



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

Outotec in Brief

- **Ranked Globally 12th most Sustainable Corporation**
<http://corporateknight.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 500m³)
 - 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

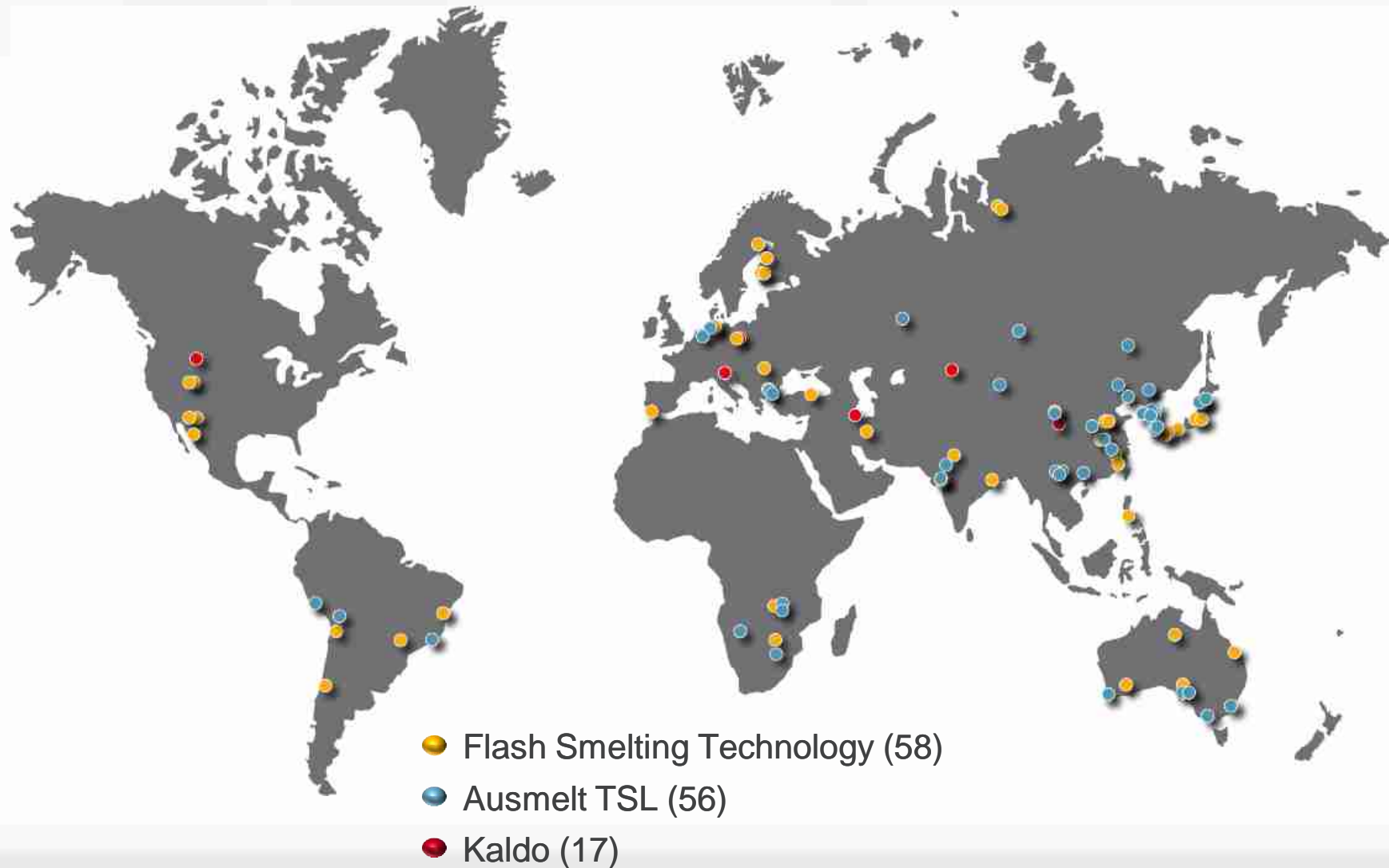


Xiangguang Copper highest
environmental award for
its smelter project from
the Chinese Government.



Resource Efficient Metal Production

More than 130 Outotec smelters around the world



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.

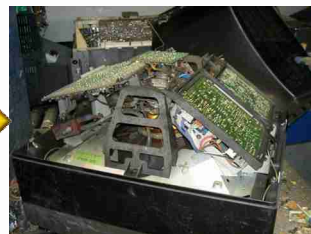
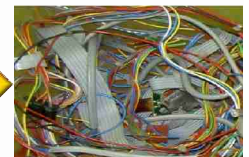
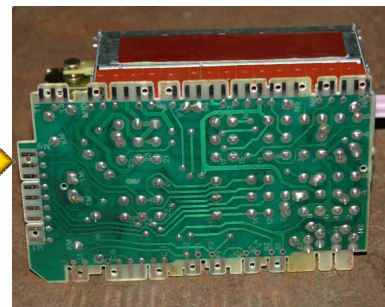
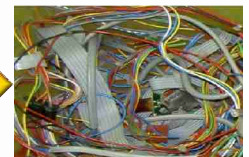
- **UNEP report on recycling with above message to appear April 24th 2013.**

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

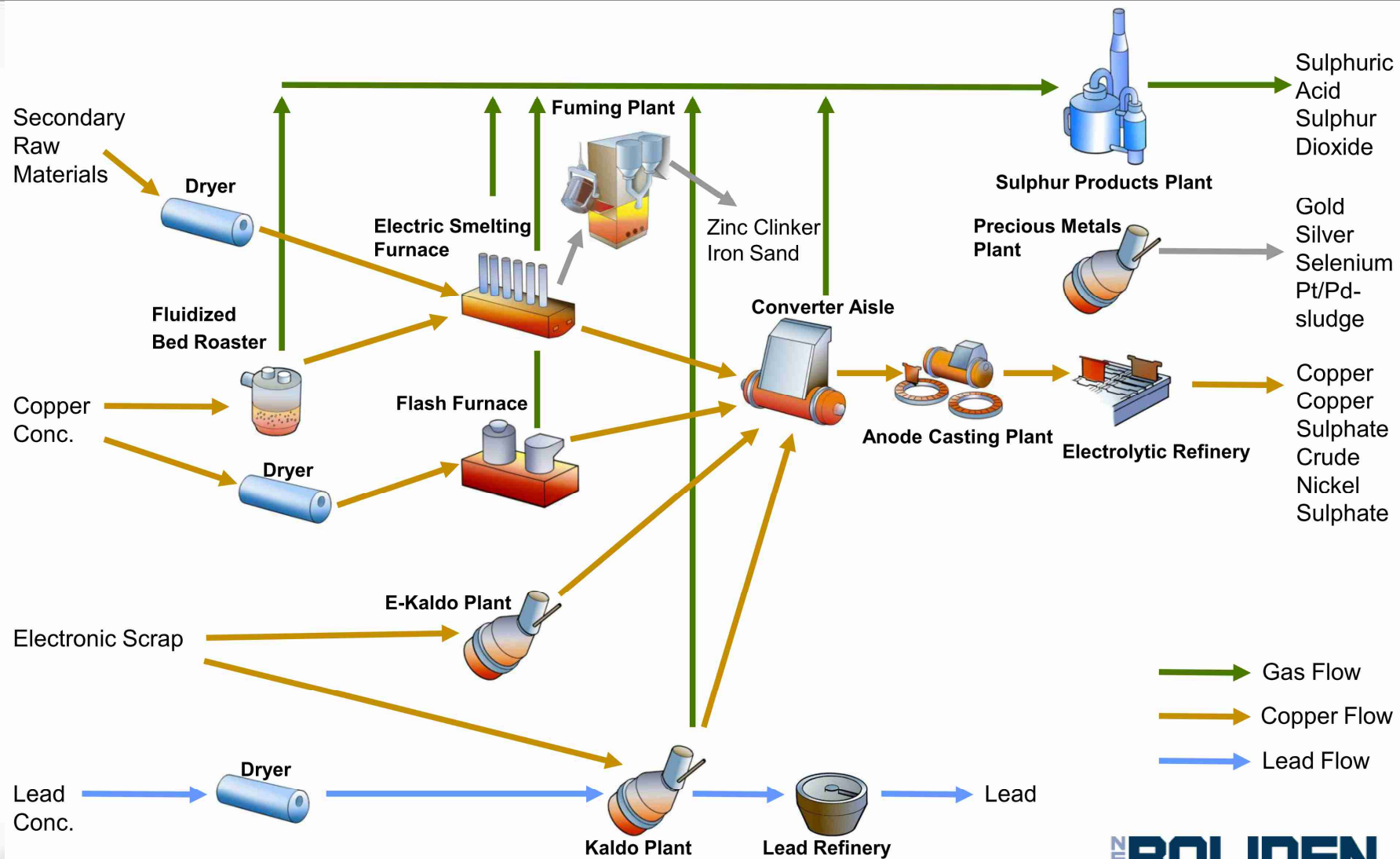
Joined
Materials

Designer Copper “Minerals”

>40 elements complexly linked

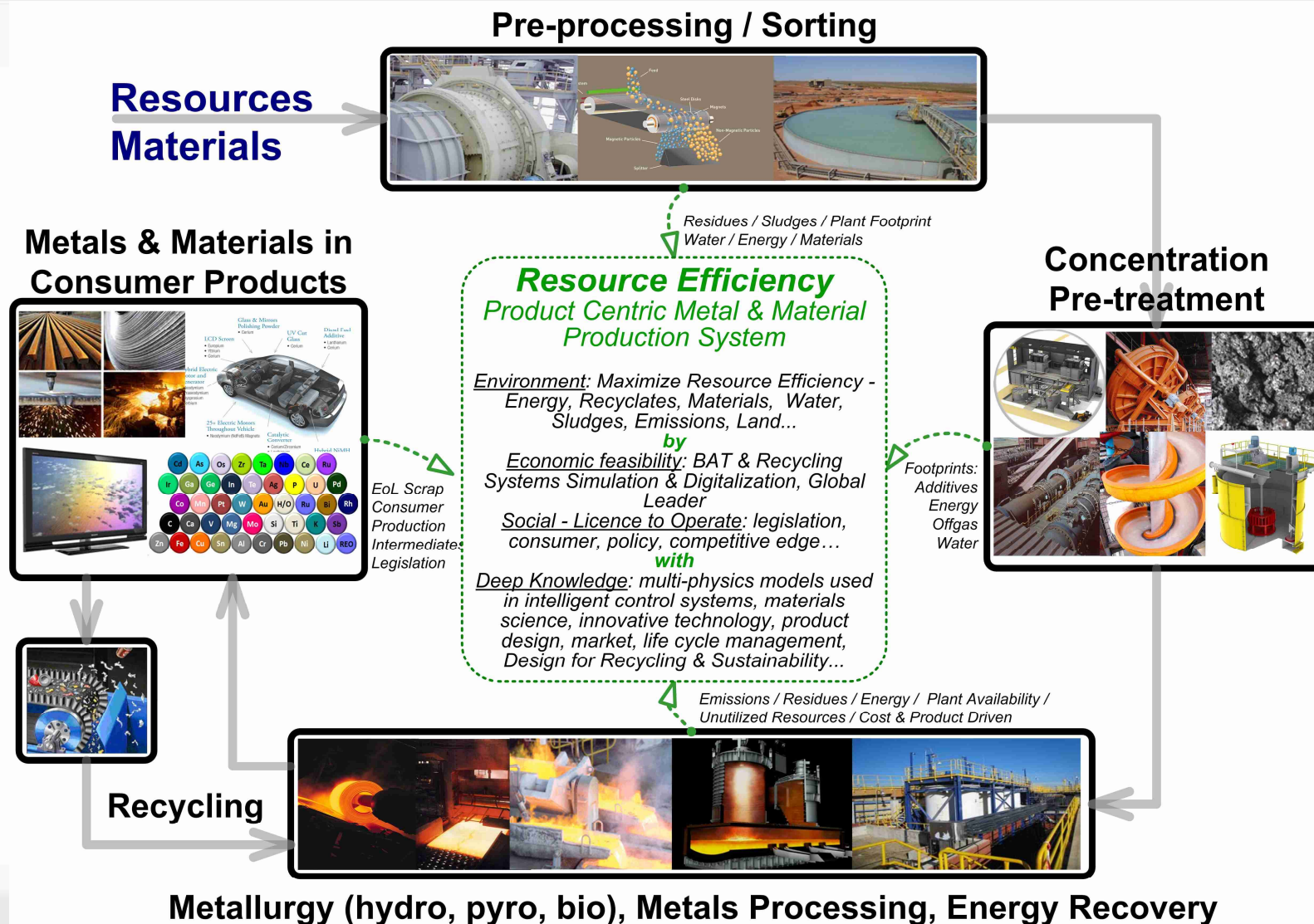


State-of-Art Copper Smelters



Resource Efficient Metal Production

Economic and multi-physics understanding key to “closing” loop



The physics and design of separation...

Understand the economics, physics...

Dismantling

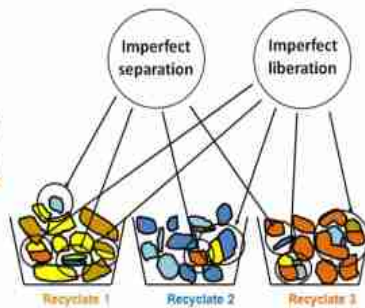


Design determines connections

Shredding

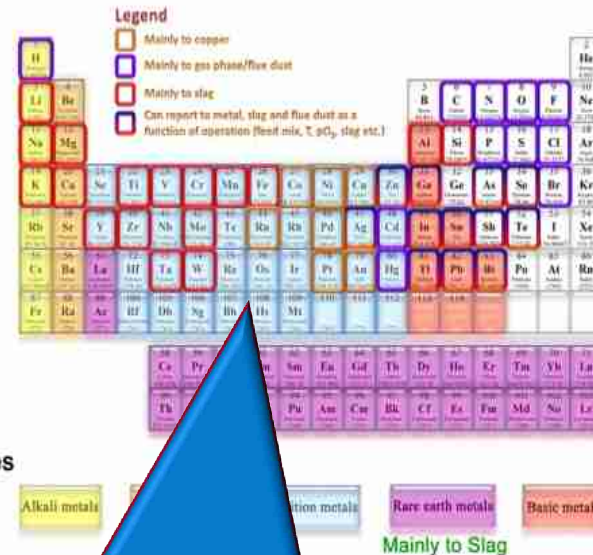


Physical Separation

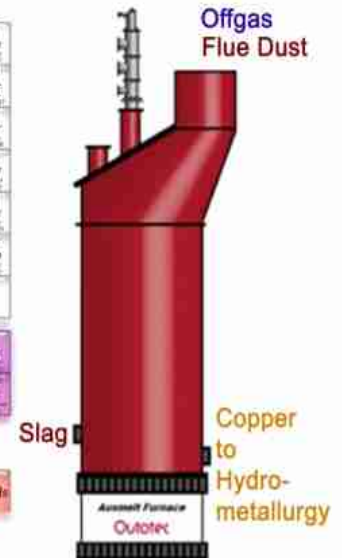


Various Grades/Qualities of Recyclates

Elements in WEEE Recyclates



Smelting Technology



Material Centric

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

Product Centric

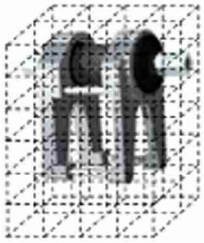


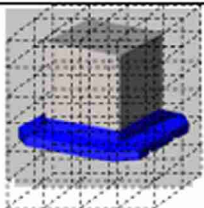
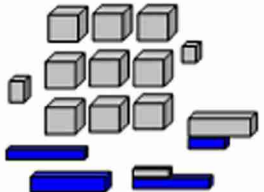

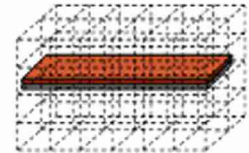


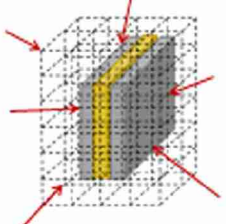


Complex products create poorly liberated complex recyclates, these are the losses, inefficiencies, the true challenge of recycling and “closing the loop”
Slag Chemistry is a Key.

The

Dismantling



Design determines c

Connection types	Before shredding	After shredding	After shredding	Liberation behaviour
Bolting/riveting				<ul style="list-style-type: none"> • High liberation • High randomness
Gluing				<ul style="list-style-type: none"> • Medium liberation • Medium randomness
Coating/ Painting				<ul style="list-style-type: none"> • Low liberation • Low randomness of liberation
Foaming				<ul style="list-style-type: none"> • Medium liberation • Medium randomness

$$\frac{dy^i(t)}{dt} = m^i(t) - x^i(t)$$

where

$$m^i(t) = \int_{t_1=t}^{t+\Delta t} \int_{w_1}^{w_2} \int_{mp_1^i}^{mp_2^i} C(t_1) mp^i h^i(w, mp^i, t_1) g(t_1, w) d(mp^i) dw dt_1$$

$$x^i(t) = \int_{t_2=t}^{t+\Delta t} \int_{t_1=0}^{YP} \int_{w_1}^{w_2} \int_{mp_1^i}^{mp_2^i} C(t_1) mp^i h^i(w, mp^i, t_1) g(t_1, w) f(t_1, t_2)$$

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

The screenshot displays the Autotek software interface for a complex industrial process flow diagram, specifically for End of Life (EOL) car recycling. The diagram is spread across multiple pages (Page 1 to Page 7) and includes various unit operations and material streams.

Process Flow Summary:

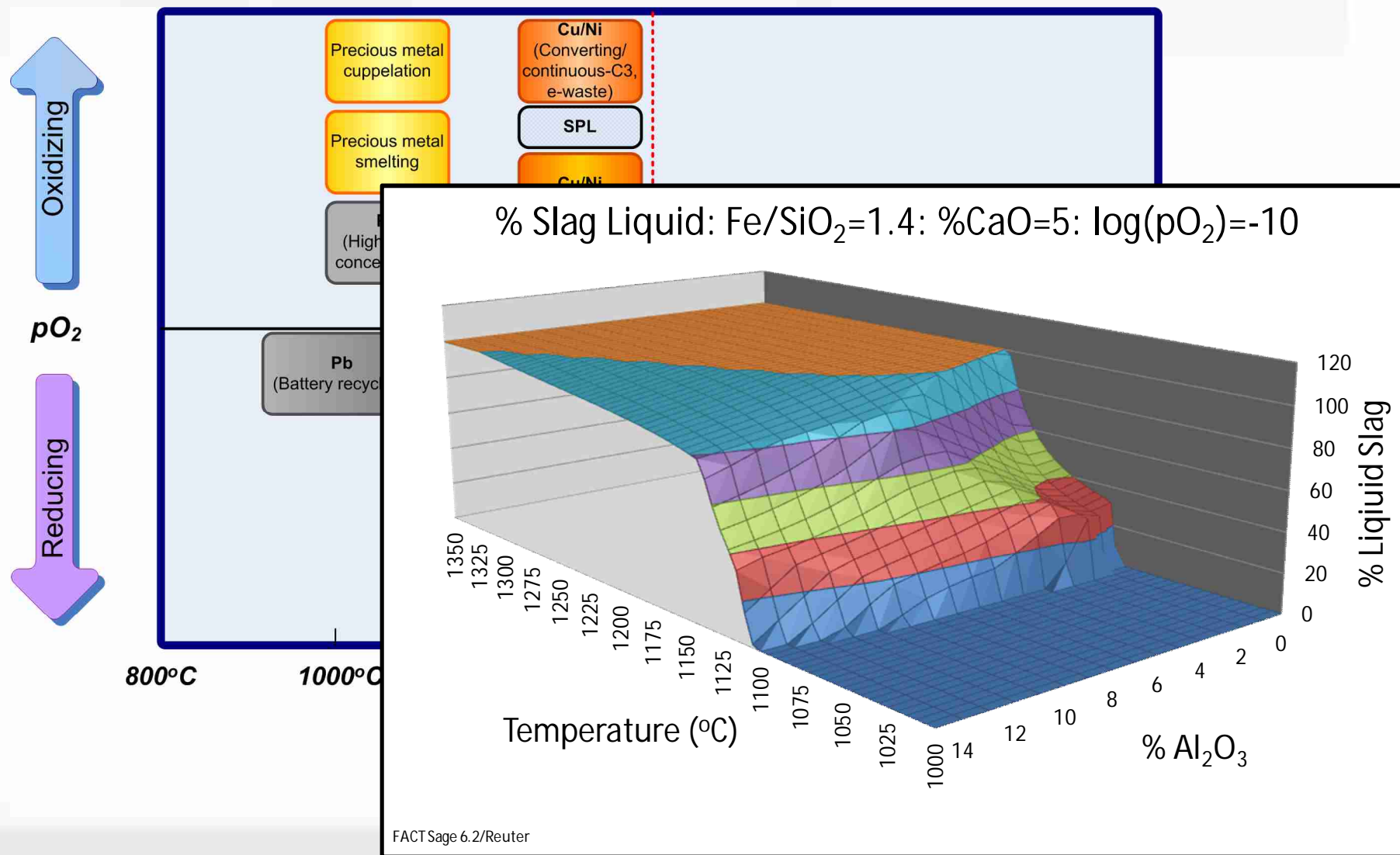
- Input:** End of Life CARS
- Initial Processing:** Dismantling/Depollution, Shredder/Air Suction, Grinding/Screening, EM Separator.
- Material Streams:**
 - Metals:** Lead Battery and Paste, Tyres, Unliberated, Metals, Non-Mag, Cu-Rich, Al-Rich LF, Mg-Rich HF, RDF 1, RDF 2, Fluff.
 - Slag/Residue:** Steel Slag, Steel Recycle, C-Steel, Steel Recycle 1, Copper Slag, Lead Slag, Al-Slag, Mg-Slag, PP-PE Recyclate, MMix Recyclate.
 - Other:** S Flue Dust, AOD, AOD-Convert, Casting, Cu-Phase, Leaching/Refining, Electrolyte, Electrowinning, Products, Cement, Flue dust to processing, Various Products, Al Flue Dust, Al Salt Slag, Aluminium Alloy, Mg Salt Slag, Magnesium Alloy, Flue dust, Ash, Effluent.
- Final Products/Outputs:** Steel Slag, Steel Recycle, C-Steel, AOD, Casting, Copper-Slag, Copper-PGM-PM, Cement, Lead-Zinc-Tin, Aluminum, Magnesium, Waste-To-Energy, Effluent.

Software Interface Details:

- Top Menu:** File, Edit, View, Run, Draw, Select, Tools, Arrange, Mode, Particles, Help.
- Left Panel:** Contains various tool icons for drawing and editing.
- Right Panel:** Properties panel with tabs for Process, Drawing, and Units. The General tab is active, showing details for the selected unit (Grinding/Screening).
- Bottom Panel:** Process panel with options for Particles (Minerals), Snap to Grid, and Persist Tool. It also shows a zoom level of 90% and a scale of 180, 3.

Controlling the Furnace

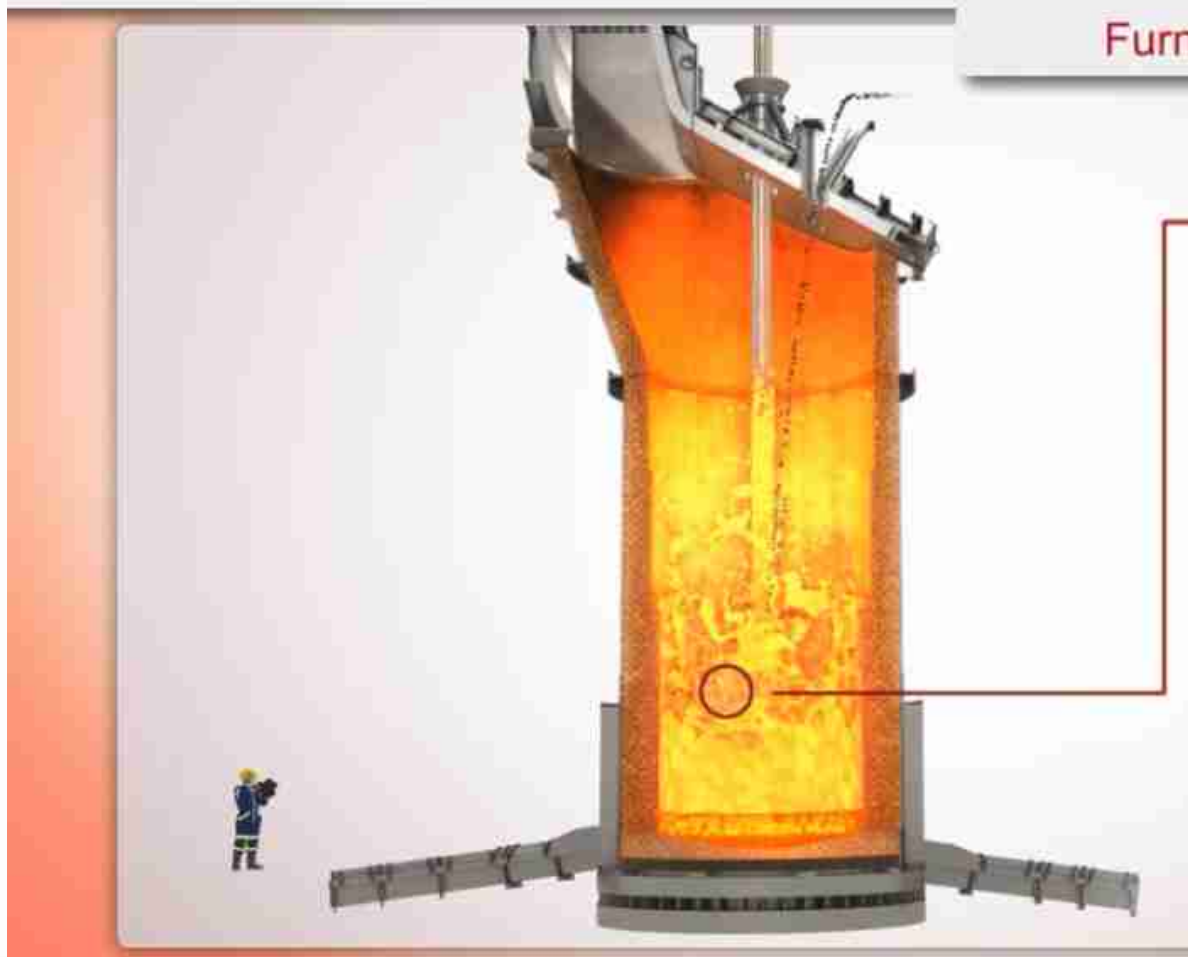
Controlling the slag...



The physics and technology of separation...

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

TSL Furnace

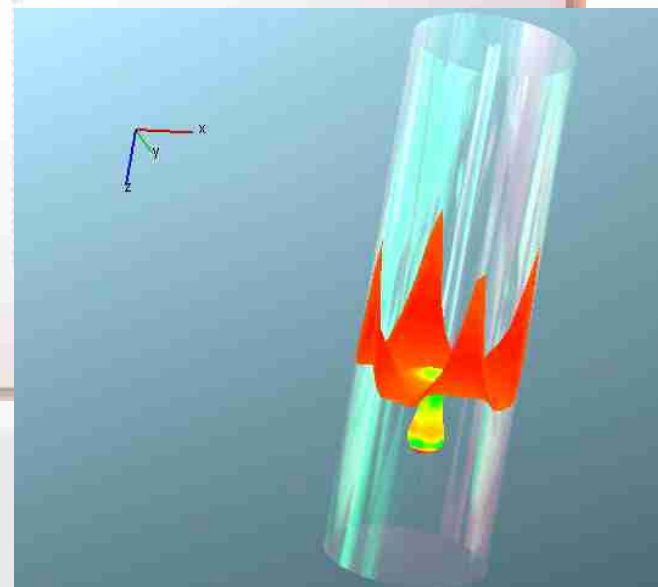


Furnace

Intense Agitation

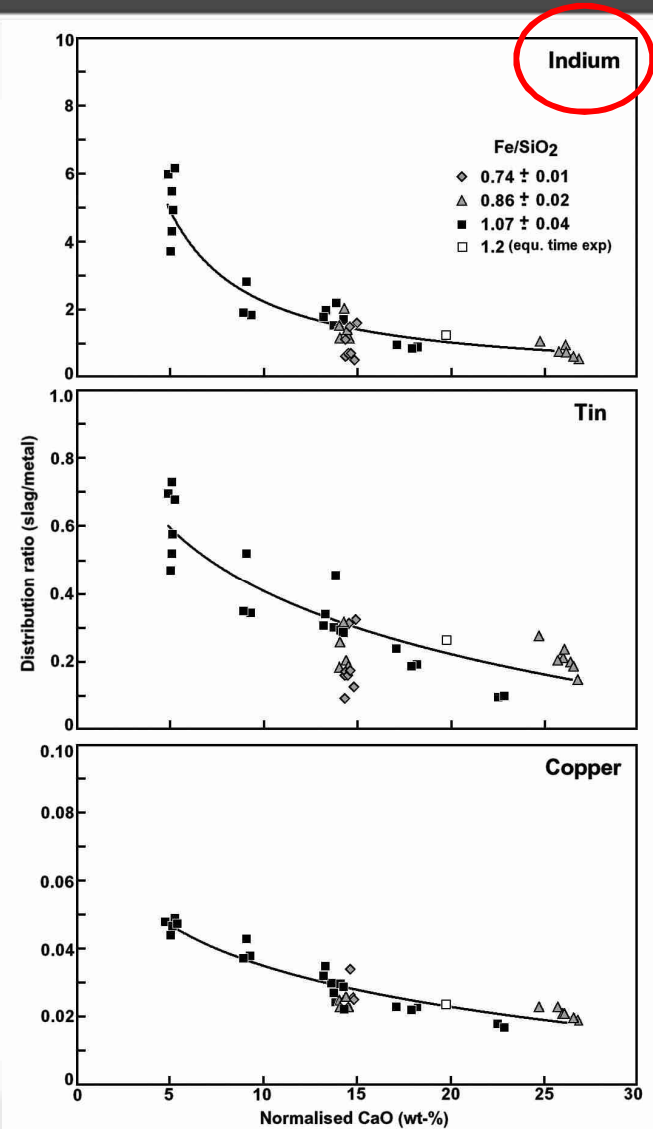
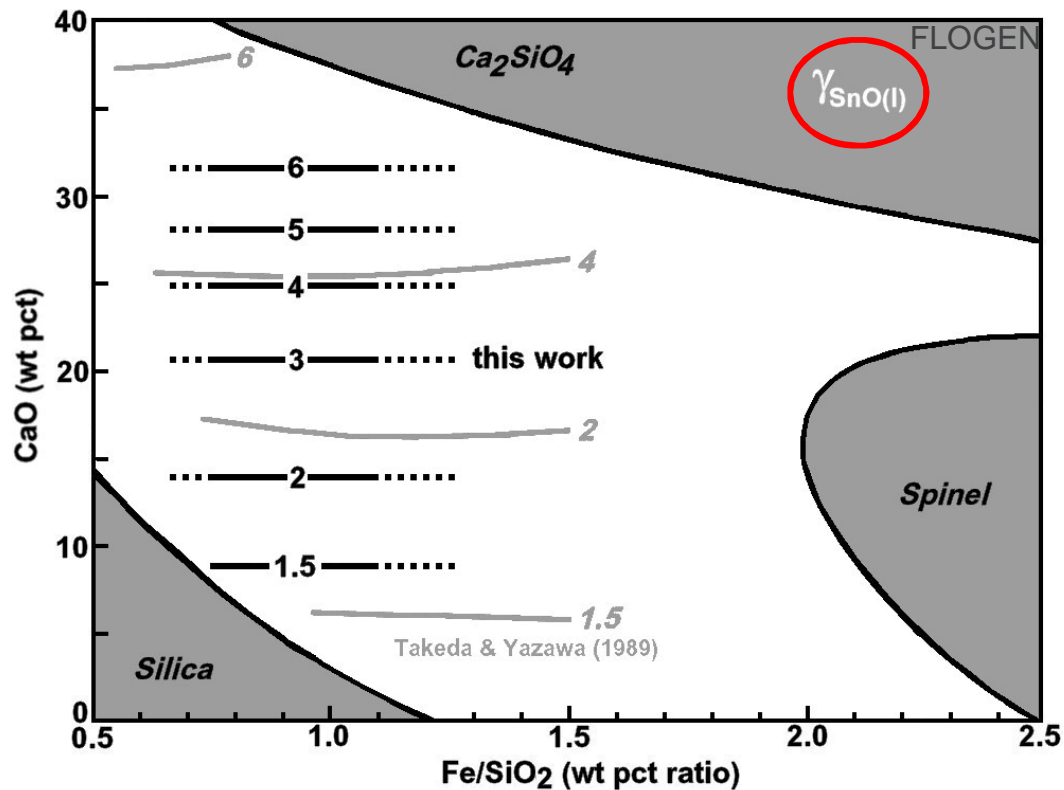
The intense mixing promotes rapid reaction kinetics and high specific smelting rates

Chemical and combustion reactions take place in slag layer



Understanding the deportation of elements

Element distributions



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)**

Outotec Ausmelt TSL

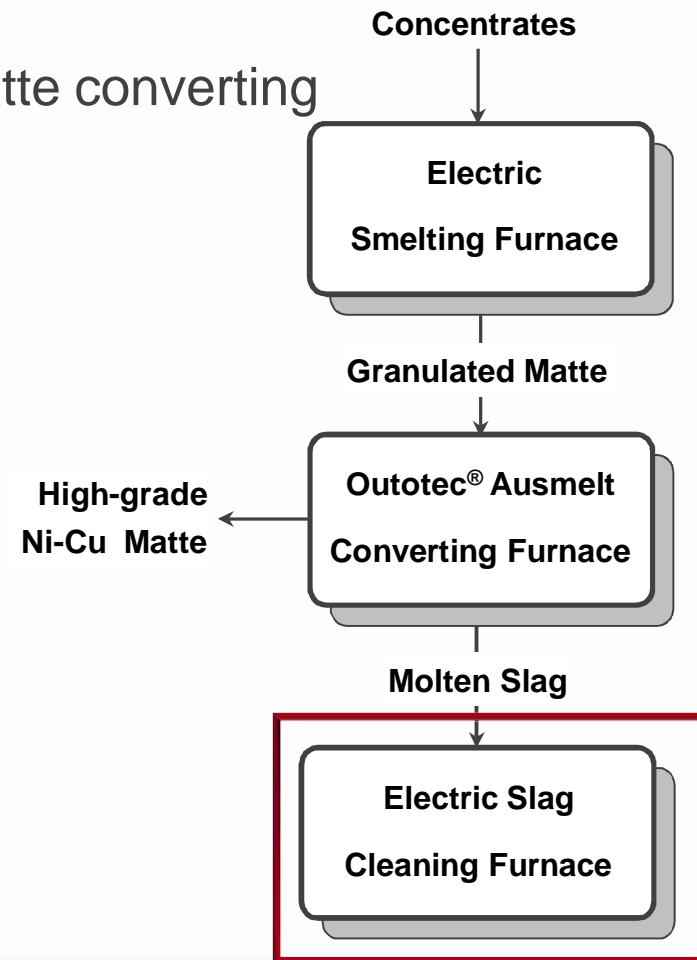
- DOWA Mining
 - **Process:** E-Waste Recycling and Residue Processing
 - **Capacity:** 140,000 tpa feed
 - **Commissioned:** 2008



Outotec® Ausmelt Converting

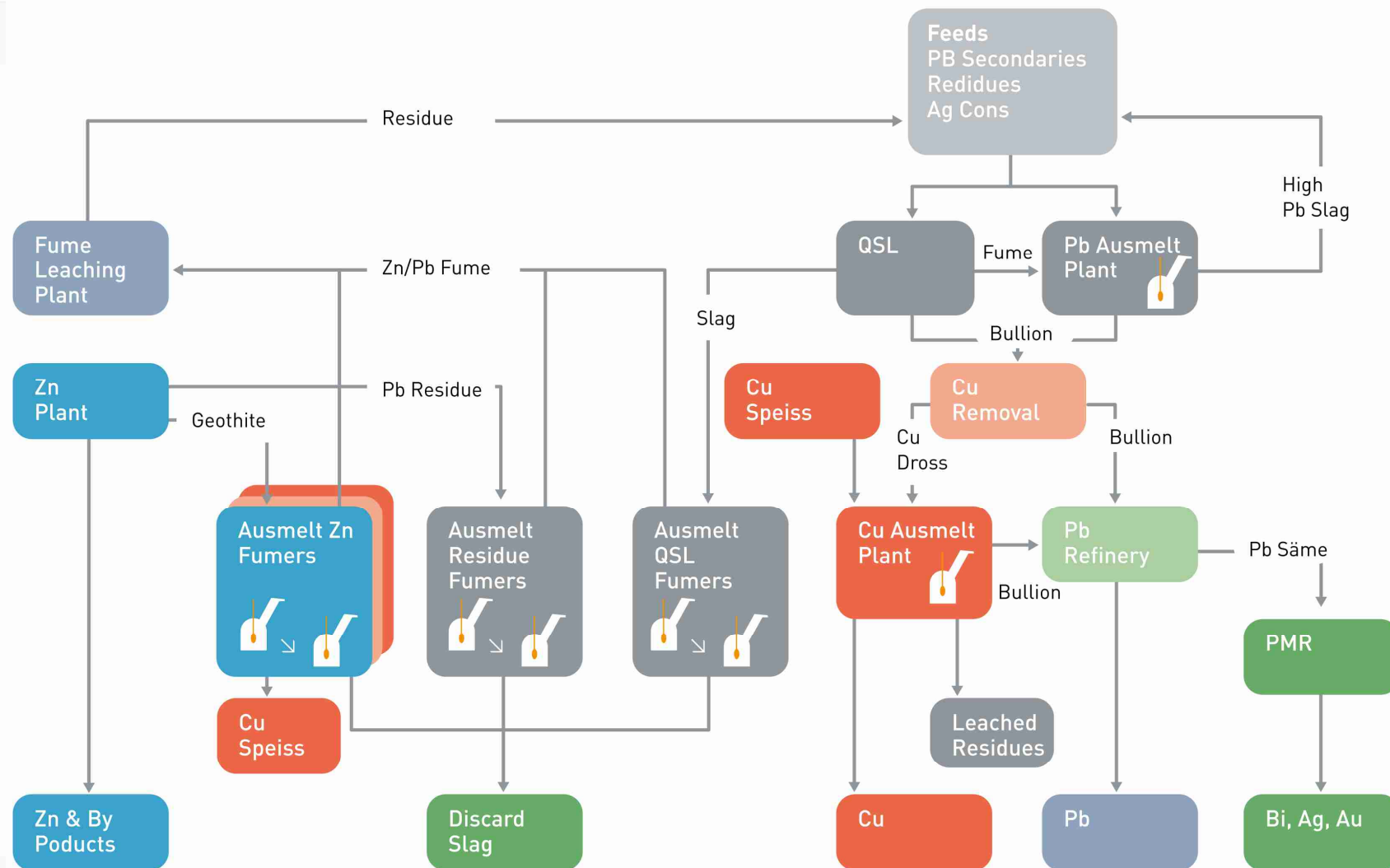
■ Anglo Platinum

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



Zn Residue Processing

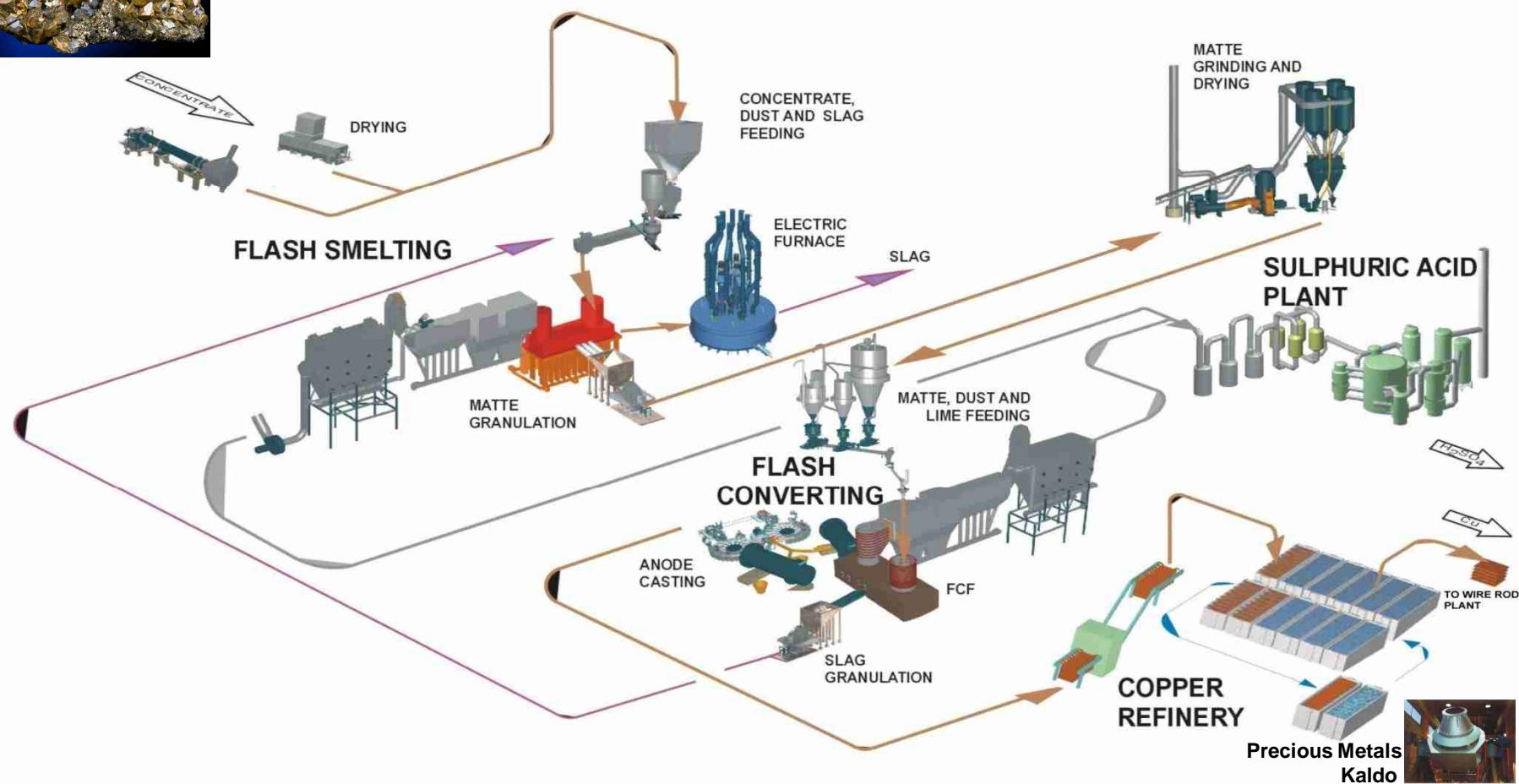
Korea Zinc applications of Outotec TSL Technology



Design for Resource Efficiency



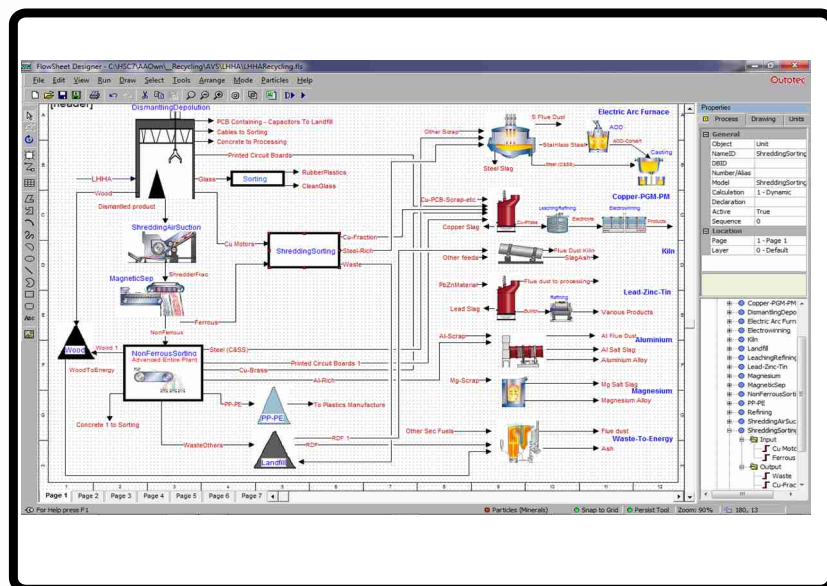
PROCESS FLOW SHEET OF COPPER PRODUCTION



Measuring Sustainability, Resource Efficiency

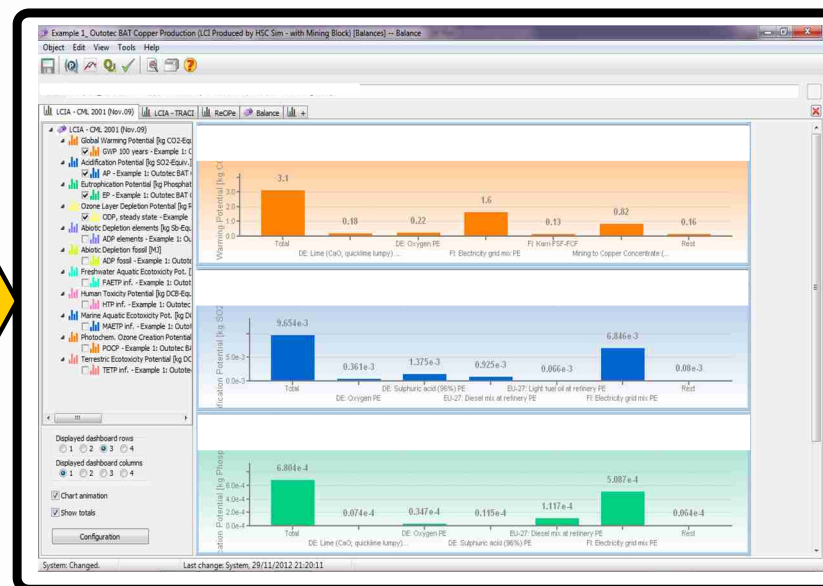
OT's HSC Sim 7.1x

(>19,000 licences www.outotec.com)



PE-International's GaBi

(www.PE-International.com)



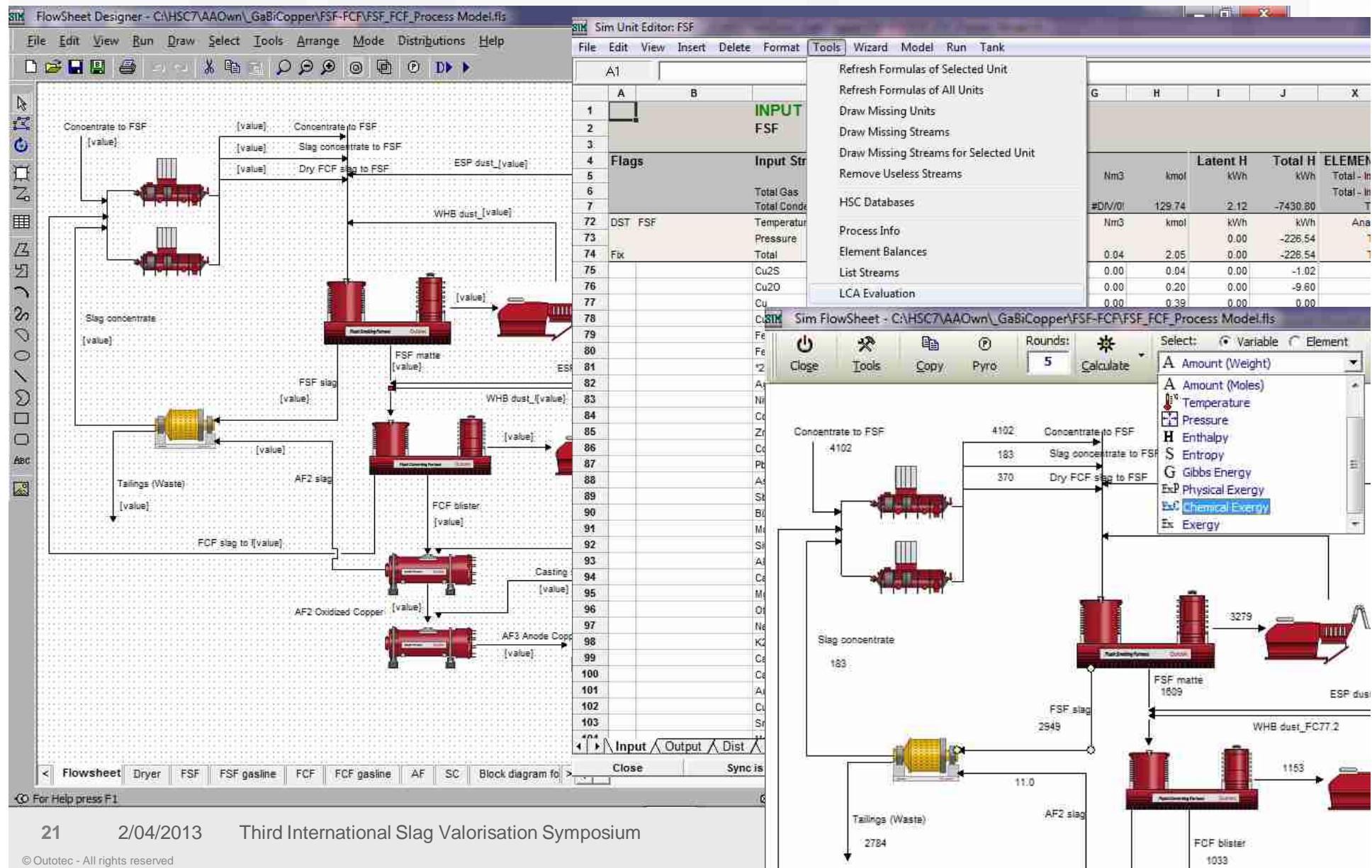
BAT. Flow Sheets & Recycling System Maximizing Resource Efficiency – Benchmarks

\$US / t Product (CAPEX & OPEX)
Recyclability Index (based on system simulation of whole cycle)
 GJ & MWh / t Product (source specific) and Exergy
 kg CO₂ / t Product
 kg SO_x / t Product
 g NO_x / t Product
 m³ Water / t Product (including ions in solution)
 kg Residue / t Product (including composition)
 kg Fugitive Emissions / t Product
 kg Particulate Emissions / t Product
 Etc.

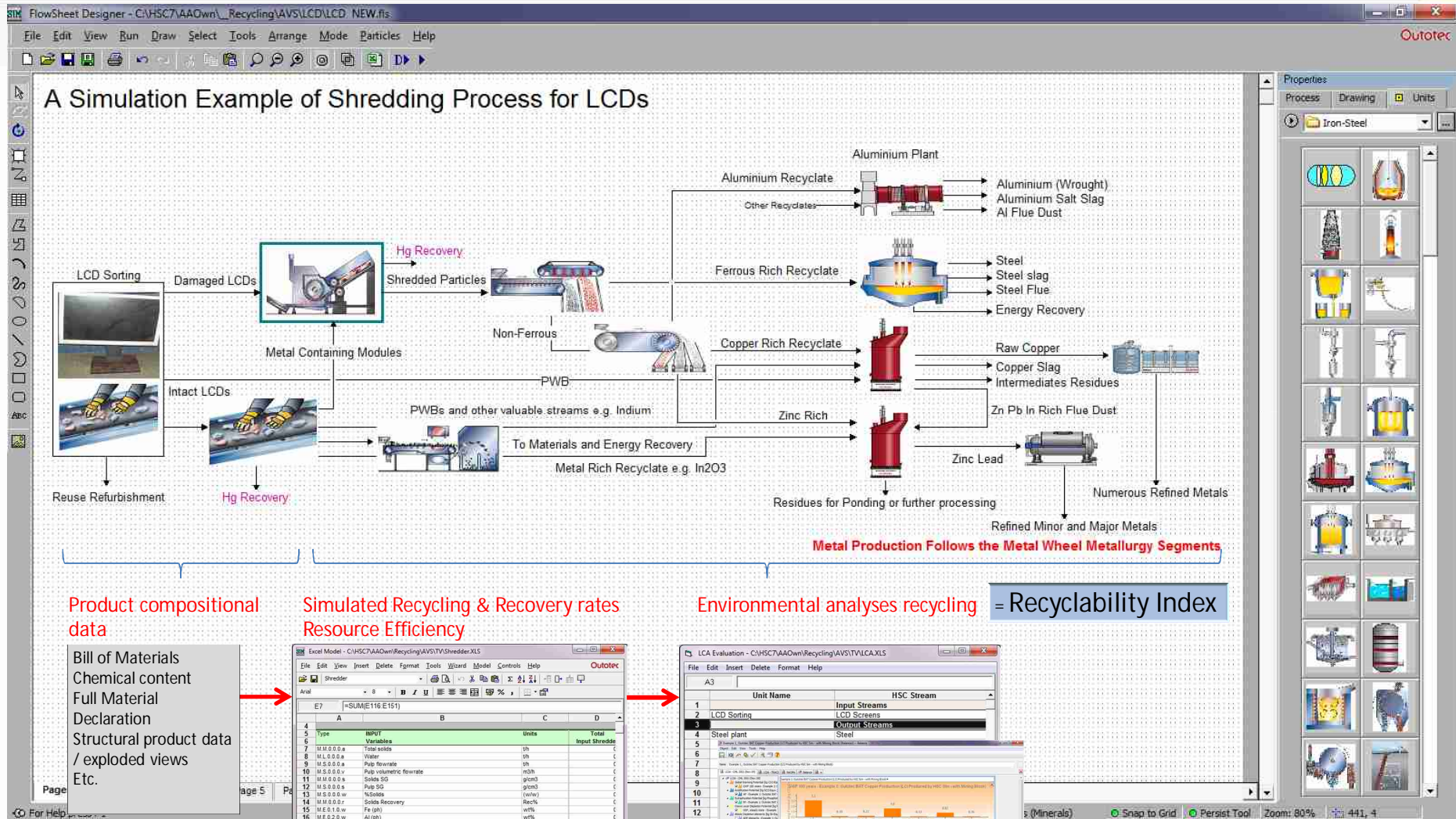
Environmental Indicators based on BAT Driving Benchmarks of Industry

Global Warming Potential (GWP)
 Acidification Potential (AP)
 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...

Design for Resource Efficiency



Urban Mining, Ecodesign, OEMs Recyclability Index



Outotec

Design for Recycling & Metal Recoverability

Recoverability per application	PGMs		PGMs		Rare Earth (Oxides)			Other					
	Ag	Au	Pd	Pt	Y	Eu	Other	Sb	Co	In	Ga	W	Ta
Recovery possible													
If separately recovered and/or if there is appropriate technology and recovery available.													
Washing machine													
Large Hh Appliance													
Video recorder													
DVD player													
Hifi unit													
Radio set													
CRT TV									●	●		●	●
Mobile telefon	●	●	●	●					●		●	●	●
Fluorescent lamps										●	●		
LED										●	●	●	
LCD screens										●	●		
Batteries (NiMH)					●	●	●		●				
Limited recovery under certain conditions													
If separately recovered. Partial or substantial losses during separation and/or processing/metallurgy. Recovery if appropriate systems exists.													
Washing machine	●●	●●	●●										
Large Hh Appliance	●●	●●	●●										
Video recorder	●	●	●										●●
DVD player	●	●	●										●●
Hifi unit	●	●	●										●●
Radio set	●	●	●										●●
CRT TV	●	●	●	●	●	●	●	●	●				●●
Mobile telefon										●	●		●●
Fluorescent lamps					●	●	●						●●
LED					●	●	●			●	●		
LCD screens	●	●	●							●	●		
Batteries (NiMH)													
No separate Recovery													
Pure recovery not possible. Lost in bulk recyclates during separation and/or during metallurgy into different non-valuable phases.													
Washing machine	●●	●●	●●										
Large Hh Appliance	●●	●●	●●										
Video recorder							●●	●					●●
DVD player							●●	●					●●
Hifi unit							●	●					●●
Radio set							●	●					●●
CRT TV							●●	●				●	●
Mobile telefon					●	●	●						●●
Fluorescent lamps							●					●	●
LED					●●	●●	●●					●	
LCD screens													
Batteries (NiMH)													
Vor a combination of colours, e.g. ●●													
Depending on process route followed high recovery or high losses possible. Needs careful attention to design, infrastructure, legislation etc.													
This is especially possible for metals closest linked where one metal can be recovered while the other due to this selection of recovery then goes lost.													
This is driven by the thermodynamics, technology, design etc.													

In summary...

- **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.

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Sustainable use of Earth's natural resources

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