Review of Metal Recycling

End-of-Life Products, Residues, Wastes, Slags, Design for Sustainability, Eco-Labeling

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Outotec

Sustainable use of Earth's natural resources

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Outotec in Brief

- **Ranked Globally 12th most Sustainable Corporation**
  http://corporateknights.com/report/9th-annual-global-100
- **Knowledge in the processing of >60 elements**
- **>130 Non-ferrous smelters (58 Flash, 56 TSLs, 17 Kaldo)**
  - 2013 Flash Milestones
    - Tongling>400,000tpa & Fanchenguang>400,000tpa
  - ca. world 50% Cu , >30% Sn in TSL , large % PGM matte converting (AngloPlatinum)
- **650 sulfuric acid plants**
  - World's largest metallurgical based, Zambia and largest in Ma'aden
- **Minerals Processing / Hydrometallurgy**
  - 1100 grinding mills
    - 28MW worlds' largest saving around 15% energy
  - >10000 flotation units (reaching 500m^3)
  - 1800 thickeners / >3500 filters
- **Ironmaking and Ferroalloys**
  - 20 pelletizing and sintering plants for chromites (ferroalloys),
  - 13 ferroalloy smelters
  - 340 iron ore sintering plants
  - 93 iron ore pelletizing plants
- **Light metals / Roasting / Waste to Energy**
  - 290 fluidized bed roasting plants / alumina calcining

Grinding mills
LKAB Sweden

World's largest pellet plant (7.5 million tpy) Samarco; Brazil

Xiangguang Copper highest environmental award for its smelter project from the Chinese Government.

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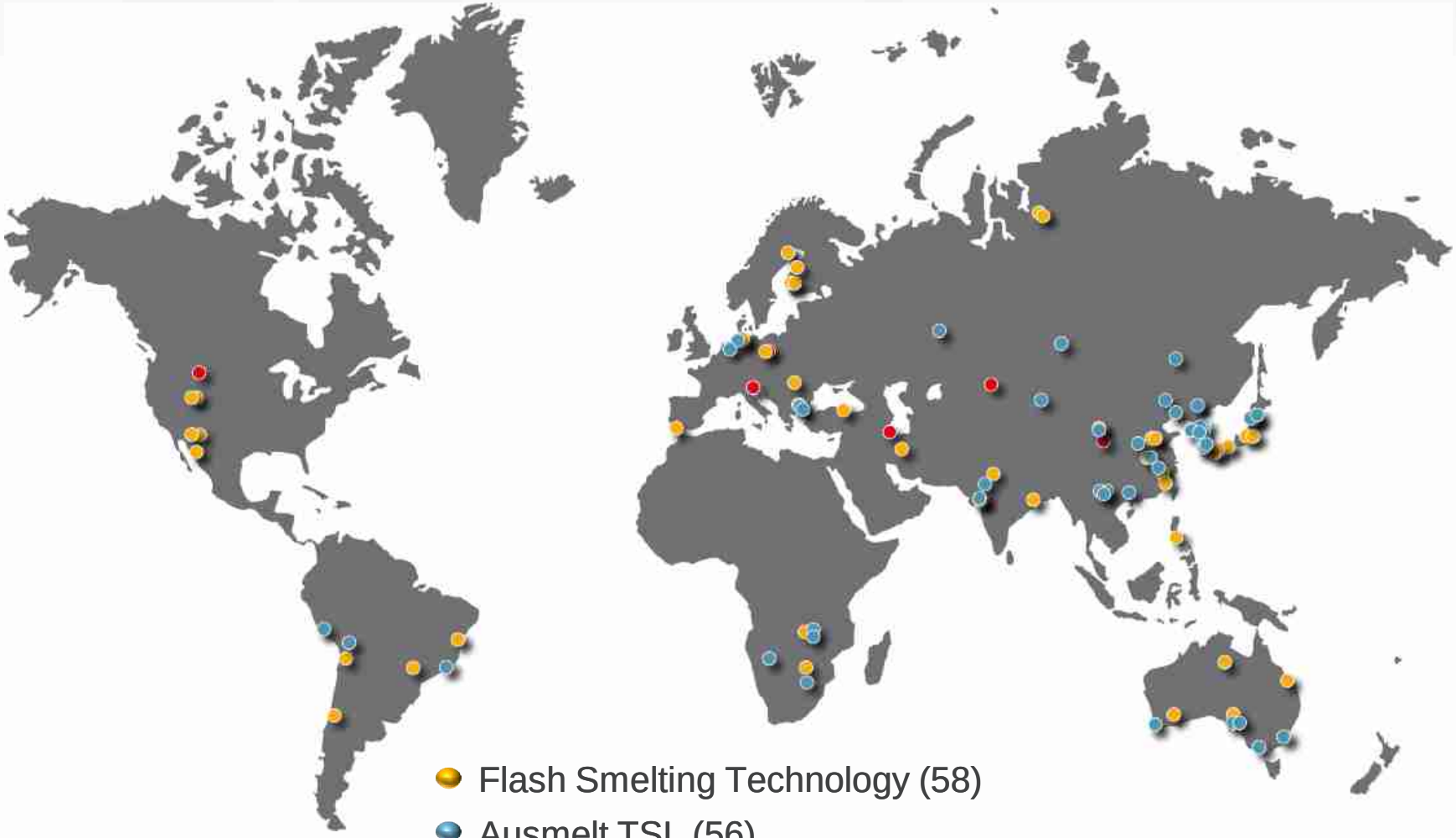
Resource Efficient Metal Production

More than 130 Outotec smelters around the world



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To achieve Resource Efficiency…

- **Mineral Processing and Metallurgy – Foundation**
  - The link Minerals to Metal has been optimized through the years including economic and technological consideration and a deep physics understanding of various processes.
  - There is a good understanding between all actors from rock to metal – also an understanding of slag chemistry.
- **Product Centric vis-à-vis Metal Centric Recycling**
  - Designer Minerals (e.g. cars, mobiles etc.) are far more complex than geological minerals; complicating recovery, requires rigorous system design taking all elements into consideration.
  - To “close” the loop requires a deep understanding and harmonization between all actors of the system than is the case presently.
  - Slag valorization, recovery of elements from it and understanding its properties is crucial for Product Centric recycling.
- **UNEP report on recycling with above message to appear April 24th 2013.**

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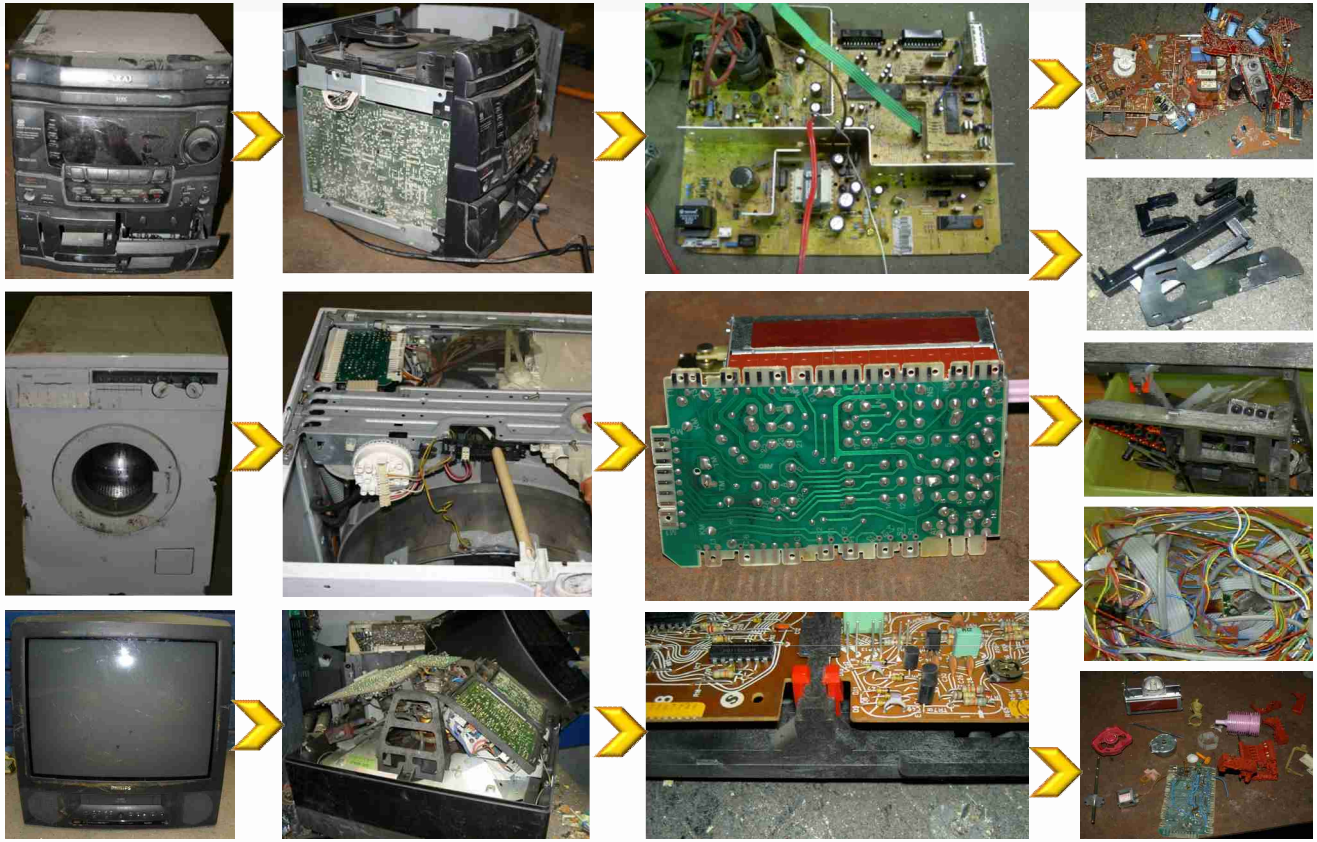
Geological *vis-à-vis* Urban Mine "Minerals"

"Mineral Centric" from classical mining equivalent to "Product Centric" in Urban Mining

Chalcopyrite $CuFeS_2$

and

>20 minors e.g. Au, As, Ag, Se etc.



Material combinations and Designed Consumer "Minerals"

Material connections

Joined Materials

Designer Copper "Minerals"

>40 elements complexly linked

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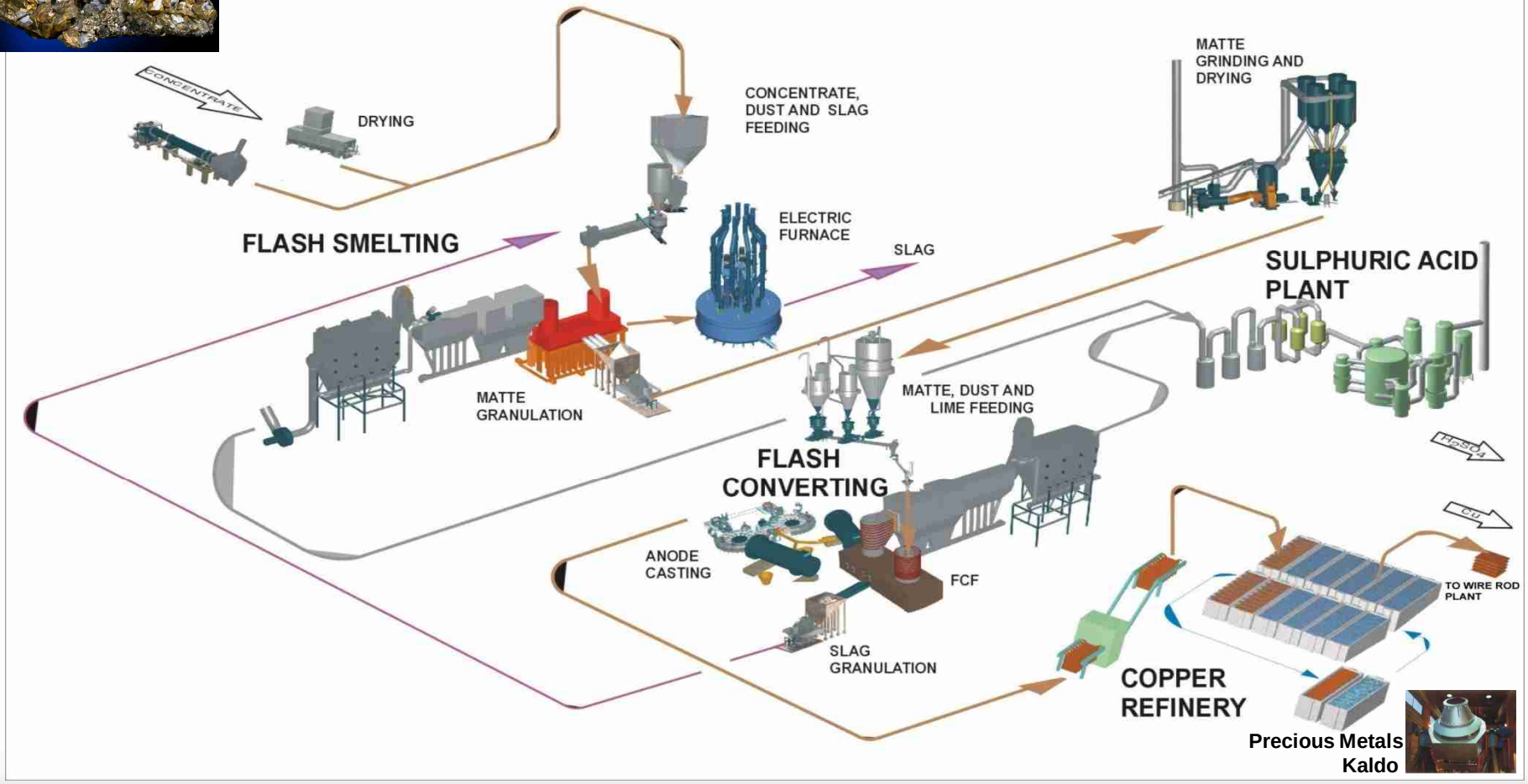
State-of-Art Copper Smelters (>400,000 tpa)

Design for Sustainability, it is happening already through Outotec…



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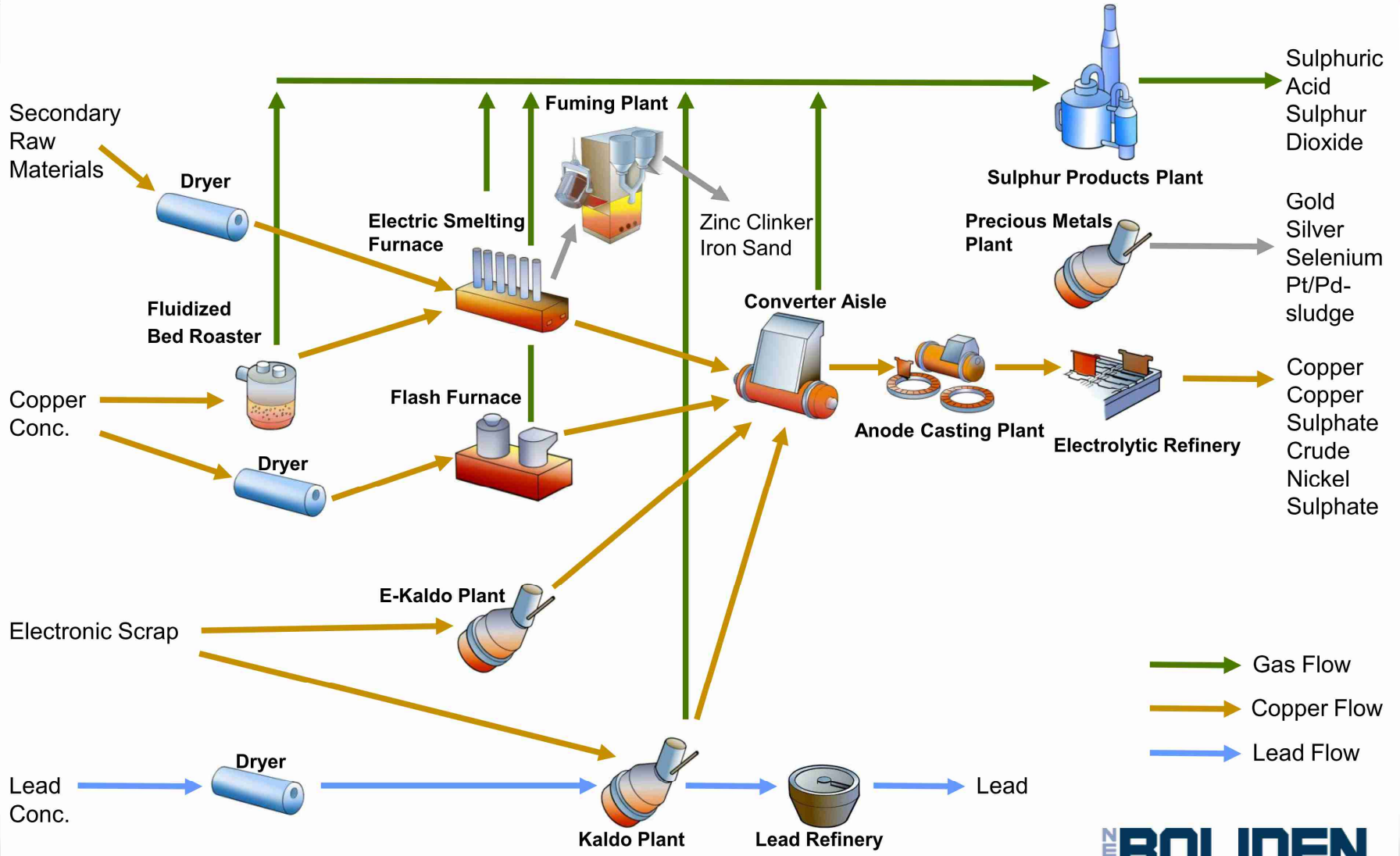
State-of-Art Copper Smelters



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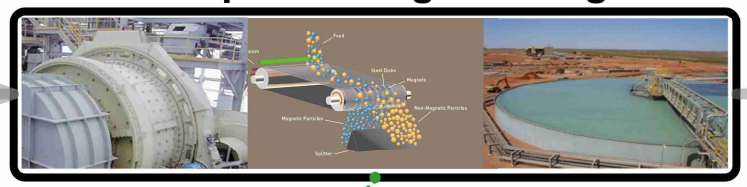
Resource Efficient Metal Production

Economic and multi-physics understanding key to "closing" loop

Pre-processing / Sorting



Resources
Materials

Residues / Sludges / Plant Footprint
Water / Energy / Materials

Metals & Materials in Consumer Products

EoL Scrap
Consumer
Production
Intermediates
Legislation

Resource Efficiency
Product Centric Metal & Material Production System

Environment: Maximize Resource Efficiency - Energy, Recyclates, Materials, Water, Sludges, Emissions, Land...
by
Economic feasibility: BAT & Recycling Systems Simulation & Digitalization, Global Leader
Social - Licence to Operate: legislation, consumer, policy, competitive edge…
with
Deep Knowledge: multi-physics models used in intelligent control systems, materials science, innovative technology, product design, market, life cycle management, Design for Recycling & Sustainability...

Concentration Pre-treatment

Footprints:
Additives
Energy
Offgas
Water

Emissions / Residues / Energy / Plant Availability / Unutilized Resources / Cost & Product Driven

Recycling

Metallurgy (hydro, pyro, bio), Metals Processing, Energy Recovery

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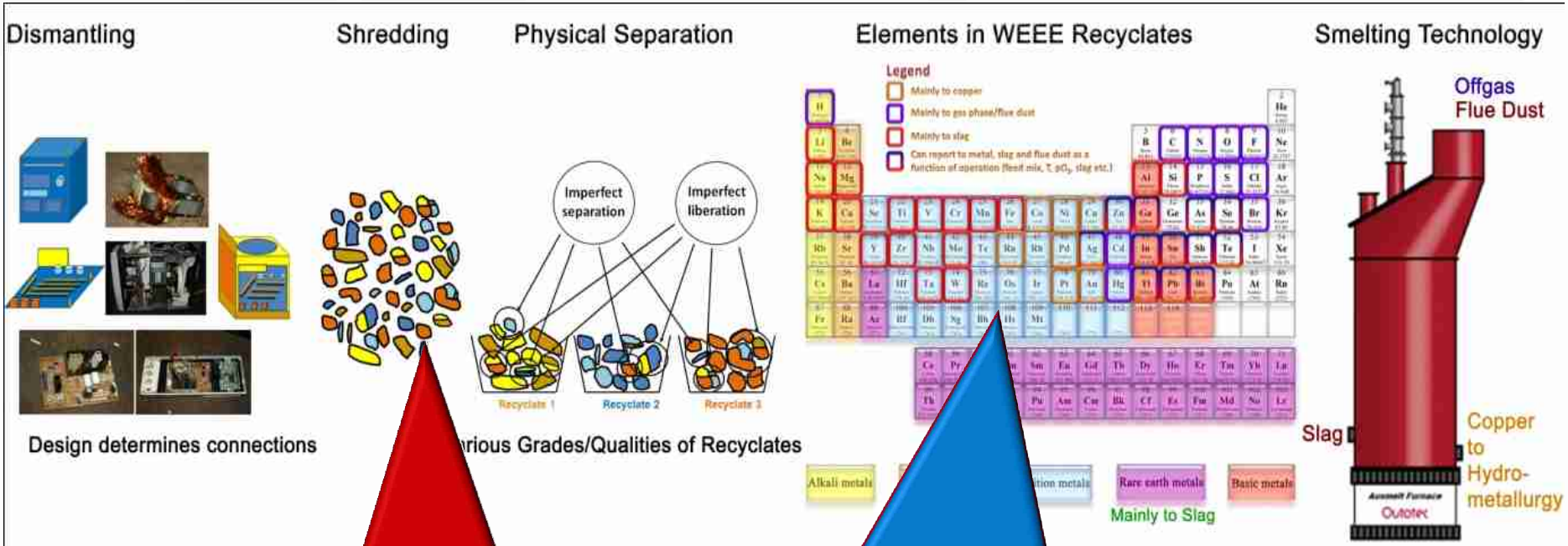
The physics and design of separation…

Understand the economics, physics…



Material Centric

Bulk recyclates well liberated with relatively little impurities – easier to recycle

Product Centric

Complex products create poorly liberated complex recyclates, these are the losses, inefficiencies, the true challenge of recycling and "closing the loop" Slag Chemistry is a Key.

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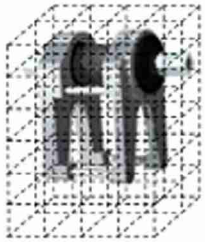
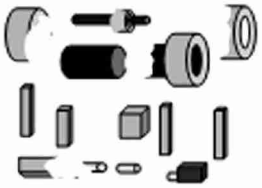
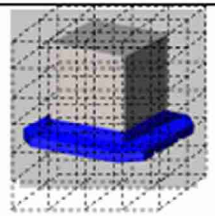
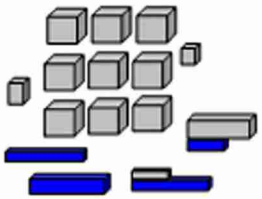
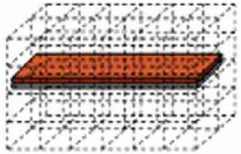
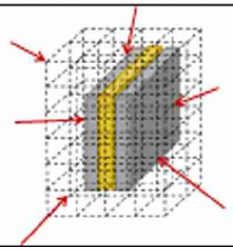
The

Dismantling

Design determines c

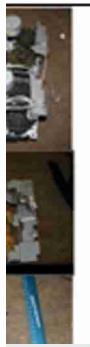
Connection types	Before shredding	After shredding	After shredding	Liberation behaviour
Bolting/riveting				• High liberation • High randomness
Gluing				• Medium liberation • Medium randomness
Coating/ Painting				• Low liberation • Low randomness of liberation
Foaming				• Medium liberation • Medium randomness

$$\frac{\mathrm{d}y^i(t)}{\mathrm{d}t} = m^i(t) - x^i(t)$$

where

$$m^i(t) = \int_{t_1=t}^{t+\Delta t} \int_{w_1}^{w_2} \int_{\mathrm{mp}_1^i}^{\mathrm{mp}_2^i} C(t_1)\mathrm{mp}^i\, h^i(w,\ \mathrm{mp}^i,\ t_1) g(t_1,\ w)\, \mathrm{d}(\mathrm{mp}^i)\, \mathrm{d}w\, \mathrm{d}t_1$$

$$x^i(t) = \int_{t_2=t}^{t+\Delta t} \int_{t_1=0}^{\mathrm{YP}} \int_{w_1}^{w_2} \int_{\mathrm{mp}_1^i}^{\mathrm{mp}_2^i} C(t_1)\mathrm{mp}^i\, h^i(w,\ \mathrm{mp}^i,\ t_1) g(t_1,\ w)\, f(t_1,\ t_2)$$



- High/medium liberation from structure
- High/medium randomness (both depending on joint type and

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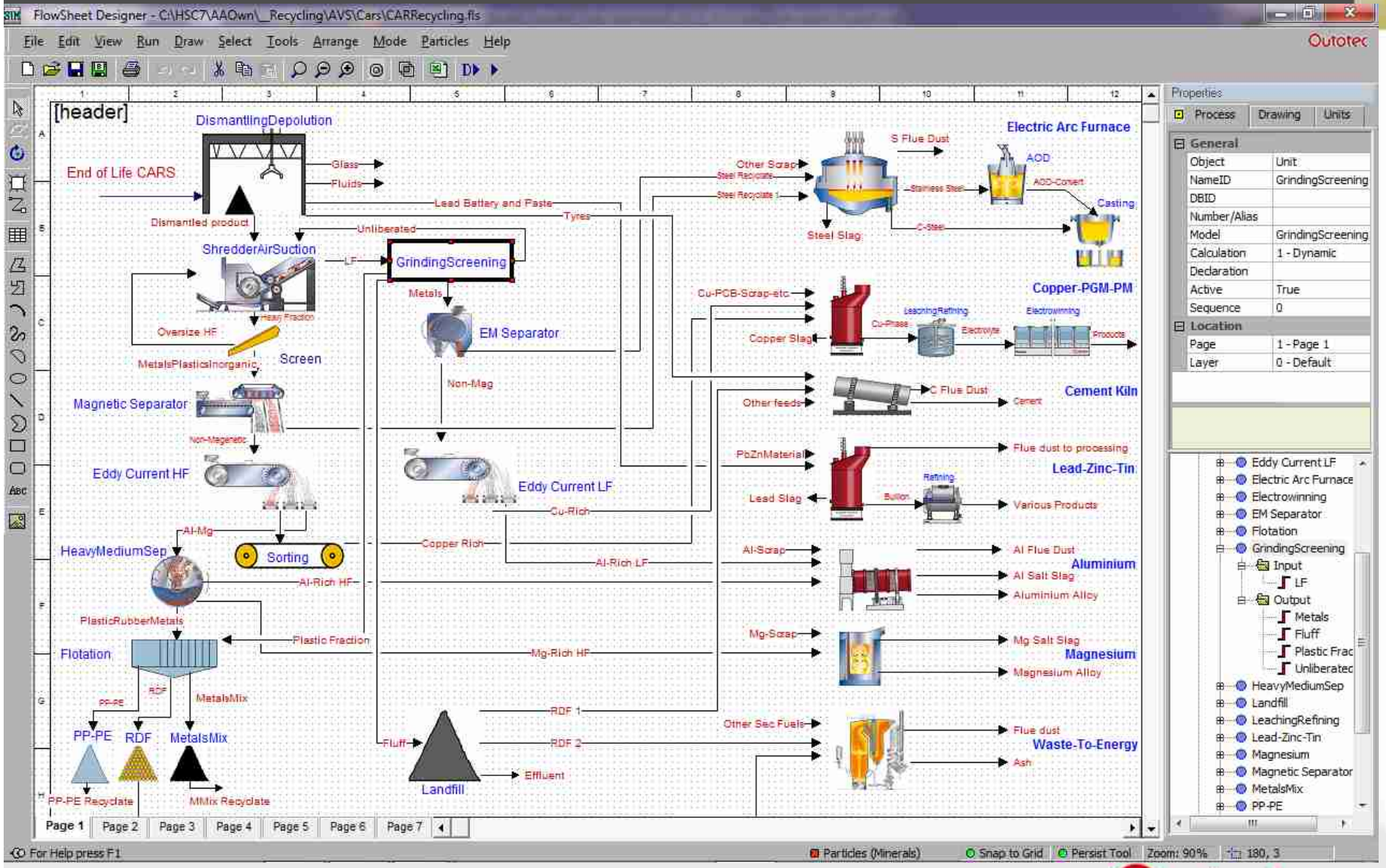
Understanding the complete system



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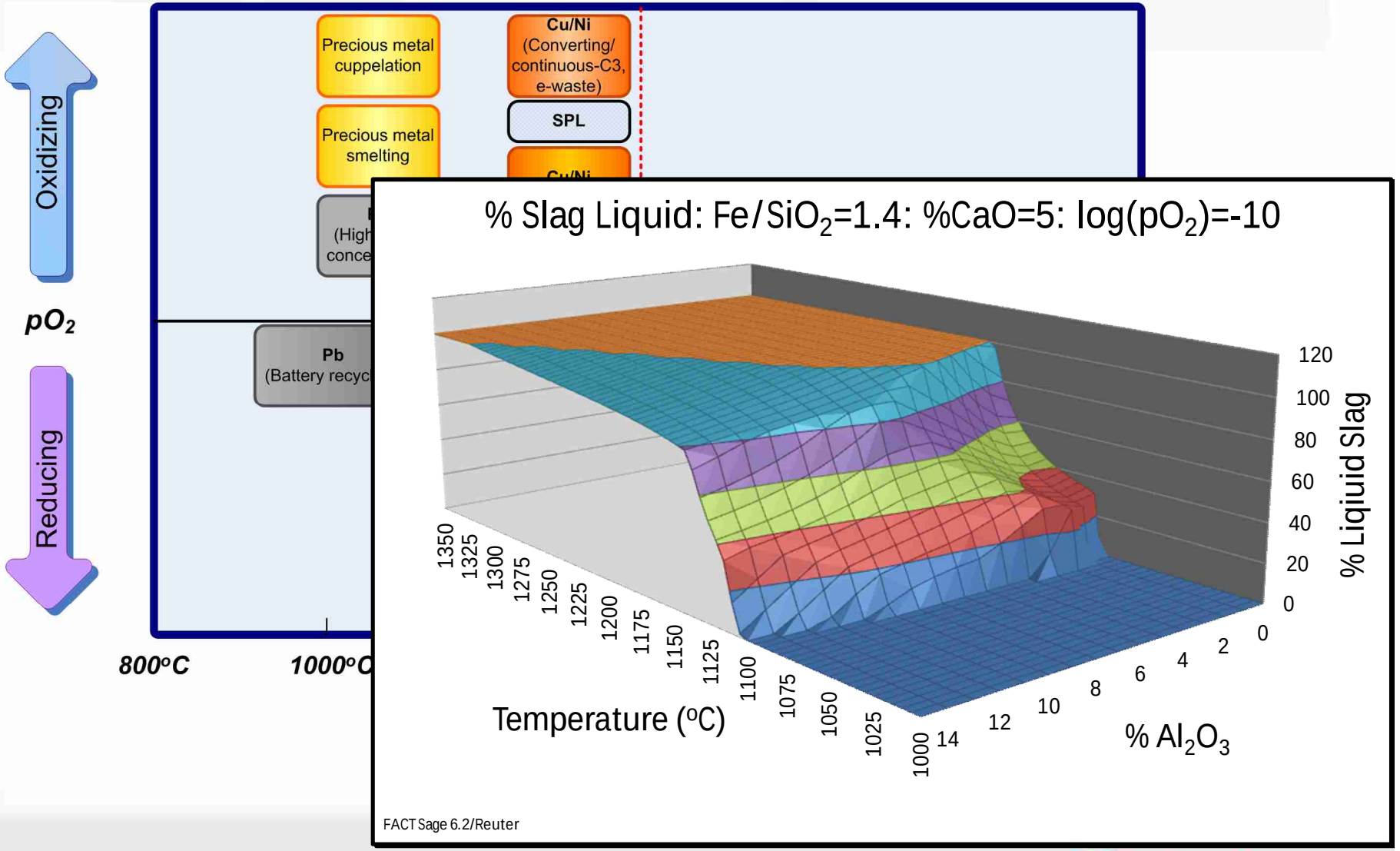
Controlling the Furnace
Controlling the slag…



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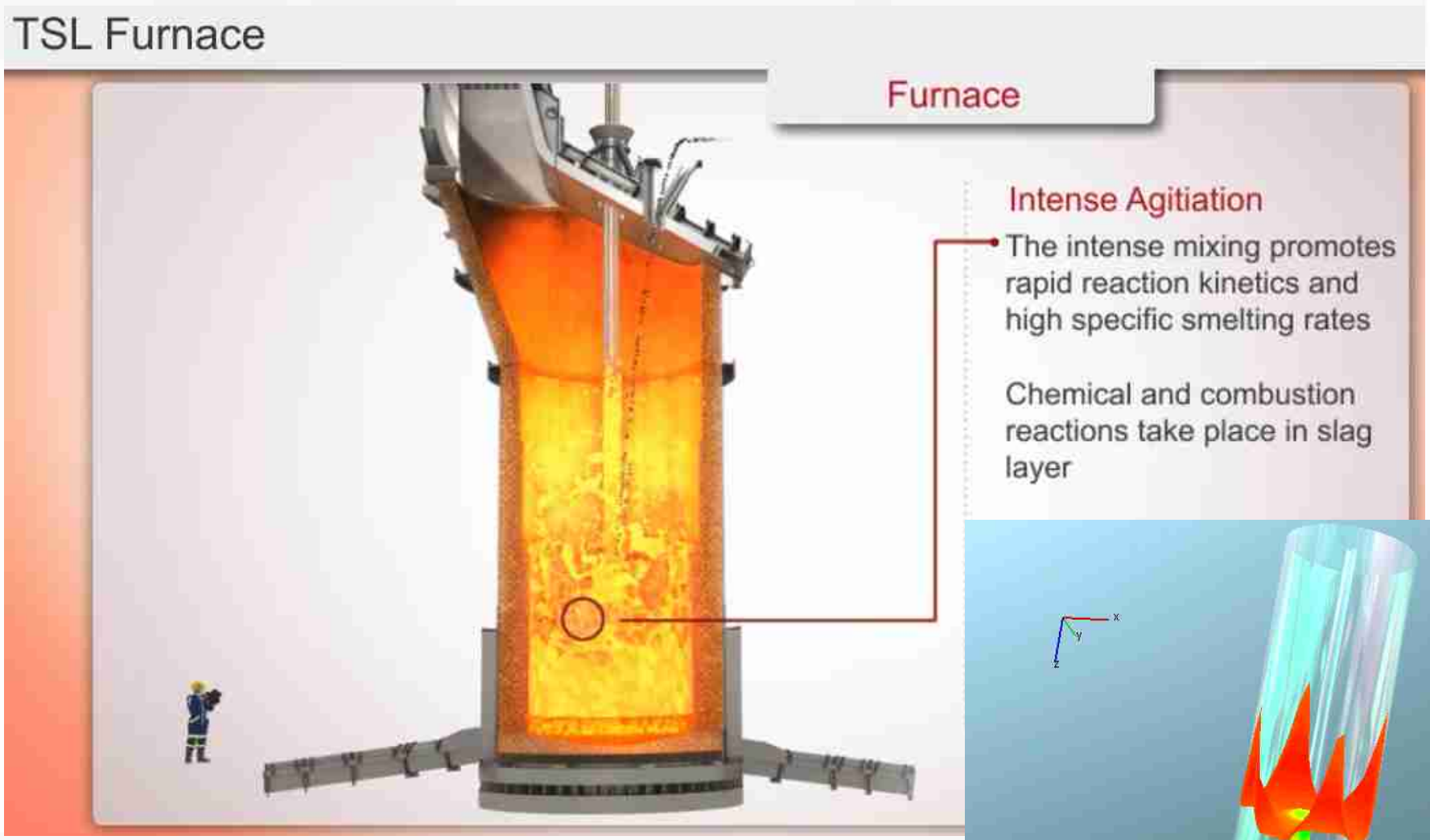
The physics and technology of separation…

Understand the physics in the context of technology and economics (Video)



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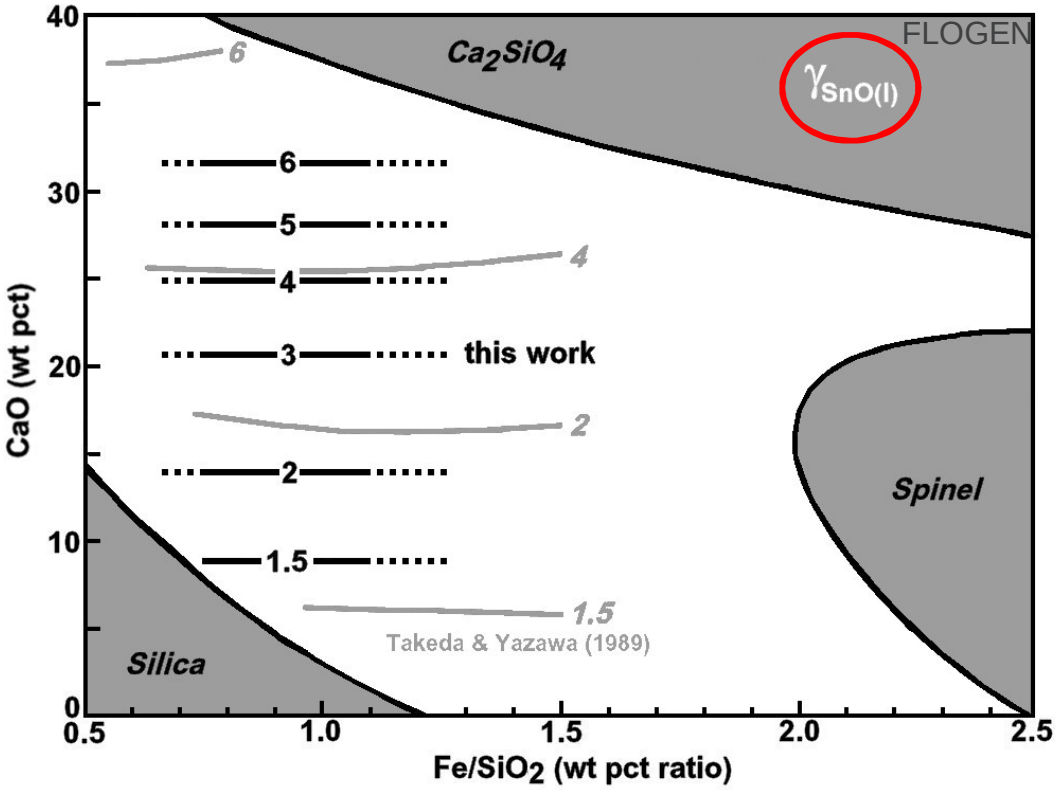
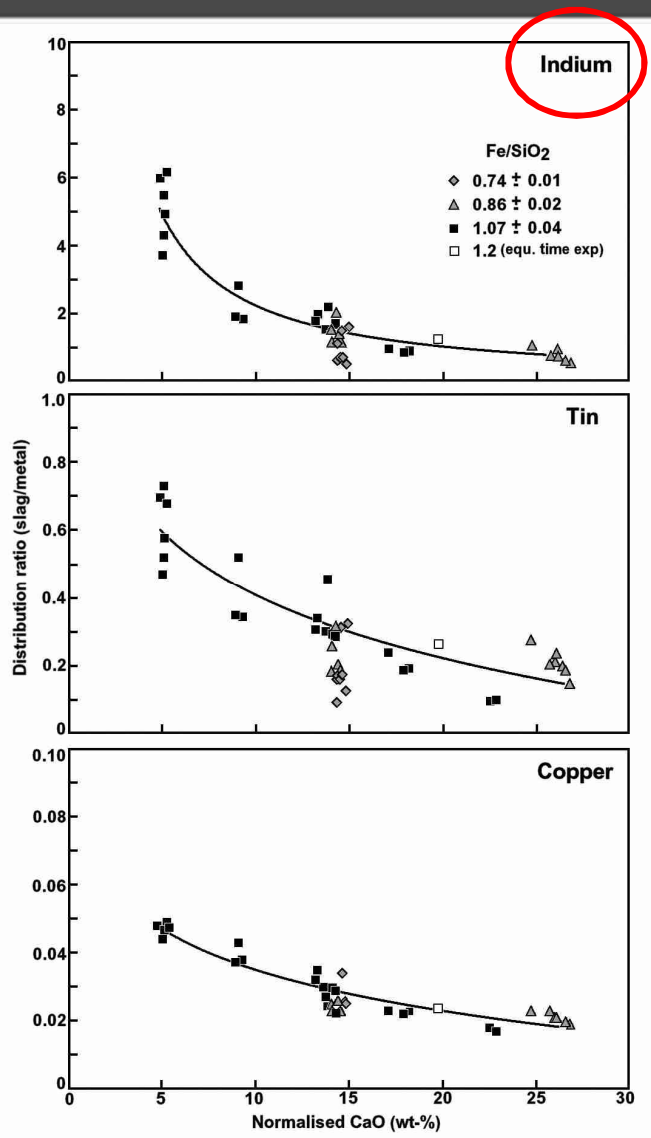
Understanding the deportation of elements

Element distributions





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Secondary Smelting Processes

E-Waste and Copper Recycling Dowa TSL (Japan)

Boliden – Rönnskår Smelter Kaldo (Sweden)

Lead Battery Recycling Recylex TSL (Germany)

Copper Recycling GRM Danyang Smelter TSL (S. Korea)

Xiangguang Yanggu Smelter Kaldo (China)

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Outotec Ausmelt TSL

- DOWA Mining
  - **Process:** E-Waste Recycling and Residue Processing
  - **Capacity:** 140,000 tpa feed
  - **Commissioned:** 2008

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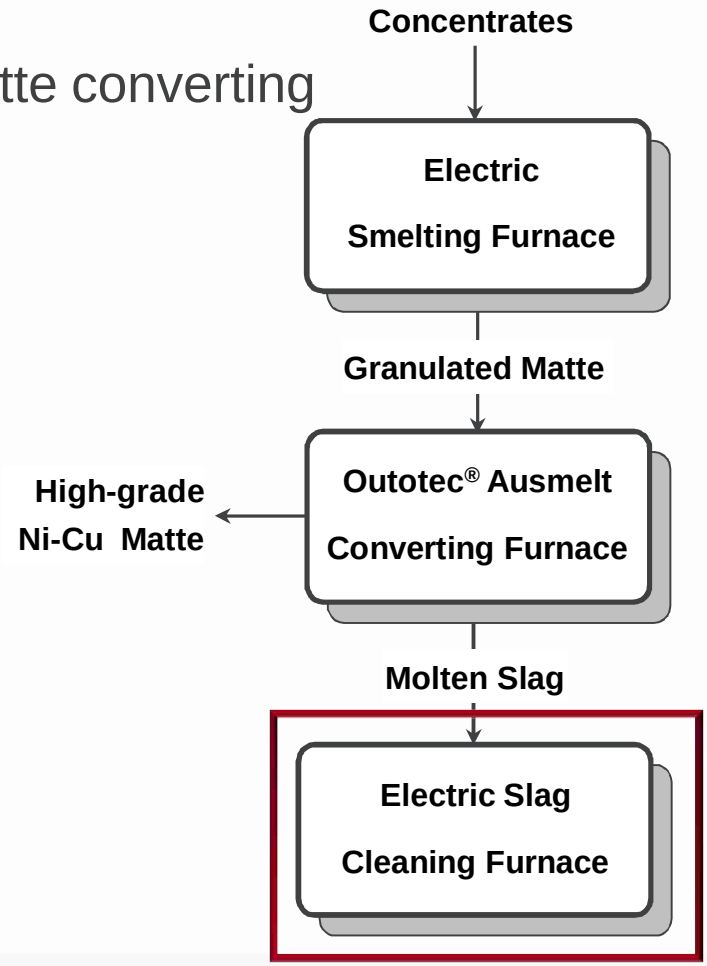
Outotec® Ausmelt Converting

- Anglo Platinum
  - **Process:** Continuous nickel-copper matte converting
  - **Capacity:** 210ktpa feed throughput
  - **Commissioned:** 2002



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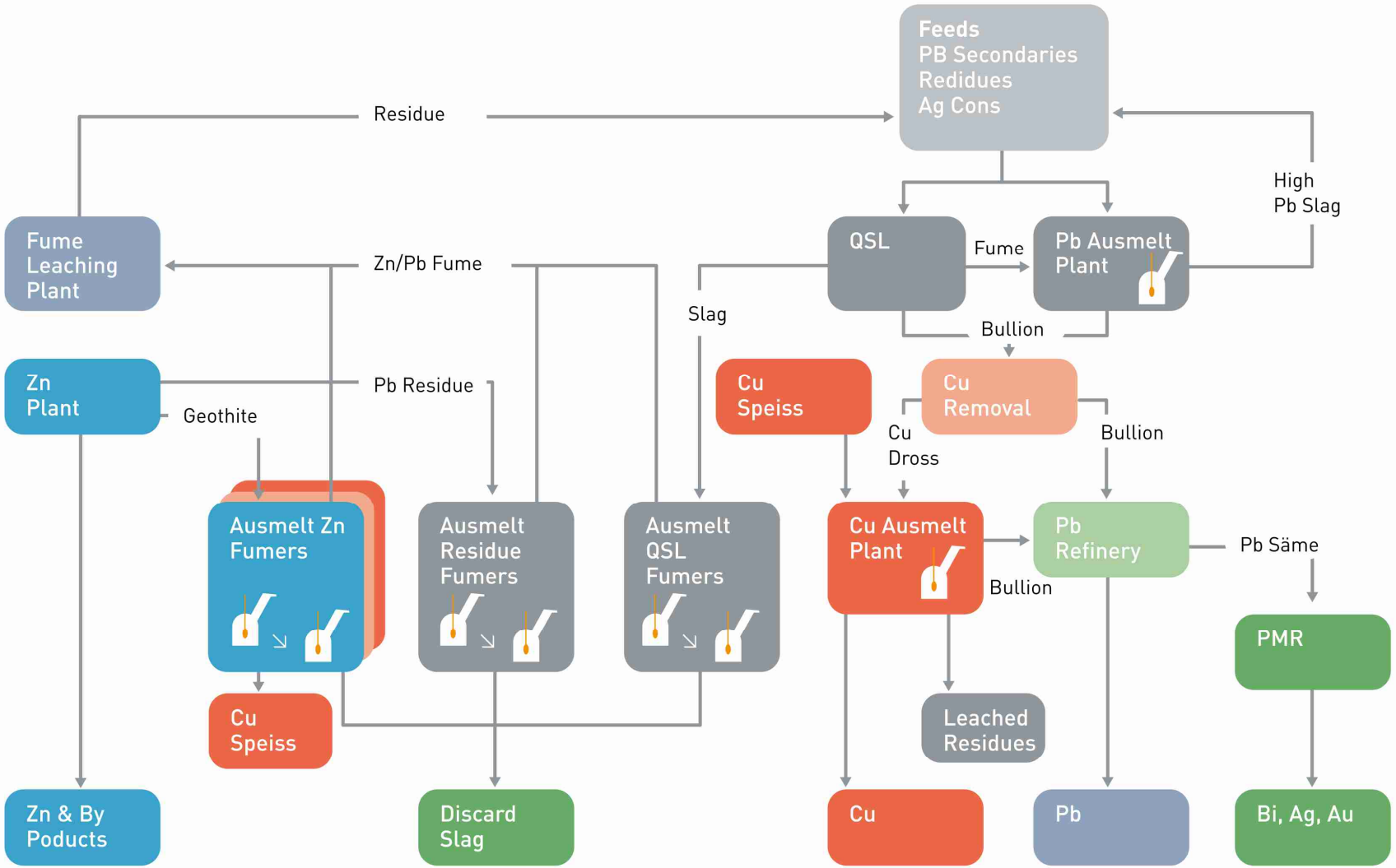
Zn Residue Processing
Korea Zinc applications of Outotec TSL Technology



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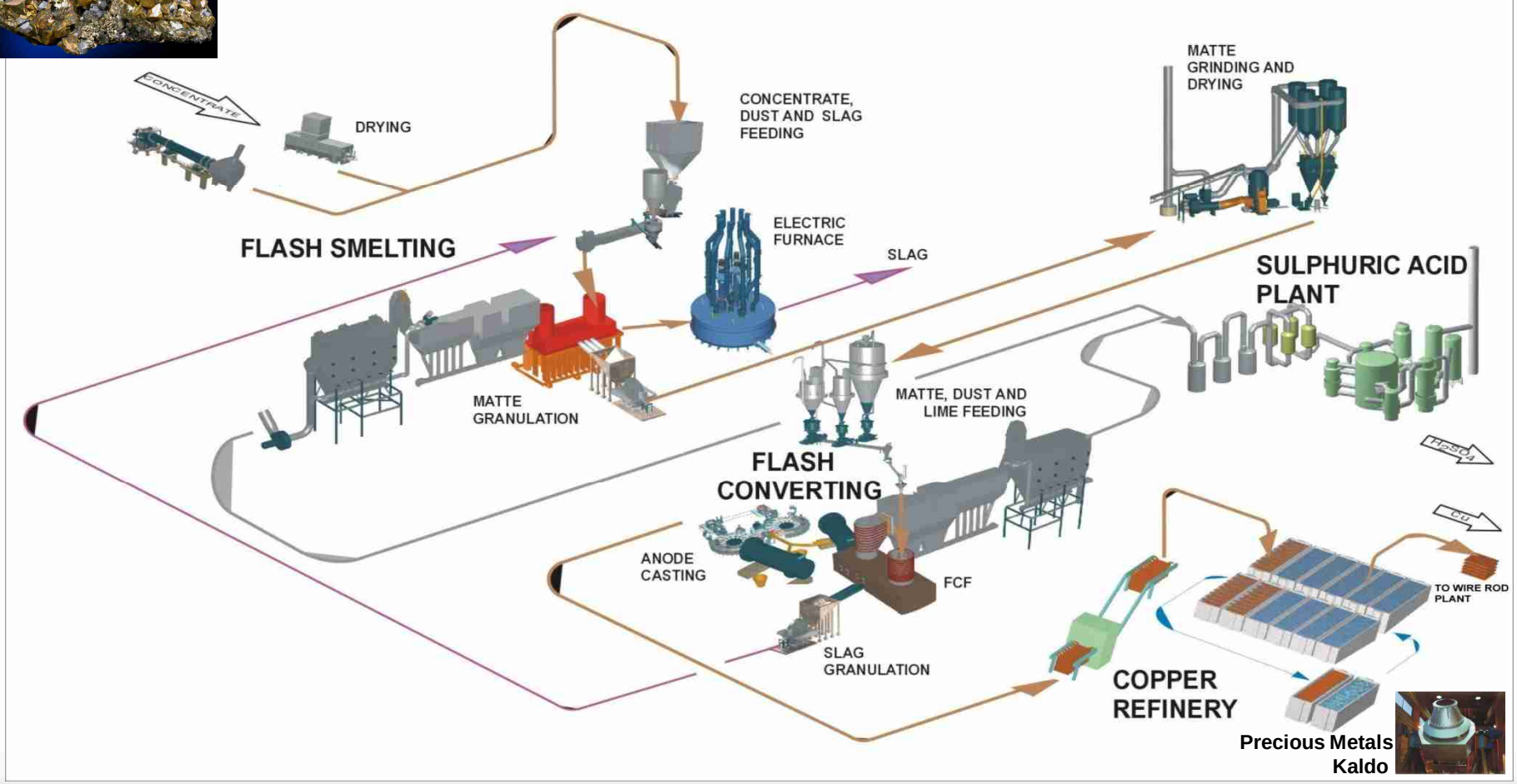
Design for Resource Efficiency



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Measuring Sustainability, Resource Efficiency

OT's HSC Sim 7.1x

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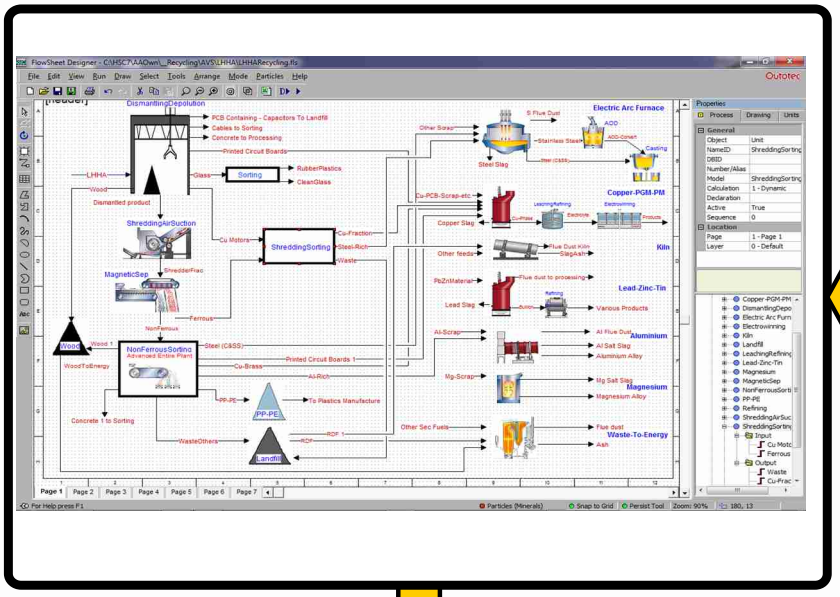
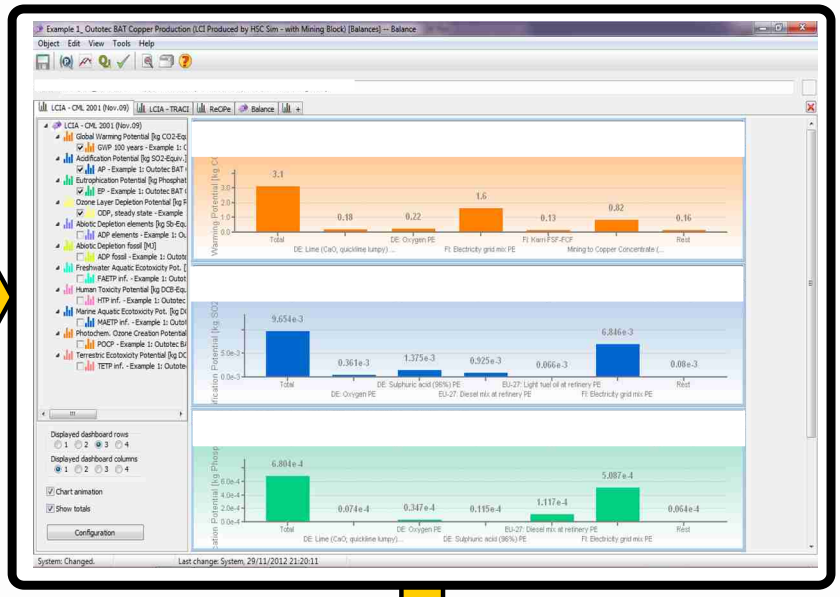


PE-International's GaBi

(www.PE-International.com)



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

$US / t Product (CAPEX & OPEX)

Recyclability Index (based on system simulation of whole cycle)

GJ & MWh / t Product (source specific) and Exergy

kg CO_2 / t Product

kg SO_x / t Product

g NO_x / t Product

m^3 Water / t Product *(including ions in solution)*

kg Residue / t Product *(including composition)*

kg Fugitive Emissions / t Product

kg Particulate Emissions / t Product

Etc.

Environmental Indicators based on BAT Driving Benchmarks of Industry

Global Warming Potential (GWP)

Acidification Potential (AP)

Eutrification Potential (EP)

Human Toxicity Potential (HTP)

Ozone Layer Depletion Potential (ODP)

Photochemical Ozone Creation Potential (POCP)

Aquatic Ecotoxicity Potential (AETP)

Abiotic Depletion (ADP)

Etc...

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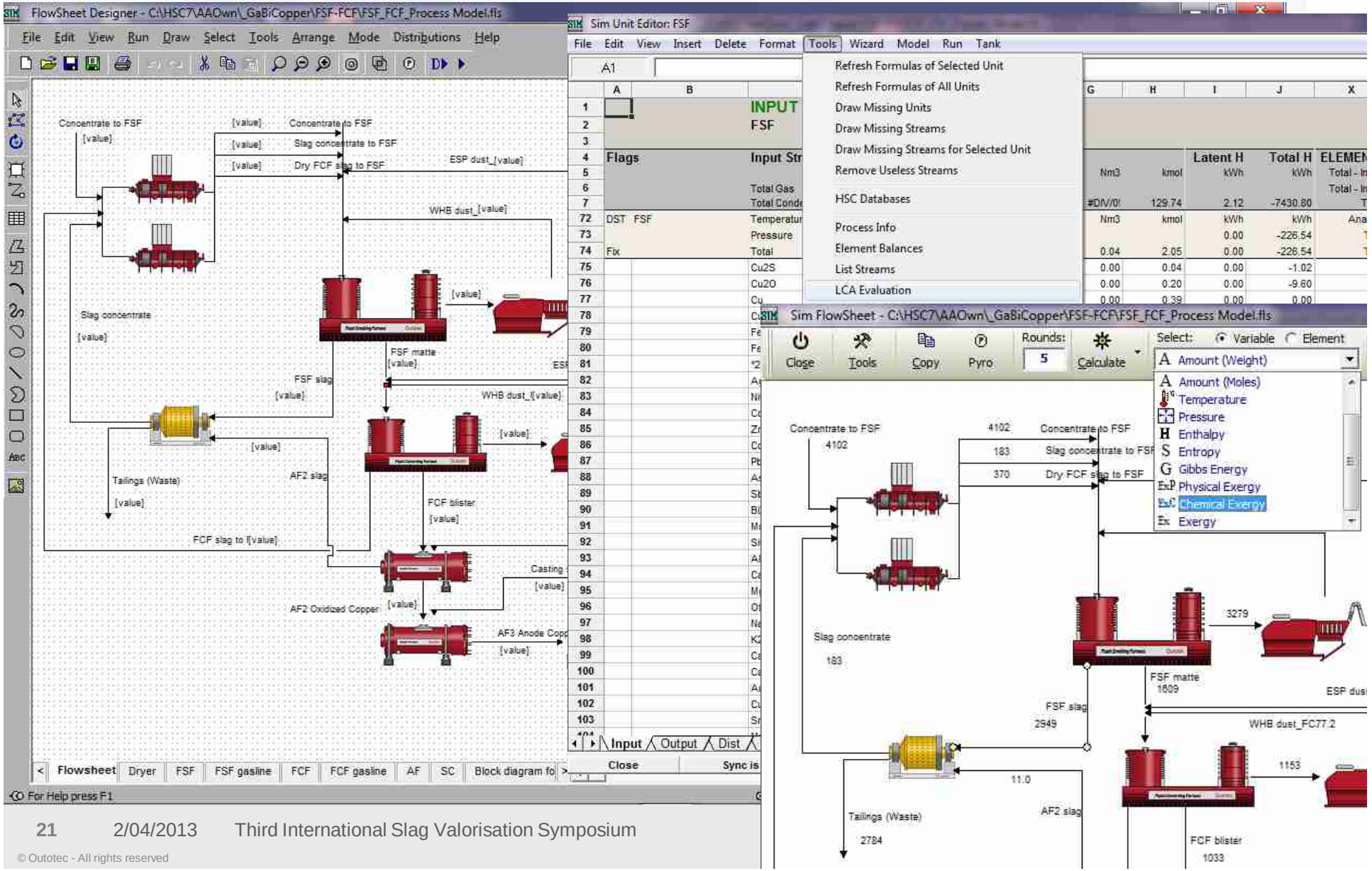
Design for Resource Efficiency



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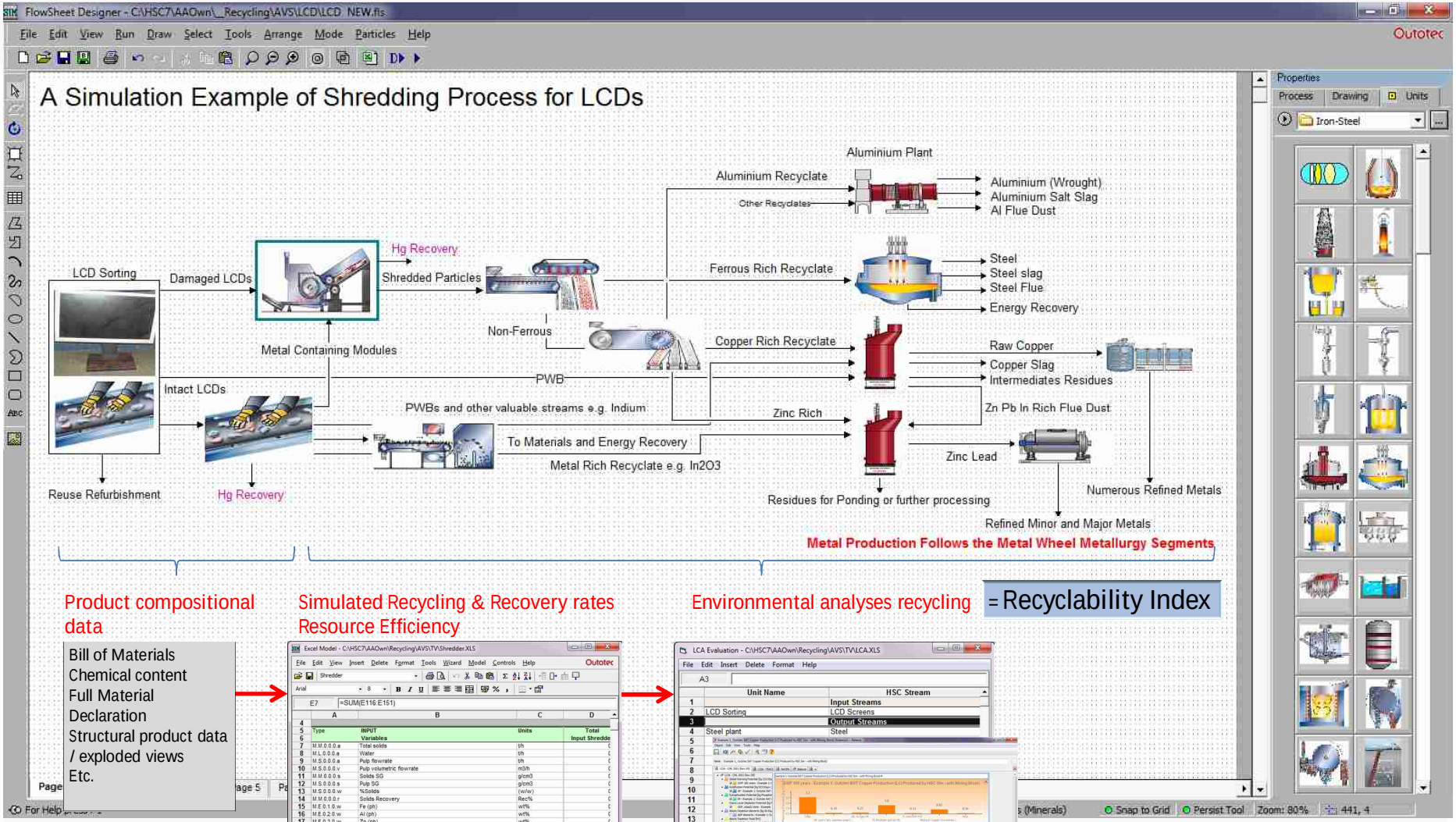
Urban Mining, Ecodesign, OEMs
Recyclability Index



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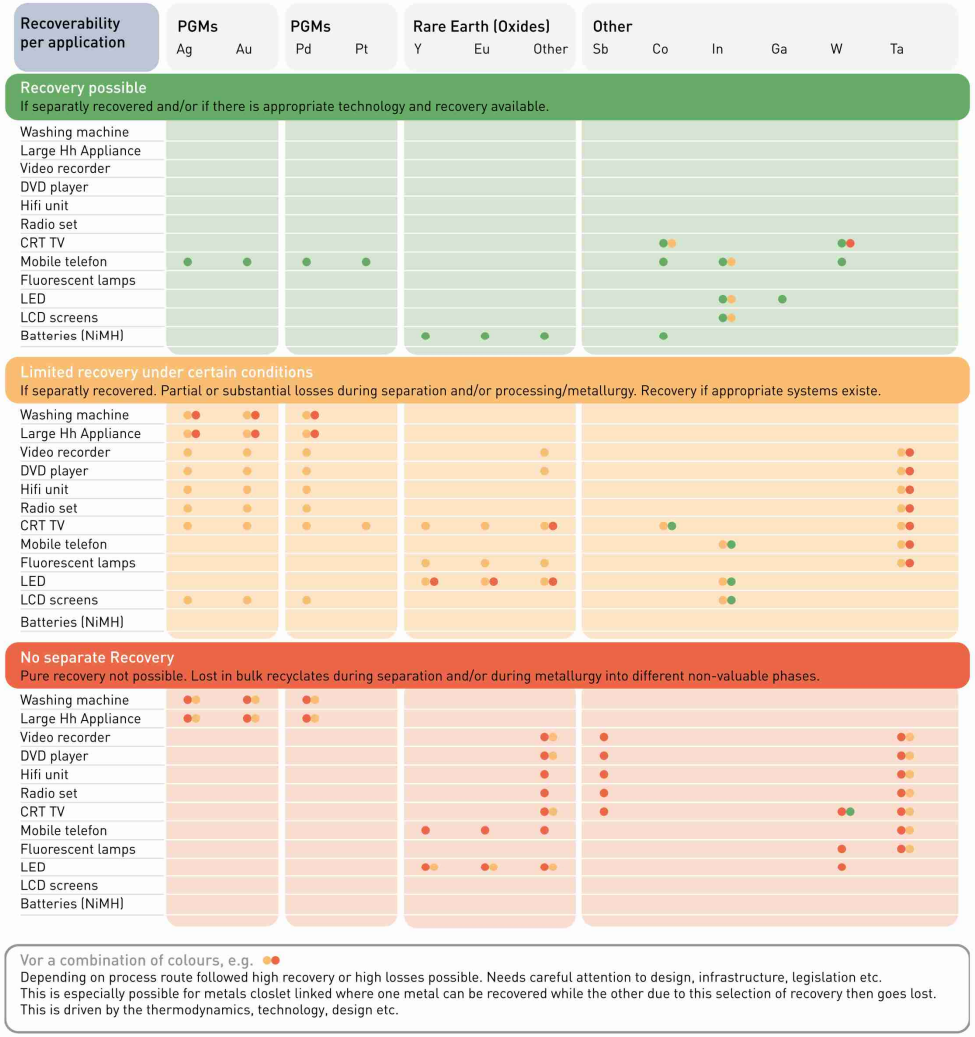
Design for Recycling & Metal Recoverability



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In summary…

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Sustainable use of Earth’s natural resources

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