Metals – Enablers of Sustainability

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

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Sustainable use of Earth's natural resources

Outotec by the numbers

- Sales EUR 2,078 million with
  EUR 476 million generated by services (2012)
- Presence in 25 countries, deliveries to 80 countries
- Over 4,500 professionals
- Extensive IPR portfolio
  - Over 5,745 national patents or applications,
    630 patent families and 70 trademarks
  - R&D expenditure EUR 41.6 million (2012)
- Listed on NASDAQ OMX Helsinki

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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. 50% Cu , >30% Sn in TSL , close to 40% PGM matte converting
- **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

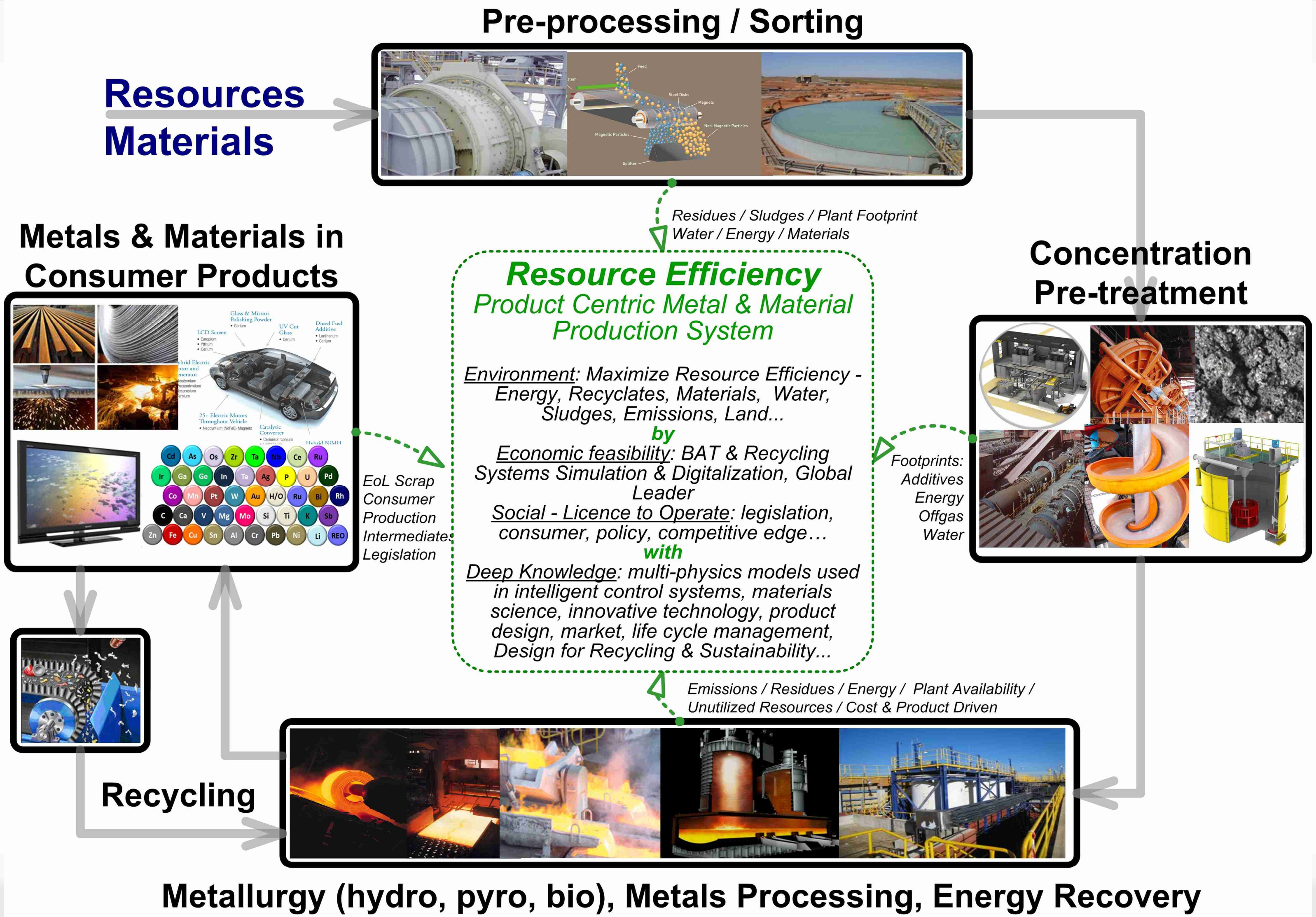
Grinding mills LKAB Sweden

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

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

Resource Efficient Metal Production

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



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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 **Geological rock to metal**
- **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.
  - **Designer rock to metal**

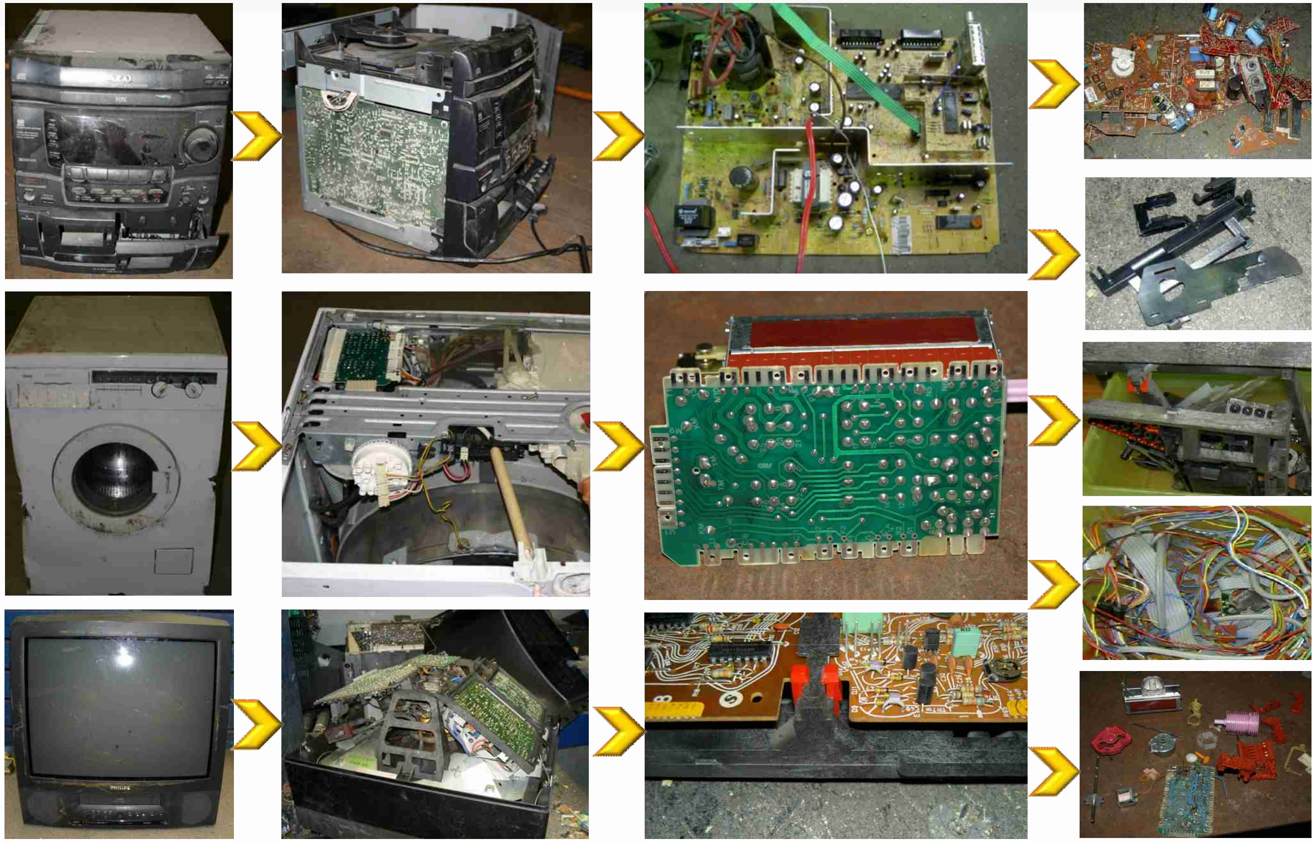
Geological *vis-à-vis* Urban Mine "Minerals"

"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

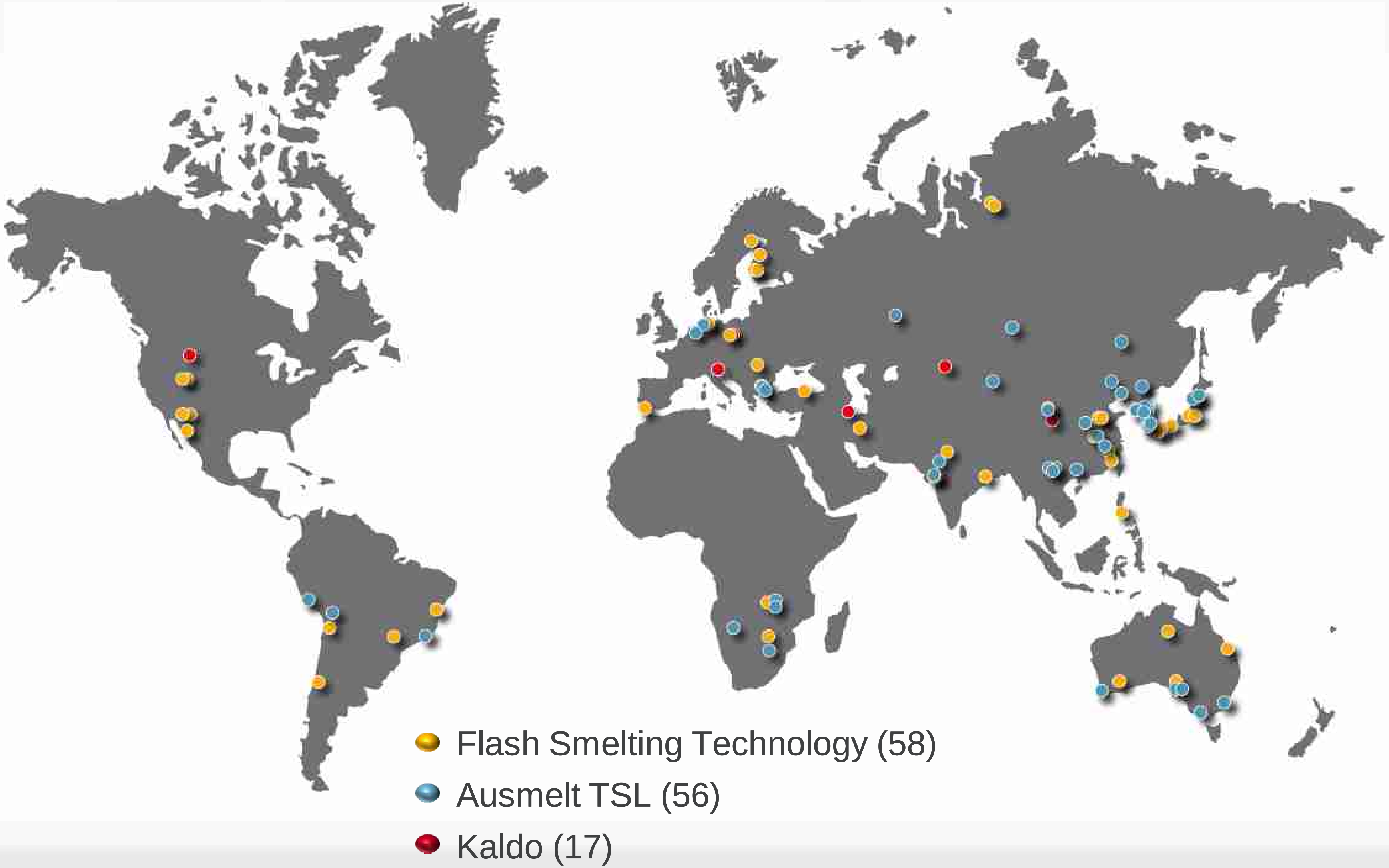
Joined Materials

Designer Copper "Minerals"

>40 elements complexly linked

Resource Efficient Metal Production

More than 130 Outotec smelters around the world



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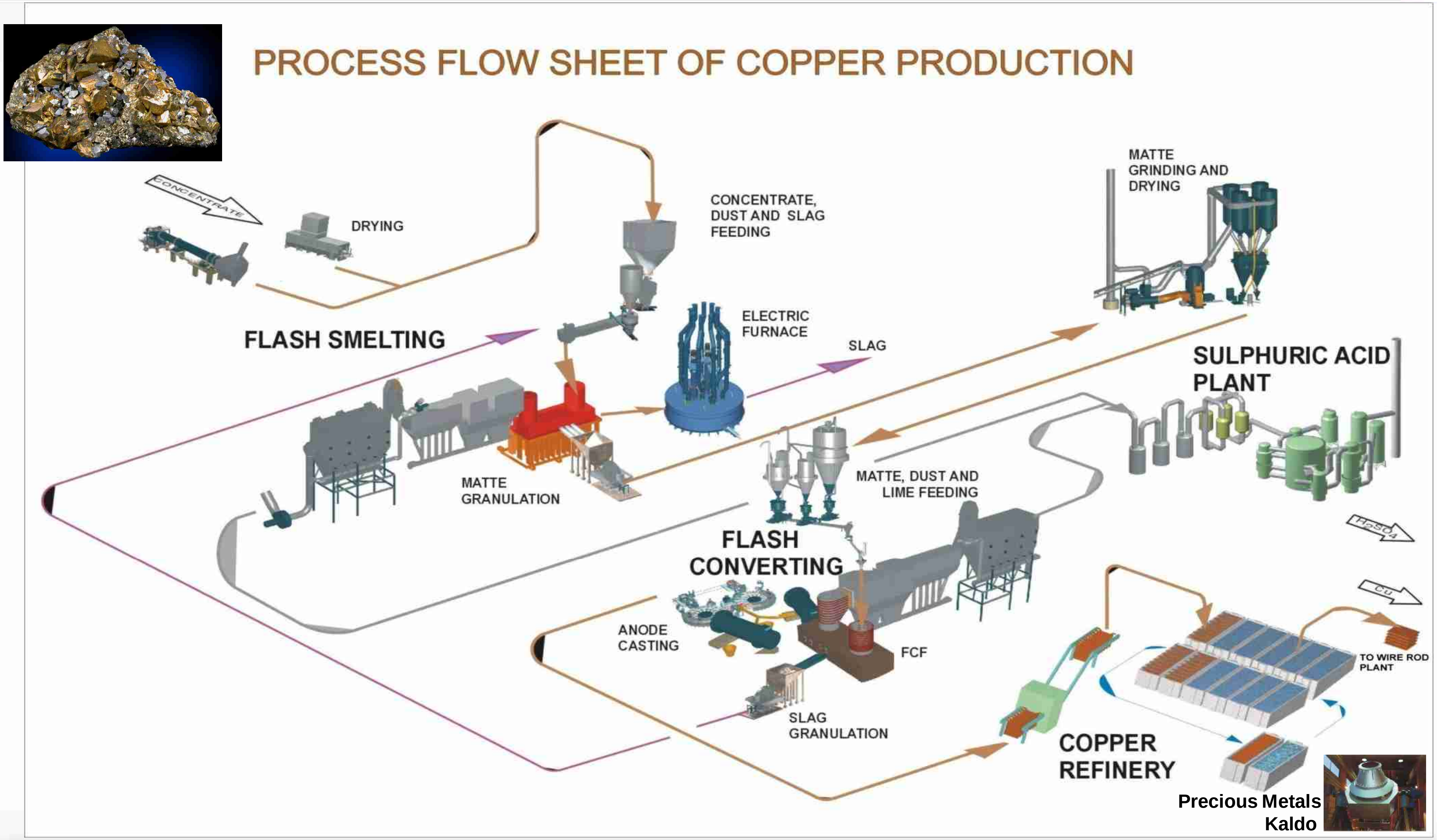
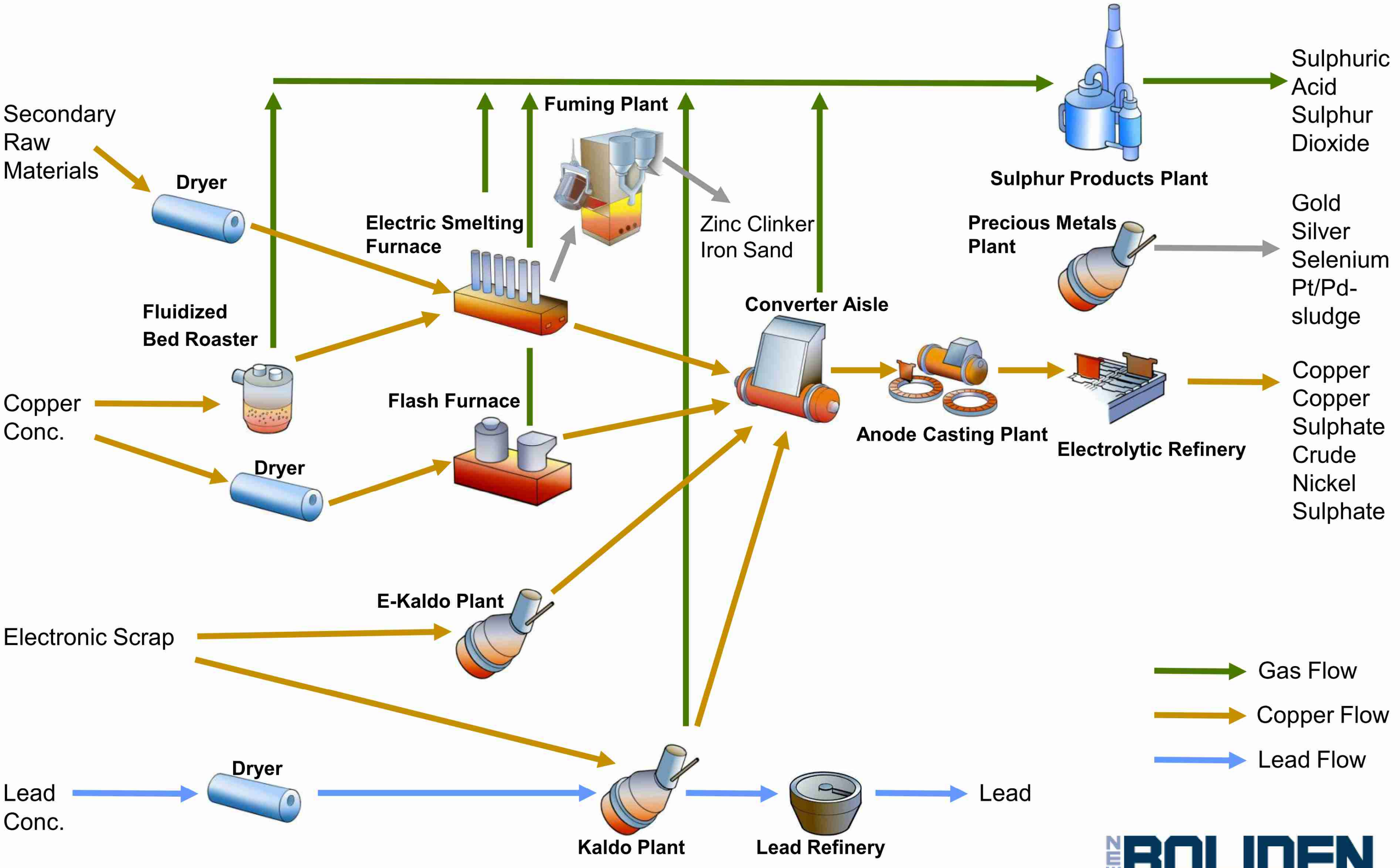
State-of-Art Copper Smelters (>400,000 tpa)

Design for Sustainability, it is happening already through Outotec…



State-of-Art Copper Smelters



NEW BOLIDEN

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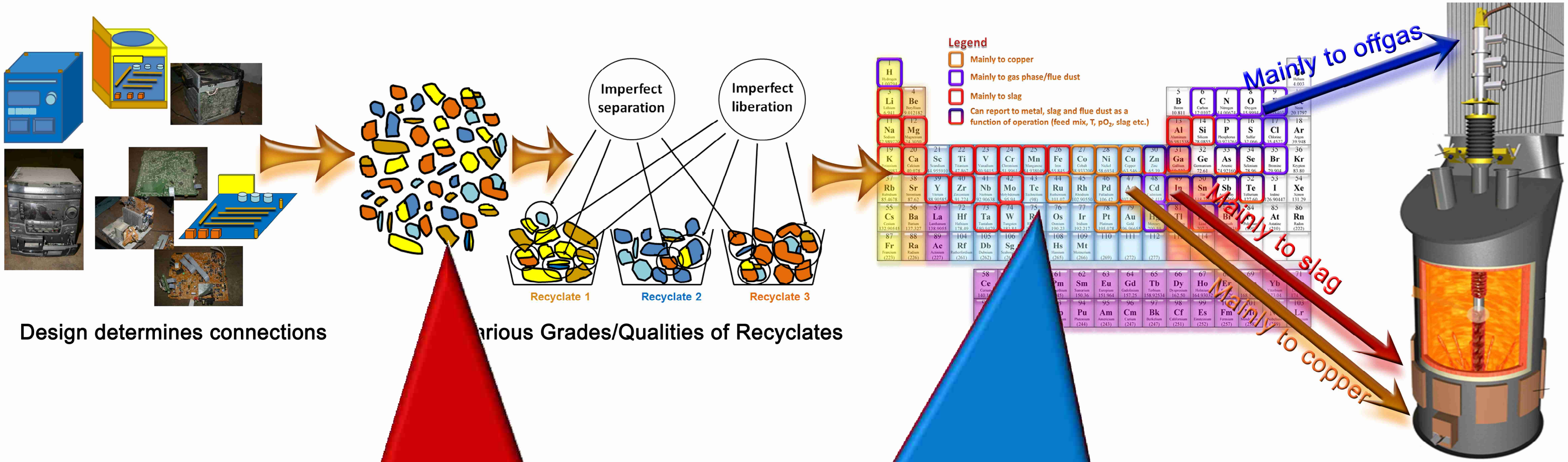
The physics and design of separation…

Understand the economics, physics…

Dismantling | Shredding | Physical Separation | Elements in WEEE recyclates | Furnace 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.

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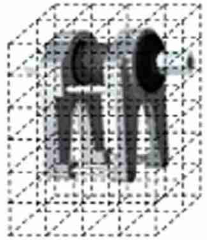
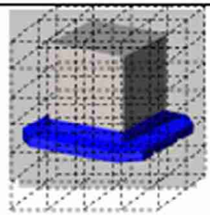
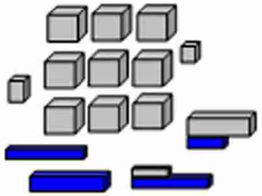
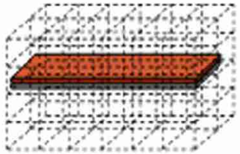
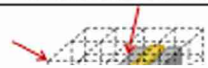
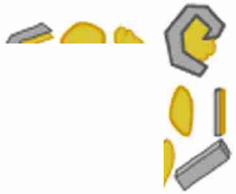
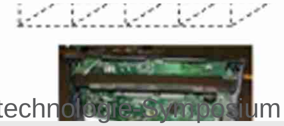
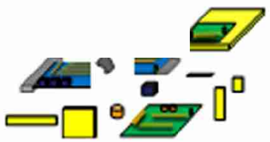
The

Dismantling

Design determines con

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
				• Medium liberation • Medium randomness
...components of different levels of complexity				• High/medium liberation from structure • High/medium randomness (both depending on joint type and

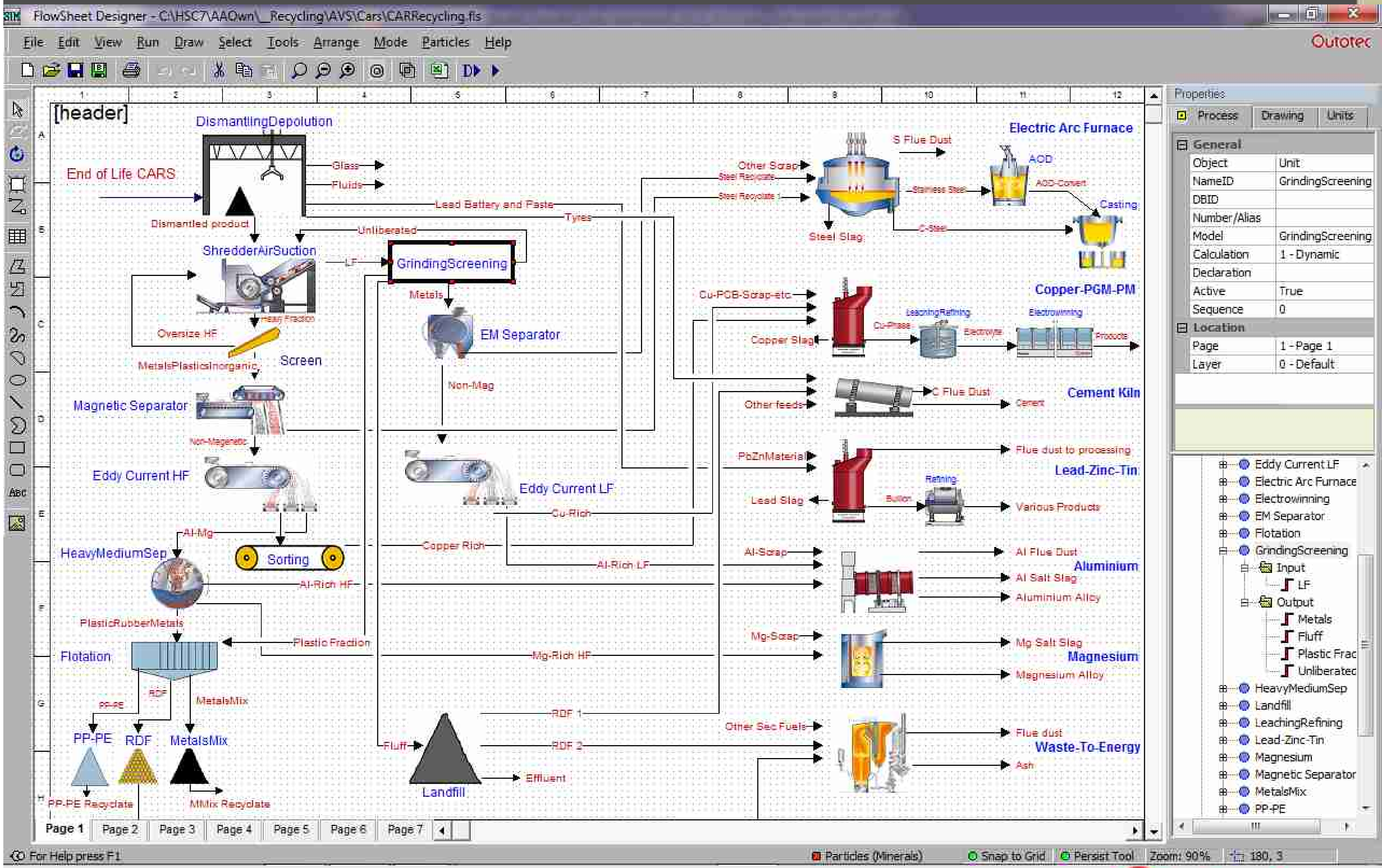
$$\frac{\mathrm{d}y^i(t)}{\mathrm{d}t} = m^i(t) - x^i(t)$$

where

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

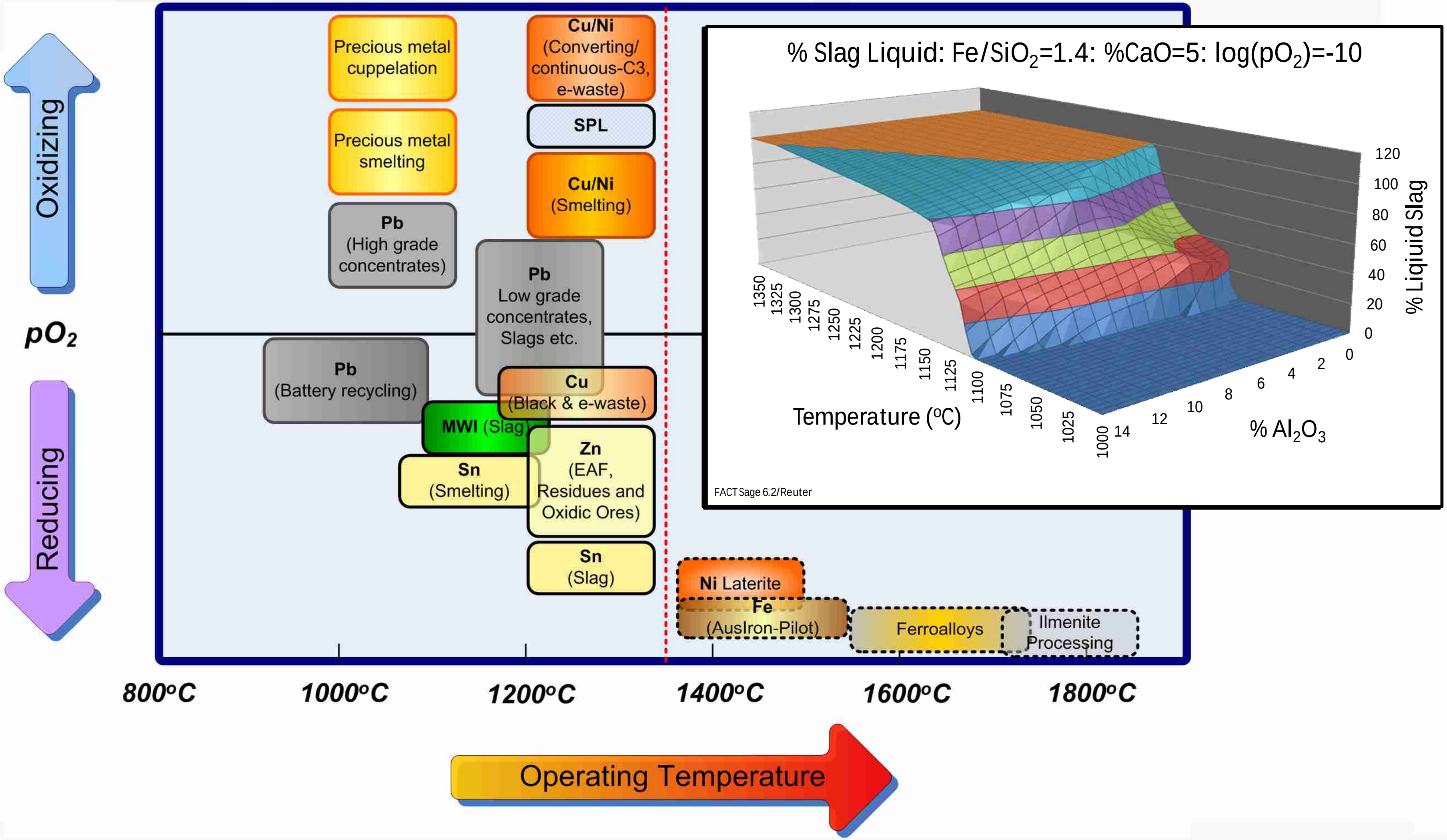
$$x^i(t) = \int_{t_2=t}^{t+\Delta t}\int_{t_1=0}^{YP}\int_{w_1}^{w_2}\int_{\mathrm{mp}_1^i}^{\mathrm{mp}_2^i} C(t_1)\mathrm{mp}^i\, h^i(w,\ \mathrm{mp}^i,\ t_1)g(t_1,\ w)\,f(t_1,\ t_2) \times \mathrm{d}(\mathrm{mp}^i)\,\mathrm{d}w\,\mathrm{d}t_1\,\mathrm{d}t_2$$

Understanding the complete system



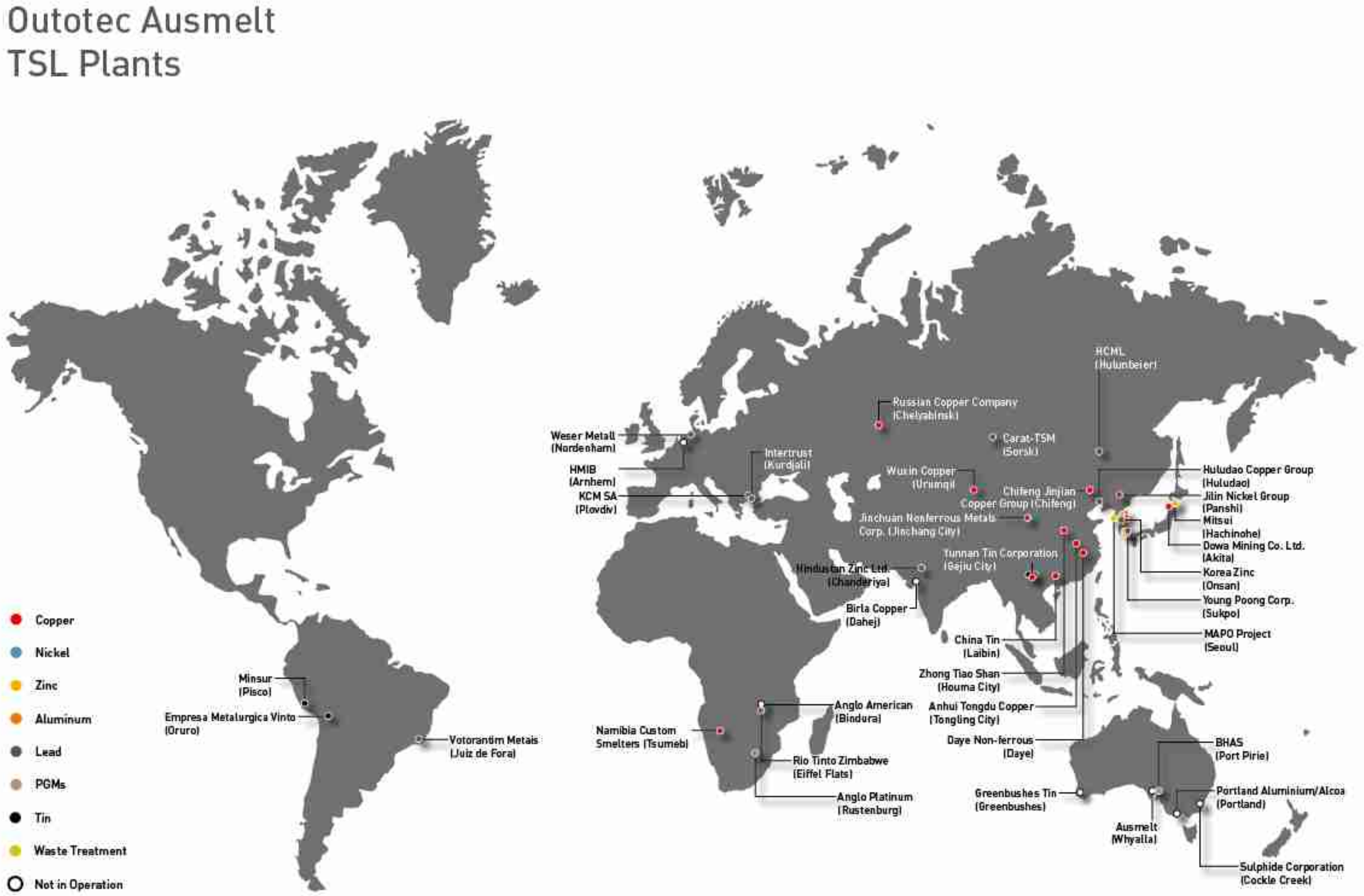
Controlling the Furnace

Controlling the slag…



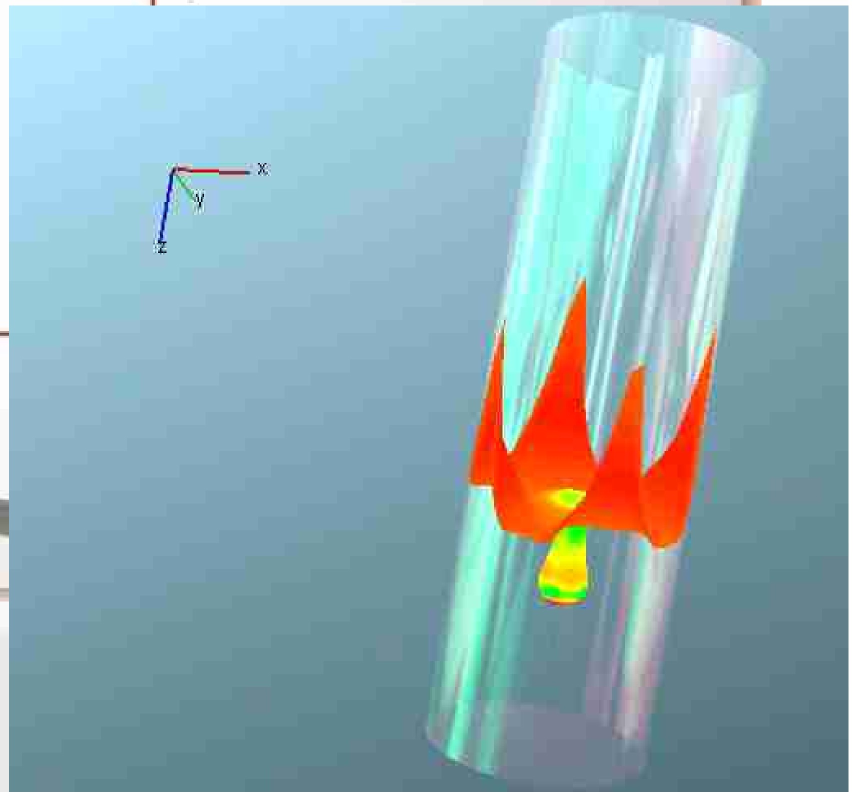
Resource Efficient Metal Production

Outotec TSL References around the World



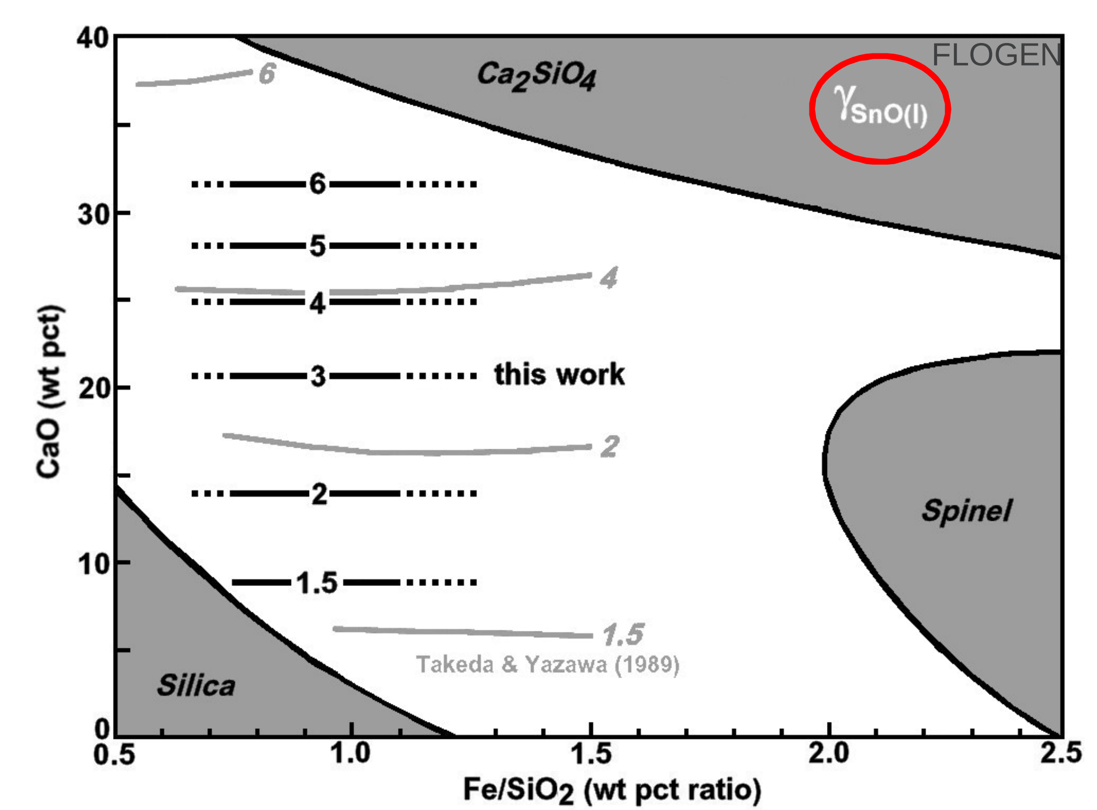
The physics and technology of separation…

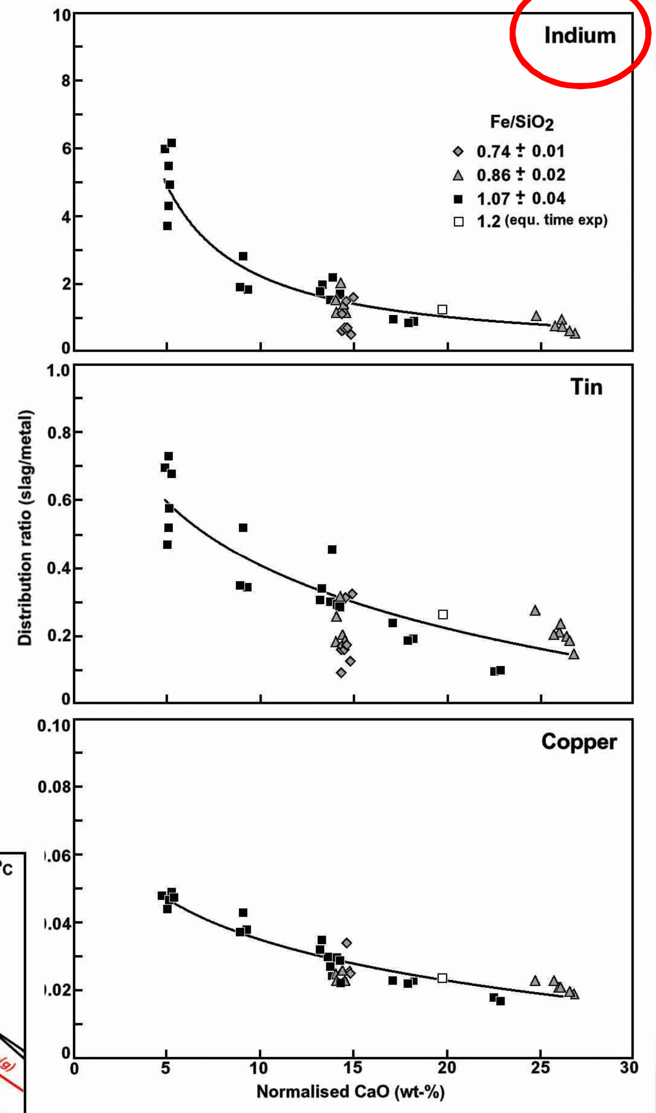
Understand the physics in the context of technology and economics

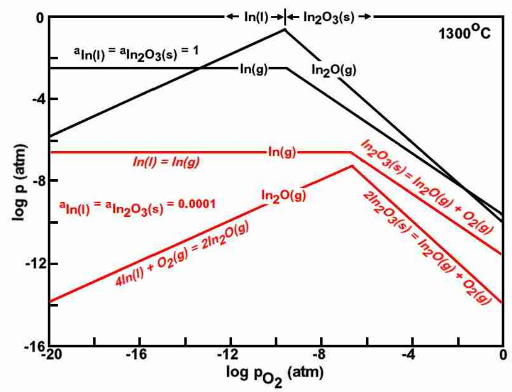


Understanding the deportation of elements

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

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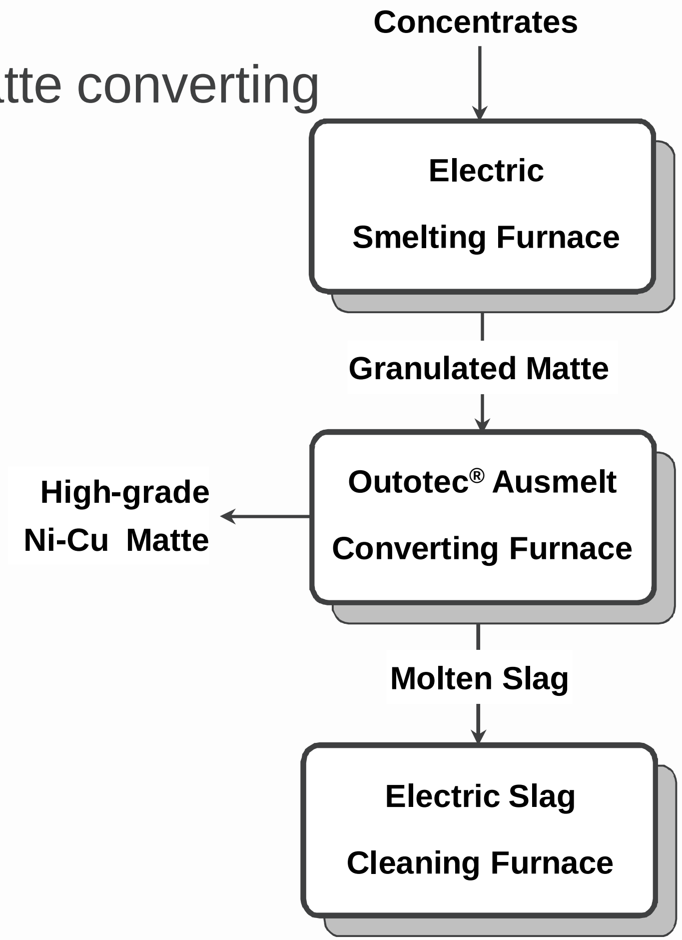
Outotec® Ausmelt Converting

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



Ausmelt in Zinc

- Reference Plant List

Client	Location	Year	Feed	Throughput
Korea Zinc (2x)	S. Korea		Zn Residue	120,000
Korea Zinc (2x)	S. Korea	2009	Zn Residue	120,000
Young Poong (2x)	S. Korea	2009	Pb Tailings	100,000
Korea Zinc (2x)	S. Korea	2007	Zn Residue	120,000
Young Poong (2x)	S. Korea	2006	Zn Residue	100,000
Korea Zinc (2x)	S. Korea	2002	Pb Tailings	100,000
Korea Zinc (2x)	S. Korea	1995	Zn Residue	120,000
Mitsui (2x)	Japan	1993	ISF Slag	80,000
Korea Zinc (2x)	S. Korea	1992	QSL Slag	100,000

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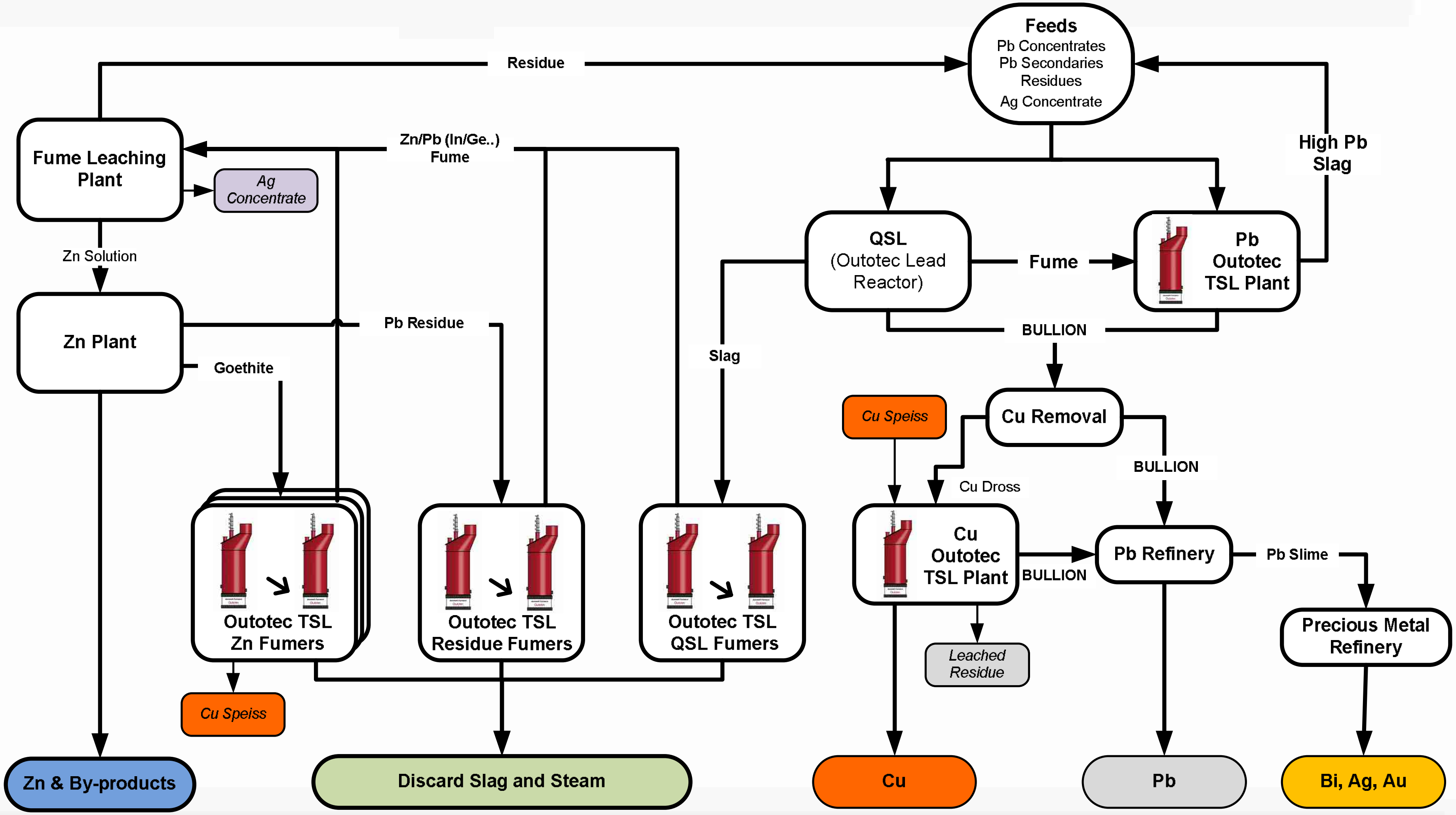
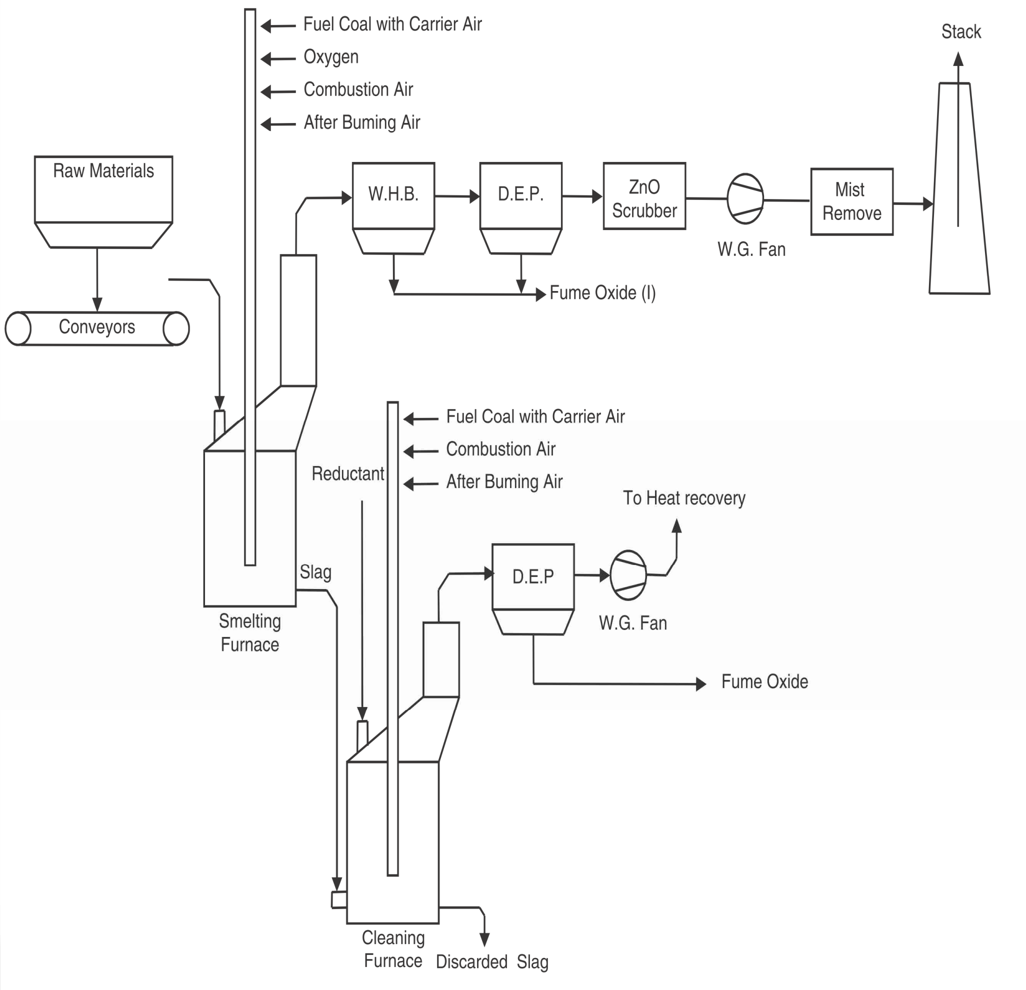
Zn Residue Processing
Korea Zinc applications of Outotec TSL Technology



Ausmelt in Zinc (TSL)

- Flowsheet of the "TSL Plant" at Sukpo Zinc Refinery (Young Poon South Korea)



Ausmelt in Zinc (TSL)

Item	Rate (kg/h)	Zn		Pb		Cu		Sb	
		mass%	kg	mass%	kg	mass%	kg	mass%	kg
<Input>									
Zinc residue	16,080	15.95	2,565	3.72					
Fuel coal	4,930								
Lump coal	1,200								
Silica sand	2,000								
Total	24,210		2,565						
<Output>									
Fume oxide	3,182	49.50	1,575	15.36					
*SFS	13,837	7.15	989	0.79					
Total			2,564						

Item	Rate (kg/h)	Zn		Pb		Cu		Sb	
		mass%	kg	mass%	kg	mass%	kg	mass%	kg
<Input>									
SFS	13,837	7.15	989	0.79	109	0.92	127	0.24	36
Fuel coal	900								
Lump coal	200								
Total	14,937		989		109		127		36
<Output>									
Fume oxide	807	67.10	541	8.00	65	0.20	2	0.20	2
Cu speiss	95					64.5	62	19.9	19
*CFS	12,800	3.50	448	0.34	44	0.50	64	0.12	15
Total			989		109		128		36

*CFS: Cleaning furnace slag.

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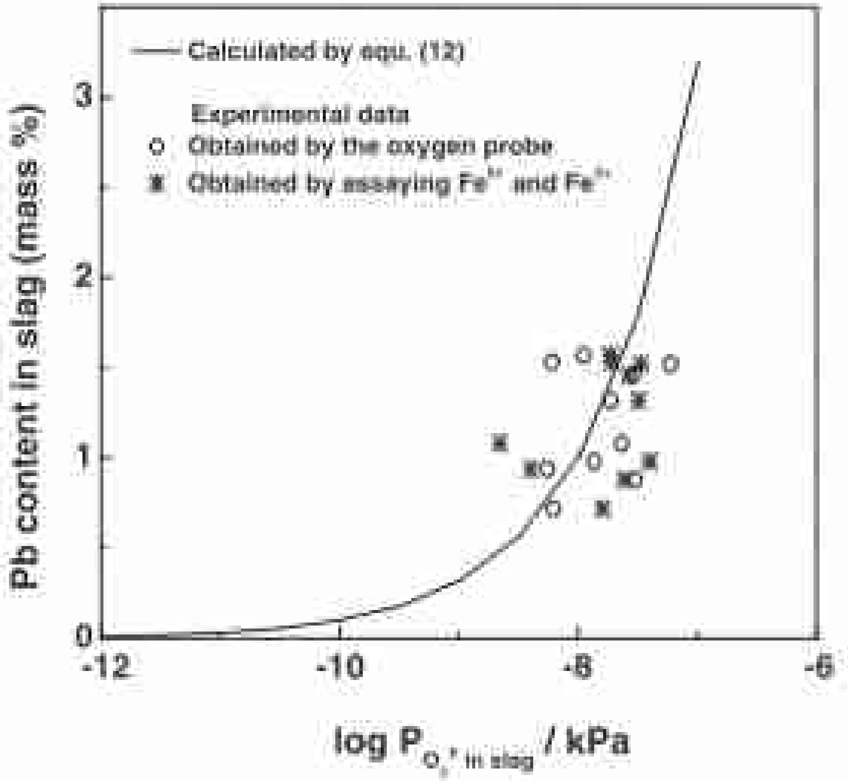
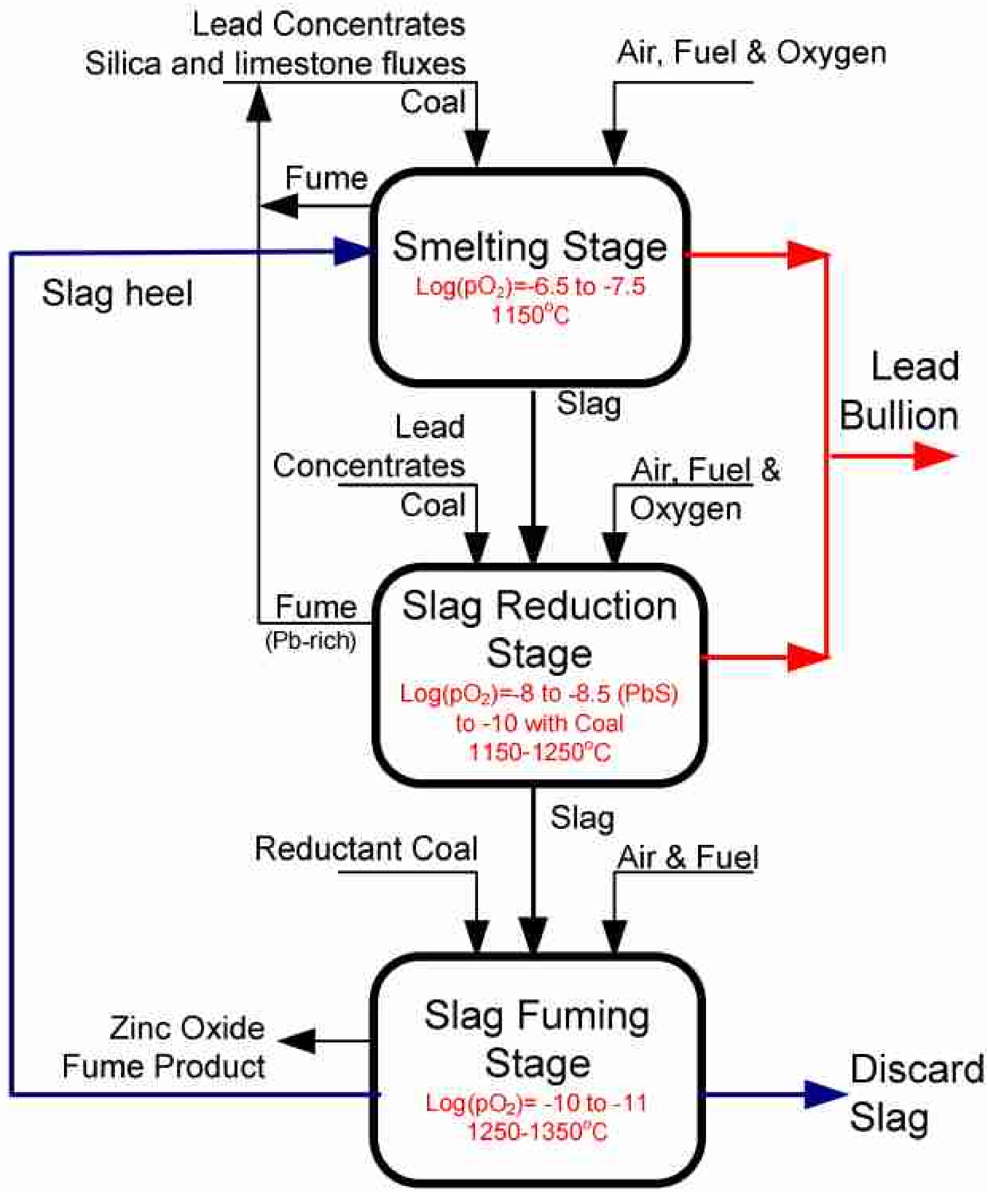
Ausmelt in Zinc





Products and Recoveries

- Products
  - Zn in solution
  - SO_2 stream (if S in feeds)
  - Slag and Tail gas to EPA standards
- Recoveries (typical values – indicative only)
  - Zn > 85%
  - Pb > 90%
  - Ag > 90%
  - In > 90%
  - Ge > 90%

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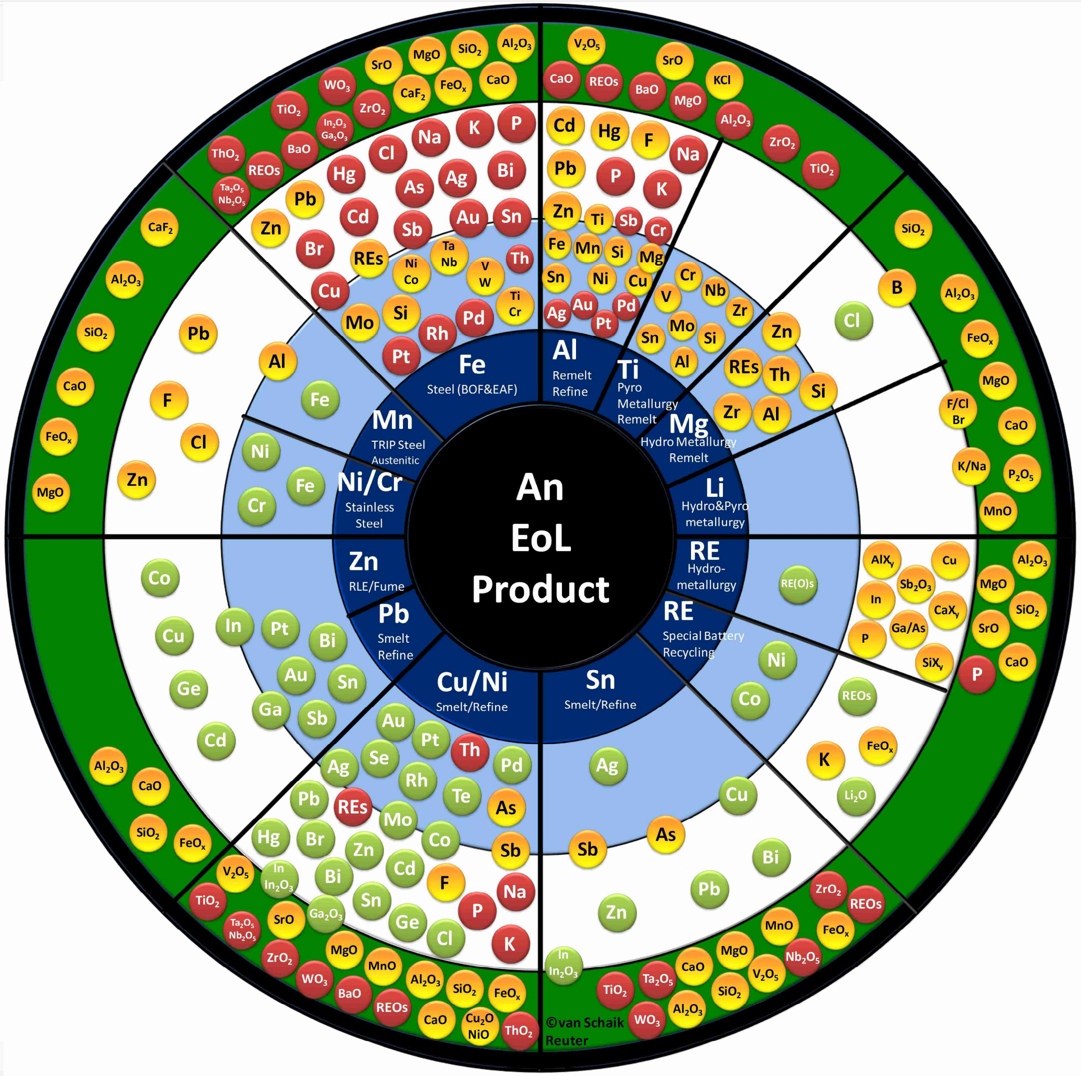
Design for Resource Efficiency



The Main Thermodynamic and Economic Destination of Metals, their Alloys and Compounds from EoL Products for the Best Available Technique (BAT) Processing Routes (Segments in Figure)

Society's Essential Carrier Metals: Primary Product
Extractive Metallurgy's Backbone (primary and recycling metallurgy)
The metallurgy infrastructure makes a "closed" loop society and recycling possible.

Dissolves mainly in Carrier Metal if Metallic (Mainly to Pyrometallurgy)
Valuable elements recovered from these or lost (metallic, speiss, compounds or alloy in EoL also determines destination as also the metallurgical conditions in reactor).

Compounds Mainly to Dust, Slime, Speiss, Slag (Mainly to Hydrometallurgy)
Collector of valuable minor elements as oxides/sulphates etc. and mainly recovered in appropriate metallurgical infrastructure if economic (EoL material and reactor conditions also affect this).

Mainly to Benign Low Value Products
Low value but inevitable part of society and materials processing. A sink for metals and loss from system as oxides and other compounds. Comply with strict environmental legislation.

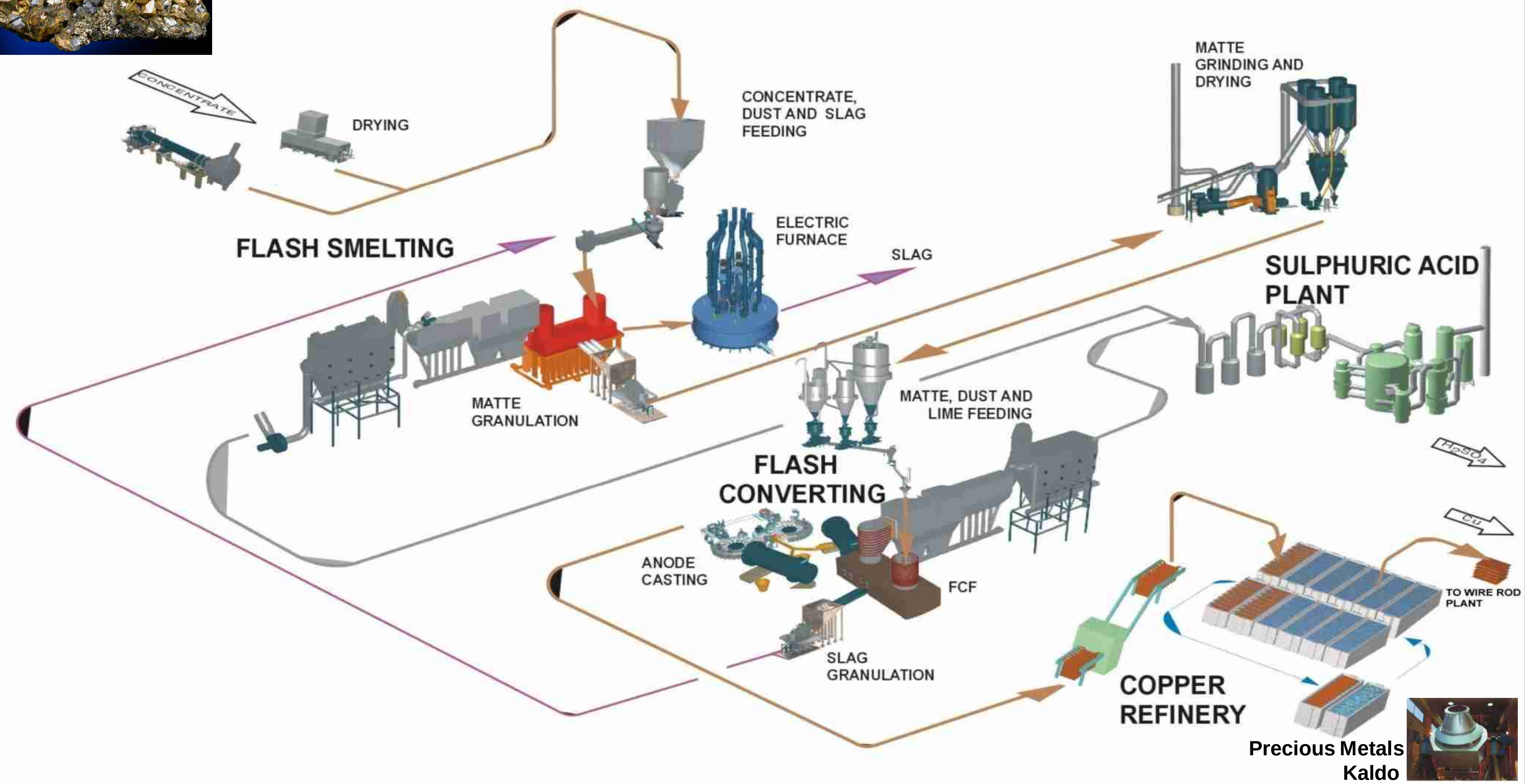
El **Mainly Recovered Element**
Compatible with Carrier Metal as alloying Element or that can be recovered in subsequent Processing.

El **Mainly Element in Alloy or Compound in Oxidic Product, probably Lost**
With possible functionality, not detrimental to Carrier Metal or product (if refractory metals as oxidic in EoL product then to slag / slag also intermediate product for cement etc.).

El **Mainly Element Lost, not always compatible with Carrier Metal or Product**
Detrimental to properties and cannot be economically recovered from e.g. slag unless e.g. iron is a collector and goes to further processing.

Design for Resource Efficiency

PROCESS FLOW SHEET OF COPPER PRODUCTION



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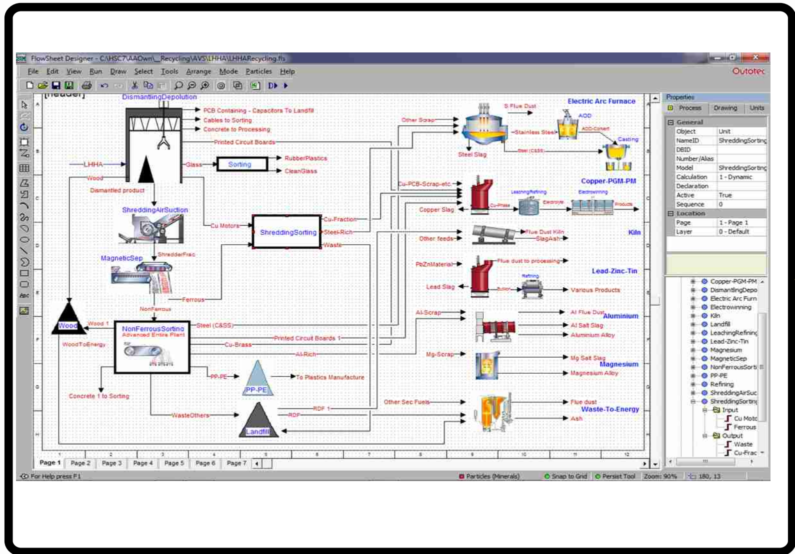
Measuring Sustainability, Resource Efficiency

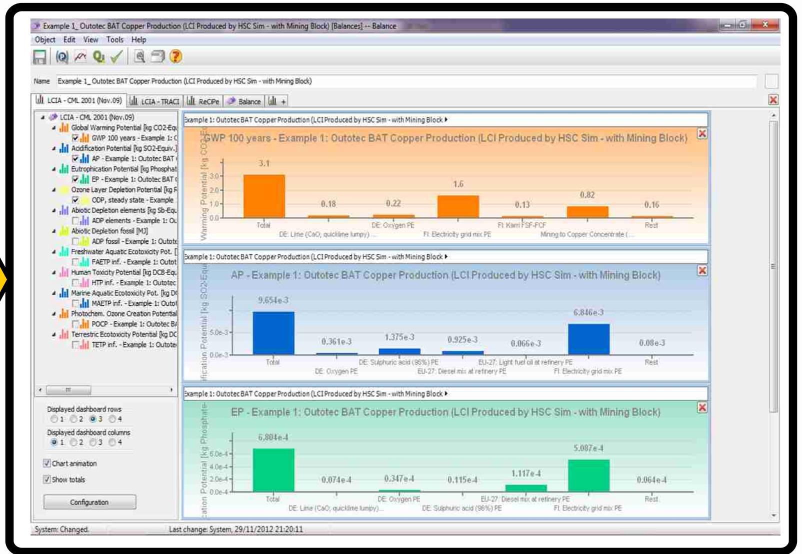
OT's HSC Sim 7.1x

(>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 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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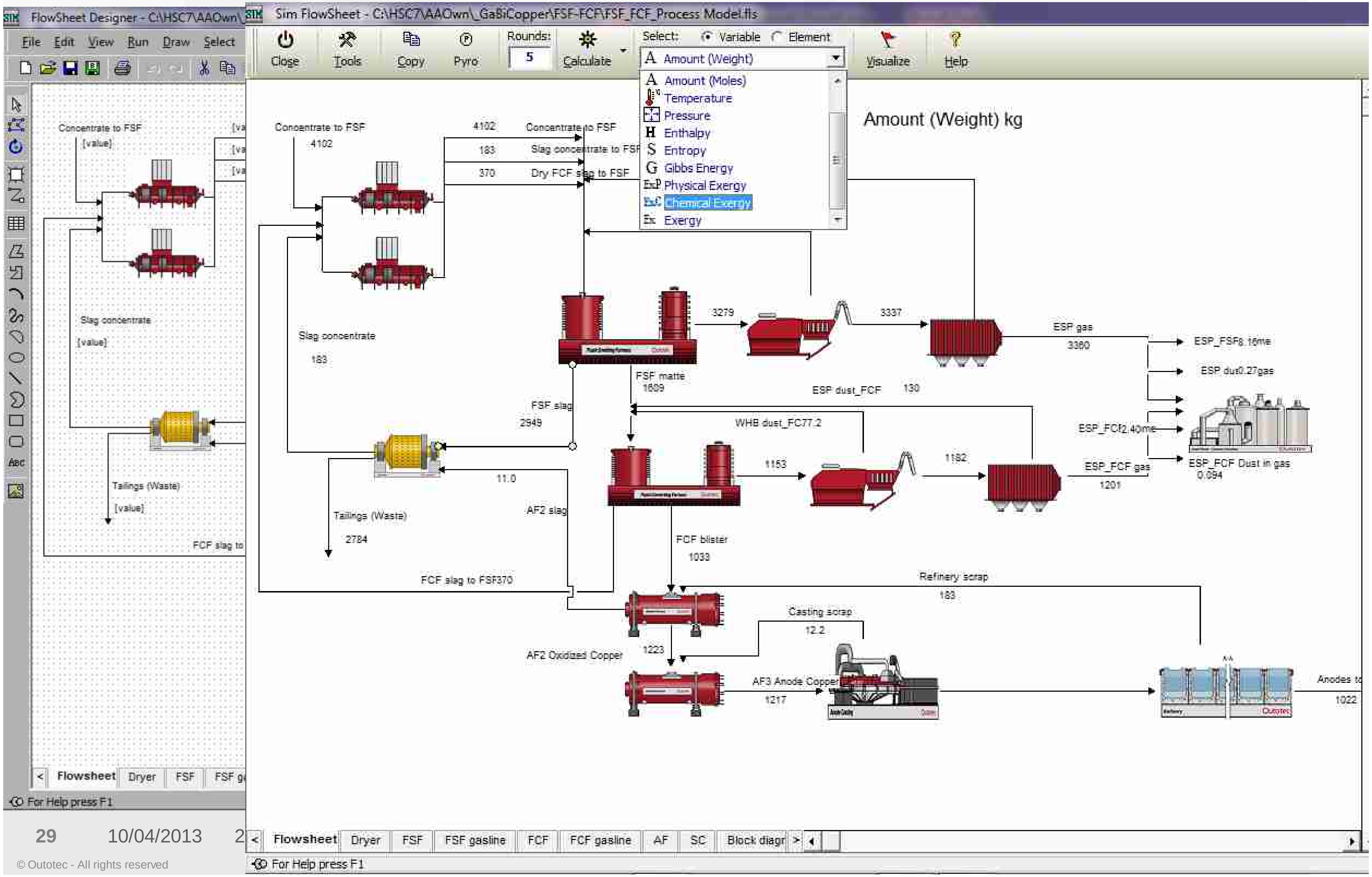
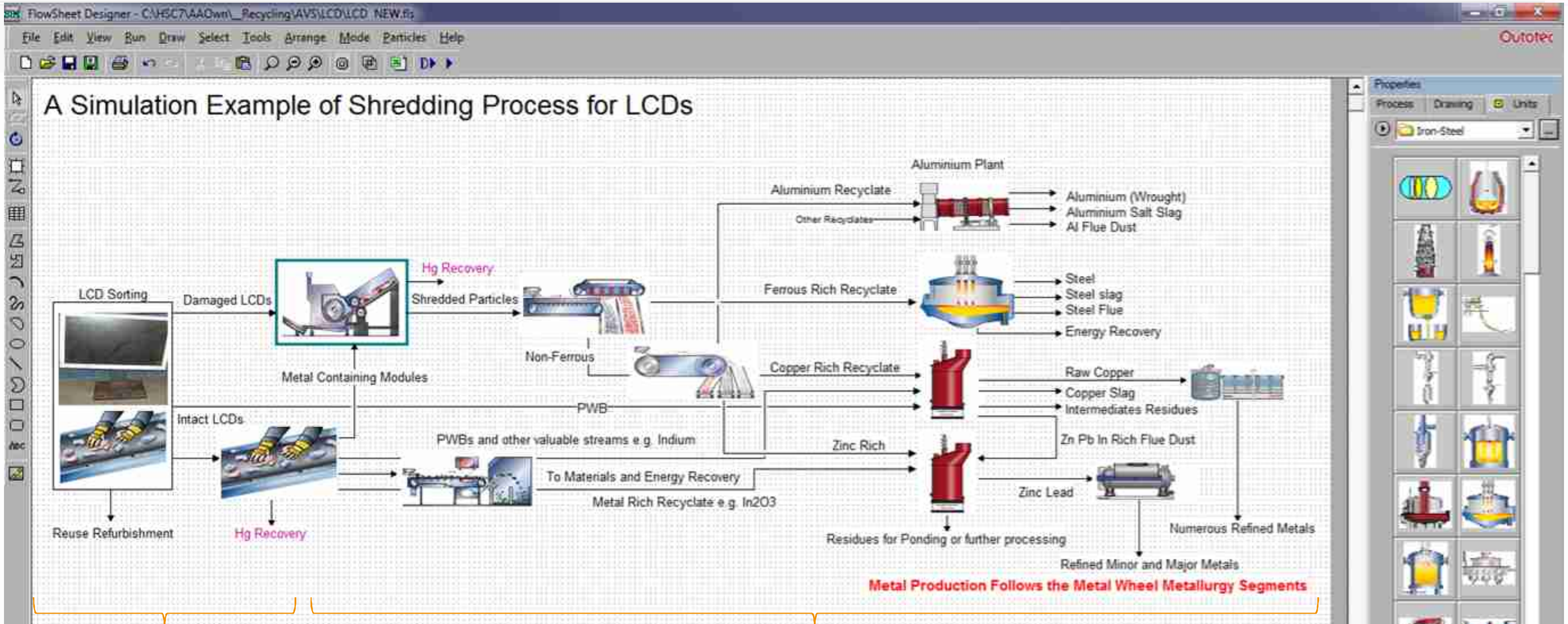
Design for Resource Efficiency



Urban Mining, Ecodesign, OEMs
Recyclability Index

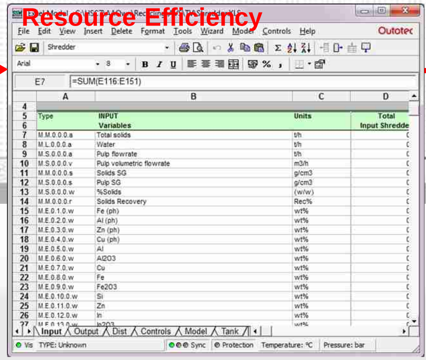


Product compositional data

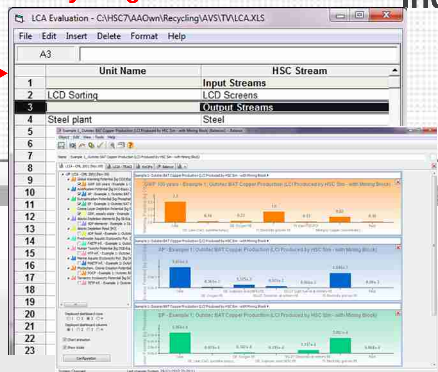
Bill of Materials
Chemical content
Full Material Declaration
Structural product data / exploded views
Etc.

Simulated Recycling & Recovery rates

Resource Efficiency



Environmental analyses recycling



= Recyclability Index

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Design for Recycling & Metal Recoverability

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  - Designer Minerals (e.g. cars, mobiles etc.) are far more complex than geological minerals; complicating recovery, requires rigorous system design taking all elements / compounds / materials into consideration.
  - To “close” the loop requires a deep understanding and harmonization between all actors of the system than is the case presently.
  - Design for Recycling and Resource Efficiency requires a deep physics, technology, economics & Product Centric thinking **Designer “rock” to metal**

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Sustainable use of Earth's natural resources

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www.outotec.com/sustainability

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