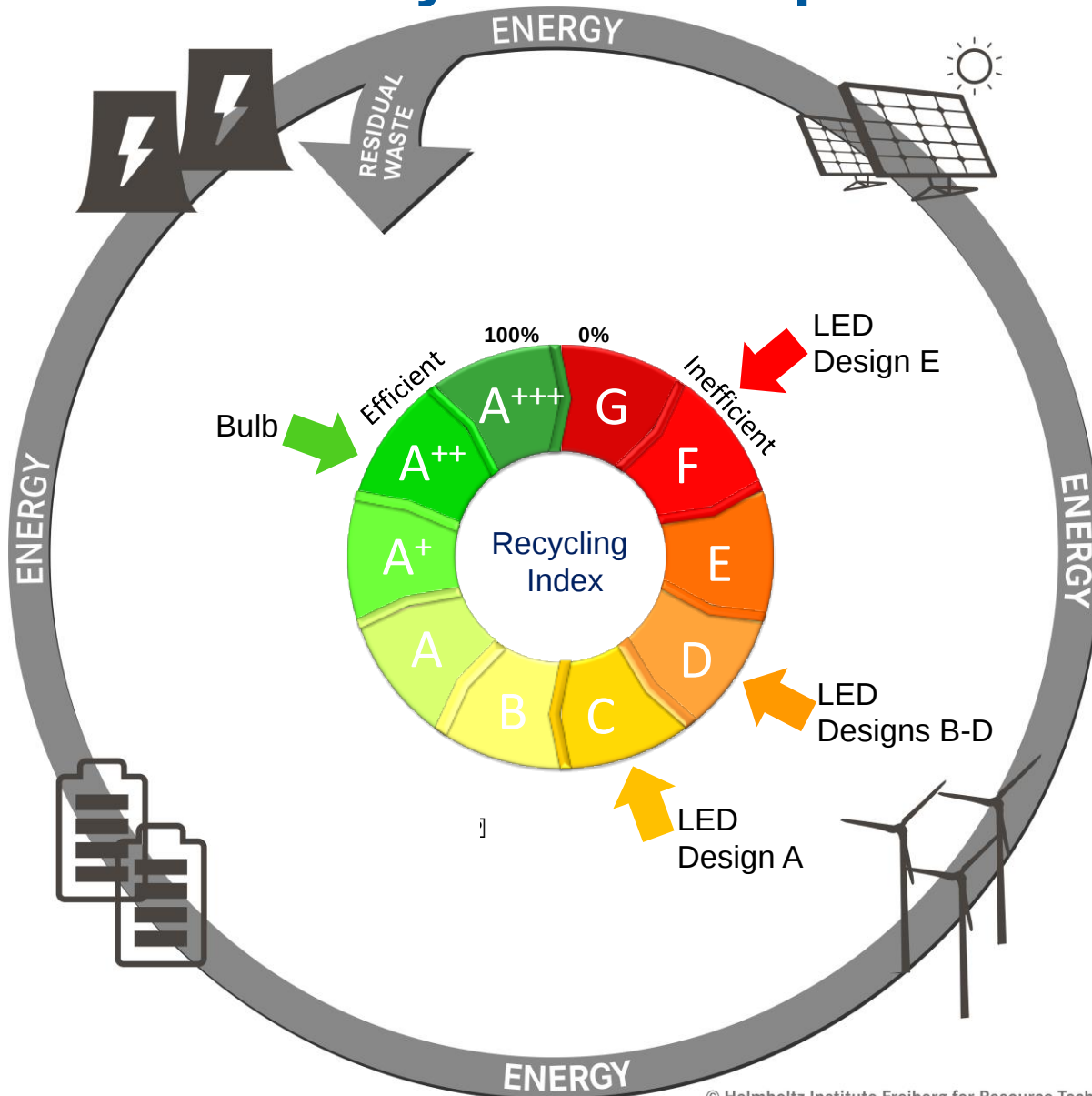
Particle/ fragment composition (liberation) after shredding



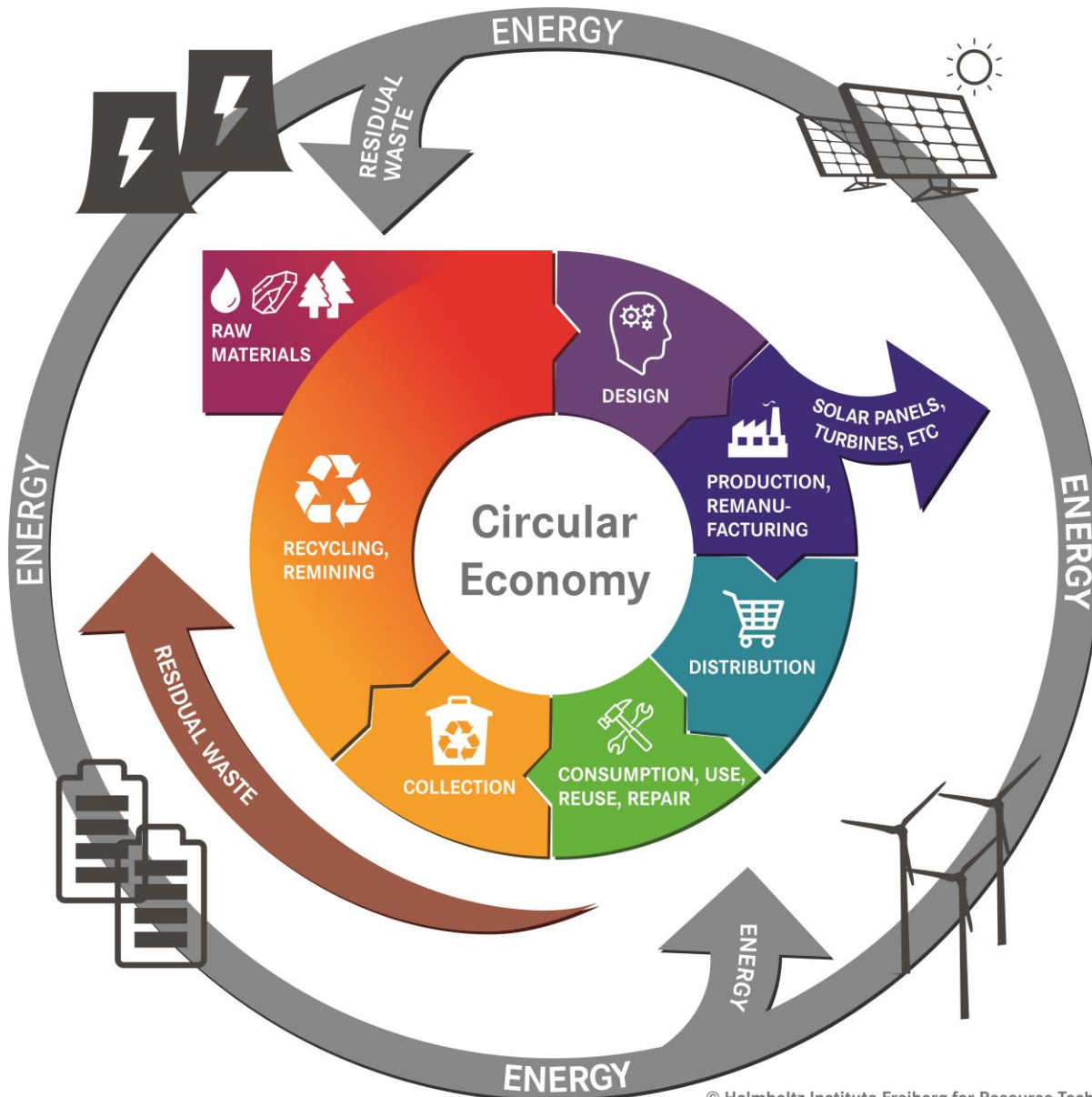
Different recyclates from LED lamp recycling : Ferrous, PCBA/ metal rich, plastics, aluminium



...and ultimately also how much material can truly flow back into the system to improve RE?

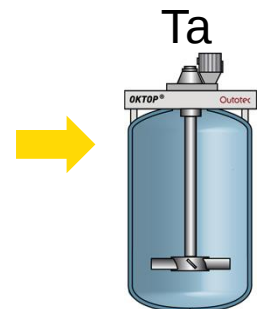
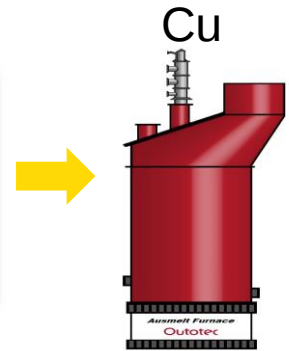
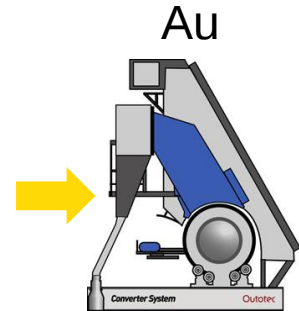
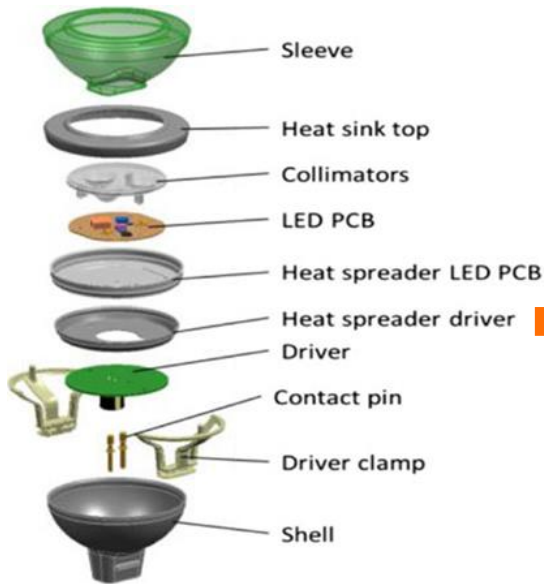


Linking resources, materials & energy systems!



So how do we optimize the “urban mine”?

(Geo)Metallurgy a key to the system?



Circular Economy Engineering – The tools...

HSC Chemistry 9

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Aqu
Aqueous Solutions

Bal
Heat & Material Balance
Energy

EpH
Eh-pH Diagrams

Est
H, S and Cp Estimates

Mas
Mass Balances

Mea
Measure Units

Ben
Benson Estimation

Con
Species Converter

Exe
Energy Balance
Exergy

Gem
Equilibrium Compositions

Rea
Reaction Equilibrium
Thermodynamic

Sam
Sampler Module

Dat
Data Processing

DB
H, S and Cp Database

Geo
Mineral Database
MLA

HTr
Heat Loss Calculator
Simulation

Sim
Flowsheet Simulation
Simulation

Tpp
Stability Diagrams

Dia
H, S, Cp and G Diagrams

Ele
Periodic Chart

Lpp
Stability Diagrams

Map
Material Stock

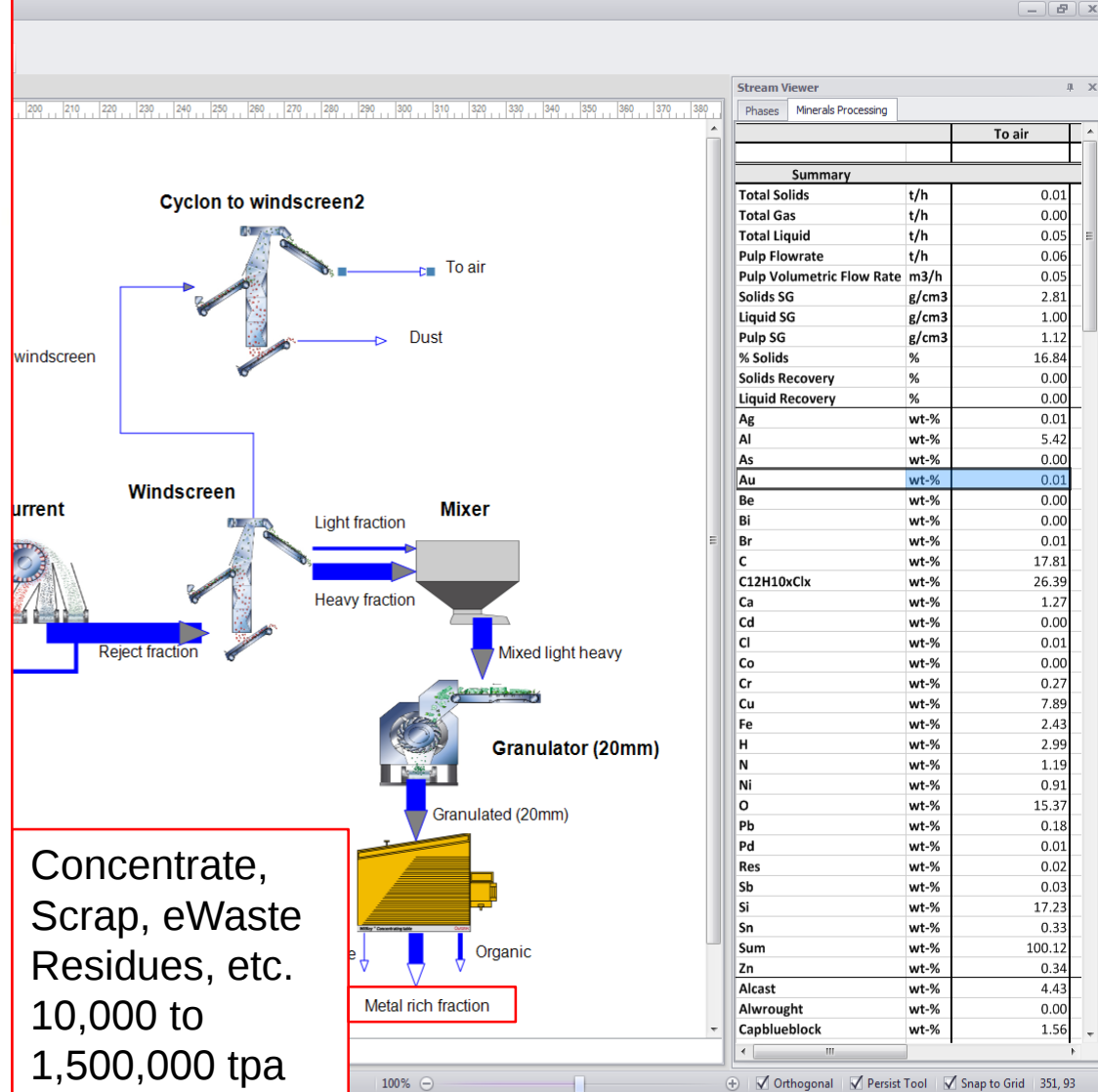
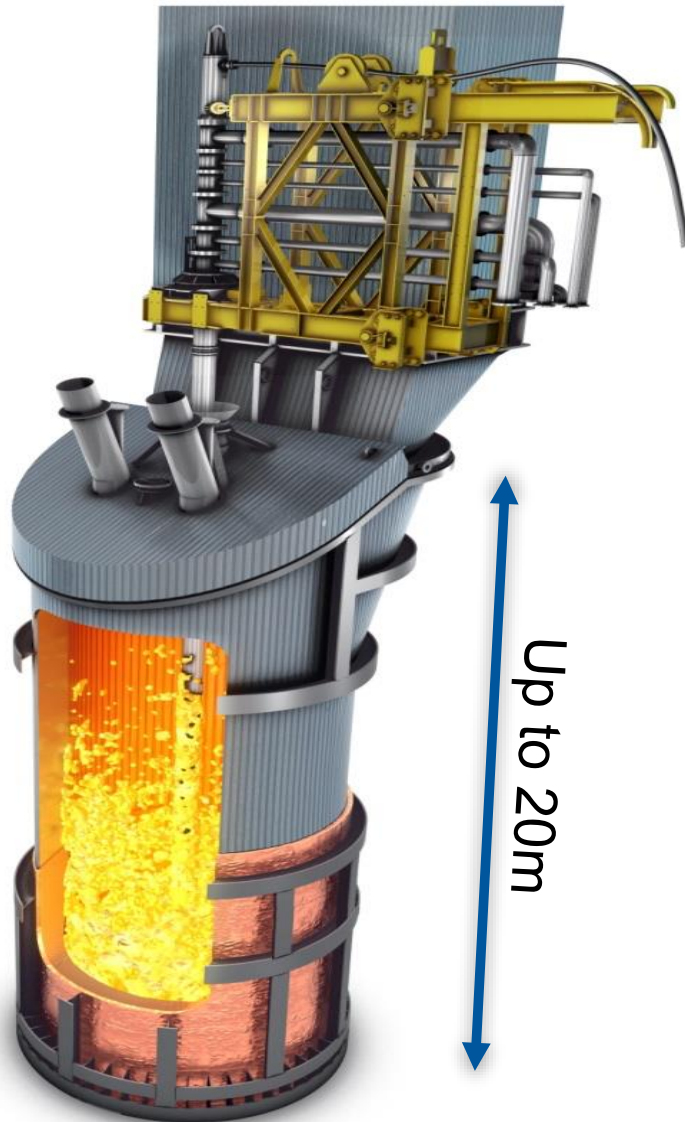
Wat
Water Calculator

?
Help Module

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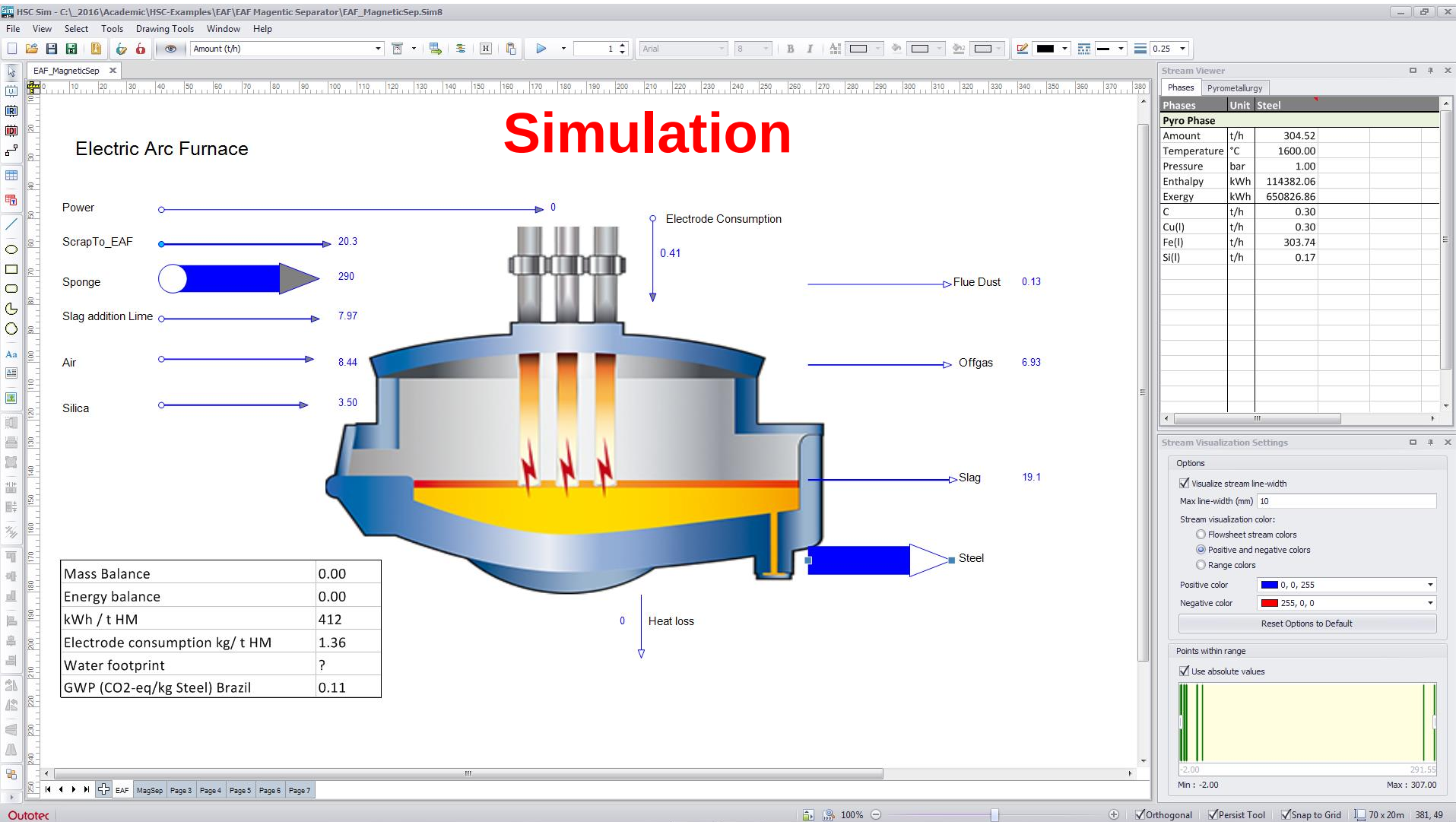
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Circular Economy Engineering – The tools...

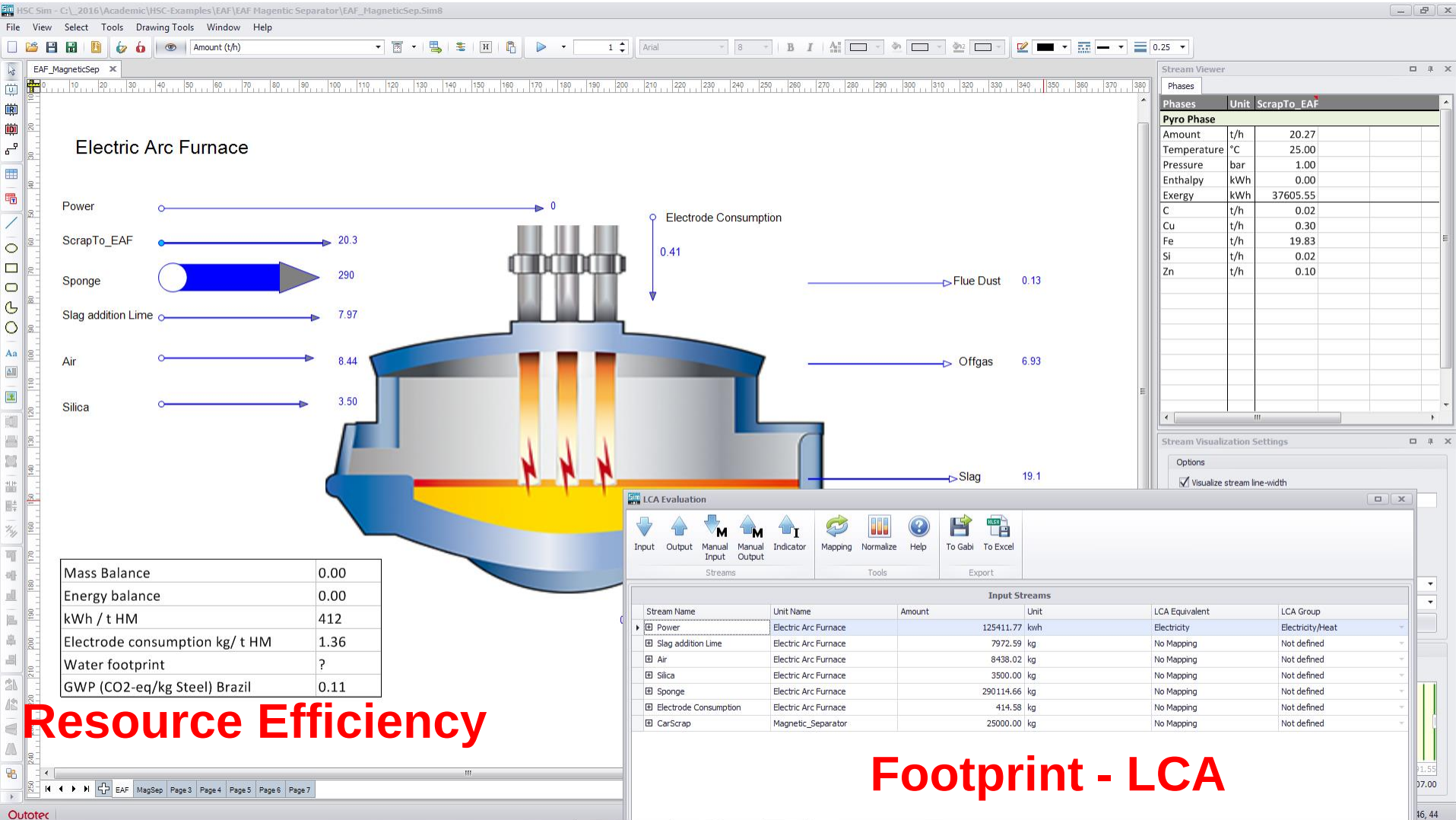


Stream Viewer		
Phases Minerals Processing		
		To air
Summary		
Total Solids	t/h	0.01
Total Gas	t/h	0.00
Total Liquid	t/h	0.05
Pulp Flowrate	t/h	0.06
Pulp Volumetric Flow Rate	m3/h	0.05
Solids SG	g/cm3	2.81
Liquid SG	g/cm3	1.00
Pulp SG	g/cm3	1.12
% Solids	%	16.84
Solids Recovery	%	0.00
Liquid Recovery	%	0.00
Ag	wt-%	0.01
Al	wt-%	5.42
As	wt-%	0.00
Au	wt-%	0.01
Be	wt-%	0.00
Bi	wt-%	0.00
Br	wt-%	0.01
C	wt-%	17.81
C12H10xClx	wt-%	26.39
Ca	wt-%	1.27
Cd	wt-%	0.00
Cl	wt-%	0.01
Co	wt-%	0.00
Cr	wt-%	0.27
Cu	wt-%	7.89
Fe	wt-%	2.43
H	wt-%	2.99
N	wt-%	1.19
Ni	wt-%	0.91
O	wt-%	15.37
Pb	wt-%	0.18
Pd	wt-%	0.01
Res	wt-%	0.02
Sb	wt-%	0.03
Si	wt-%	17.23
Sn	wt-%	0.33
Sum	wt-%	100.12
Zn	wt-%	0.34
Alcast	wt-%	4.43
Alwrought	wt-%	0.00
Capblueblock	wt-%	1.56

Resource efficiency of industrial systems



Resource efficiency of industrial systems



Resource efficiency of industrial systems - Copper

General system boundaries for case study

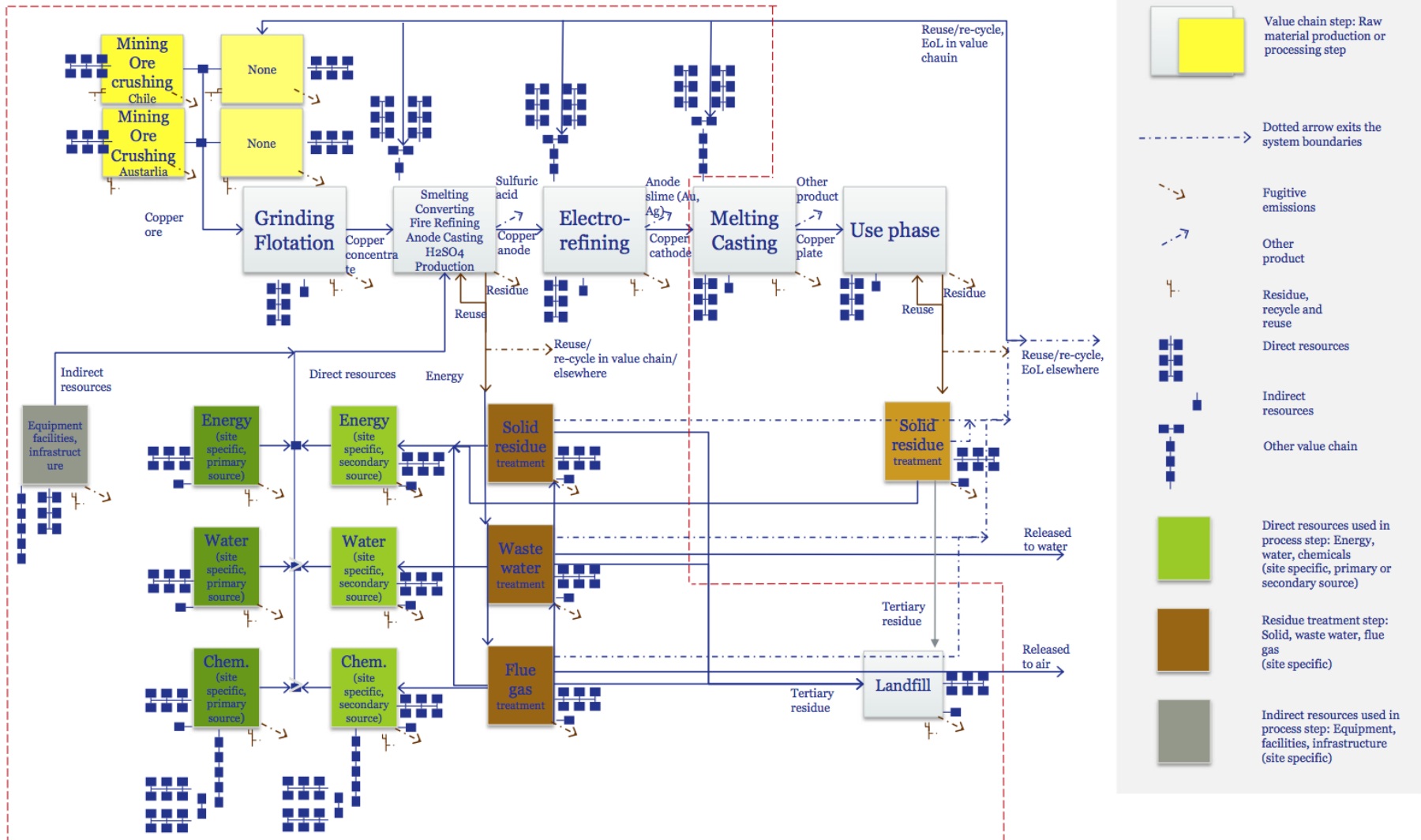
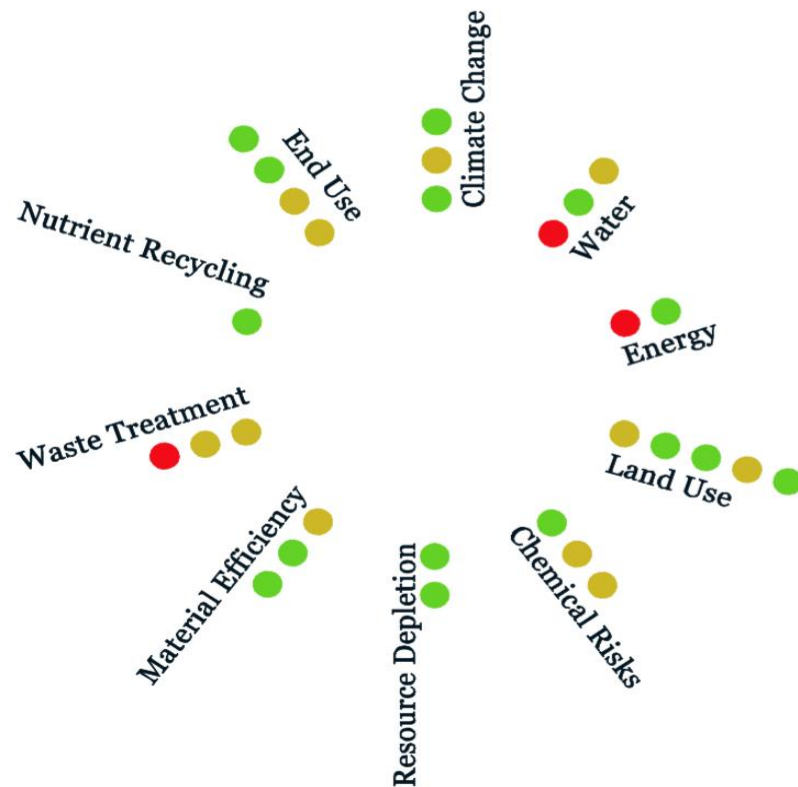


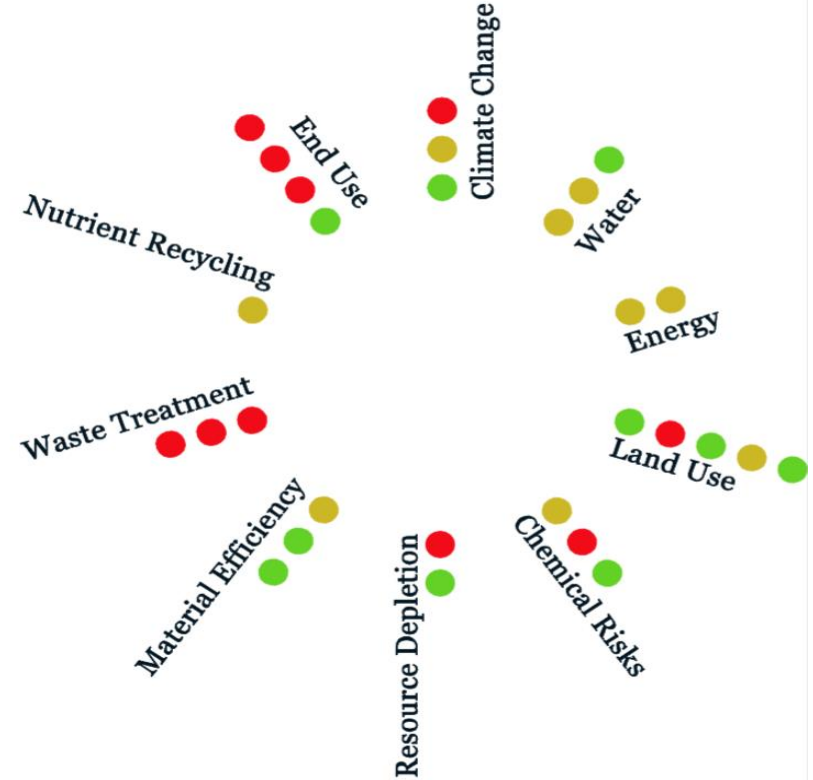
Fig. 1 The scope of the analysis is signified by the *golden dashed line*

Quantifying Resource Efficiency

Footprint of industrial solutions relative to baseline



Copper System 1

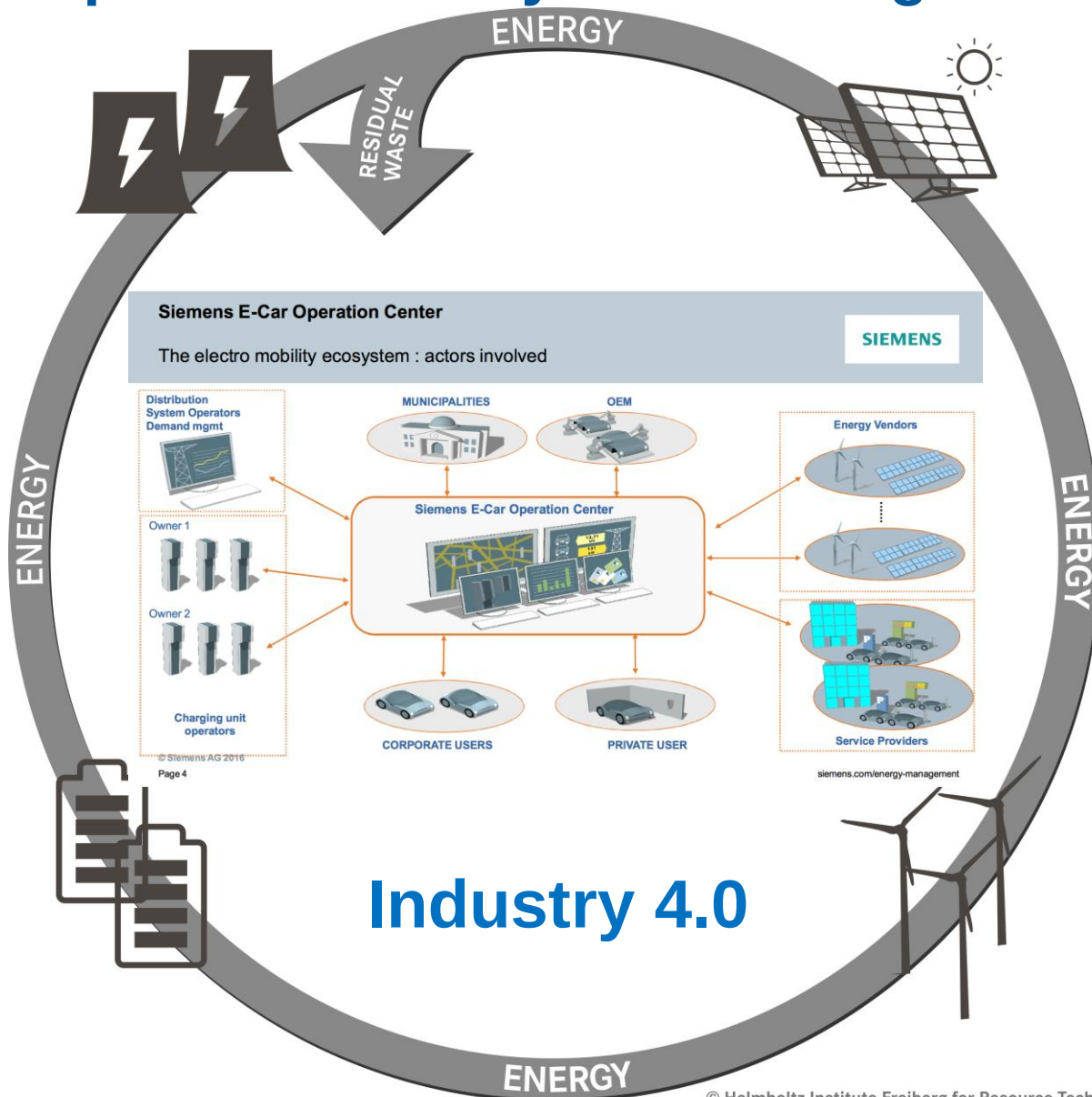


Copper System 2

- Potential competitive advantage
- Neutral
- Potential risk

I. Rönnlund, M.A. Reuter, S. Horn, J. Aho, M. Päällysaho, L. Ylimäki, T. Pursula (2016): Sustainability indicator framework implemented in the metallurgical industry: Part 1-A comprehensive view and benchmark, Part 2-A case study from the copper industry, [International Journal of Life Cycle Assessment](#) (online).

Has anybody spoken about the footprint & embodied energy impact of Industry 4.0? Ecological break-even?



Circular Economy: Optimizing Resource Efficiency

