



Rethinking the lifecycle of materials and metals

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<https://dgm.de/materialsweek/>

Lessons Learnt

Lesson learnt n°1

- A landmark for metallurgists



Lesson learnt n°1

- Baptismal Fonts (1107-1118)
 - Lost wax brass casting
 - Aurichalcum



Lesson learnt n°1

- First ever building covered with zinc sheets (1812)
 - Development of Altenberg / Vieille-Montagne(1806-...)
 - Now Umicore, Nyrstar,...



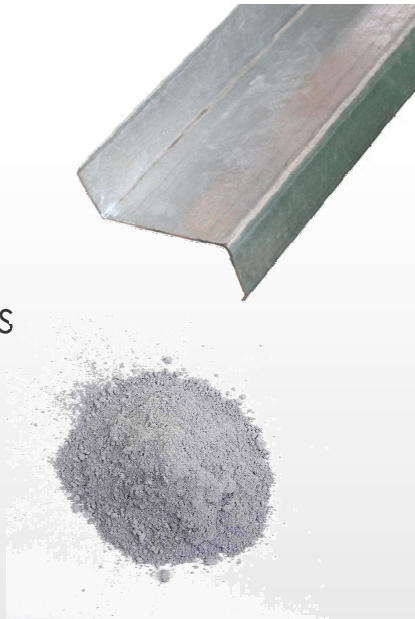
Roofs of Paris (Hausmann, 1860)
Future World Heritage ?

Lesson learnt n°1

- Zinc sheets
 - Environmentally friendly specifications for zinc sheets
 - Lo-Pb, Lo-Cd

- Galvanized steel
 - 50% current zinc use

- Zinc oxide powders
 - Paper, rubber,...



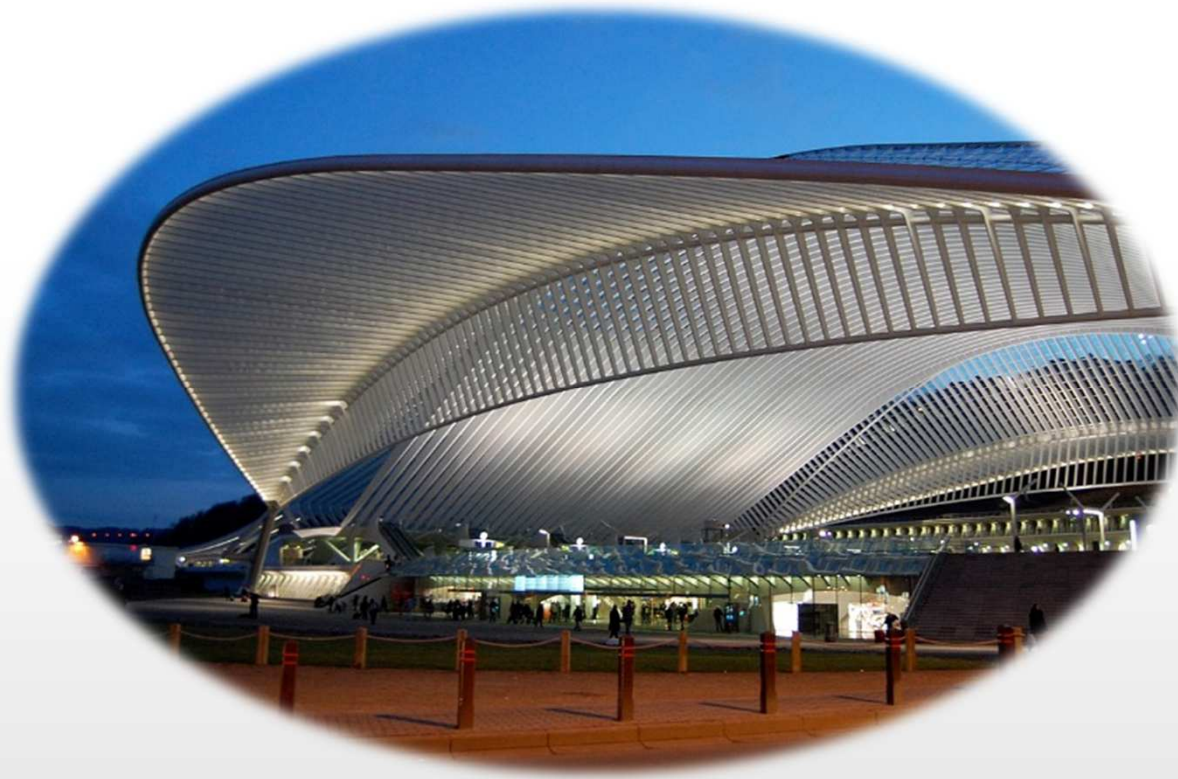
Lesson Learnt n°1

- Specifications should be adapted to stimulate recycling
 - Why such a high purity on our roofs?
- Dispersion should be limited
 - Roofs of Paris vs. batteries and PV panels in Africa
- Dissipative use should be limited
 - Massive and uncoated is better than galvanised
- Ban of metals should be considered in a global perspective
 - Importance of lead metallurgy



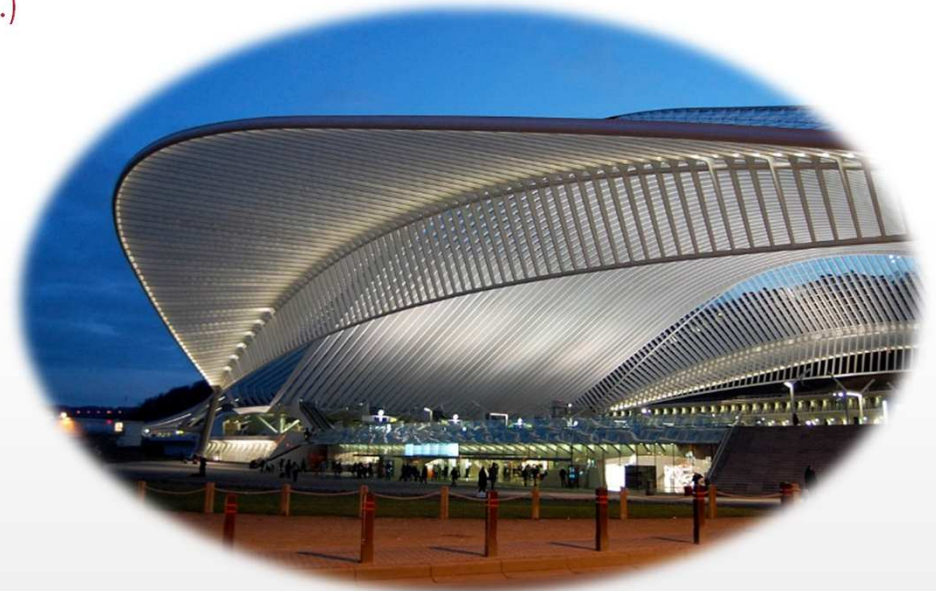
Lesson learnt n°2

- A future urban mine ?



Lesson learnt n°2

- Previous railway station lasted < 50 years
 - Poor quality (insulation, ...)
 - No anticipation for growing needs (ICE-TGV trains,...)
 - ...
- How long will this one last ?
 - 500 years ?
 - More ?
- Large stock of iron in the Anthroposphere
 - 10 tons steel / cap. in Europe



Lesson learnt n°2

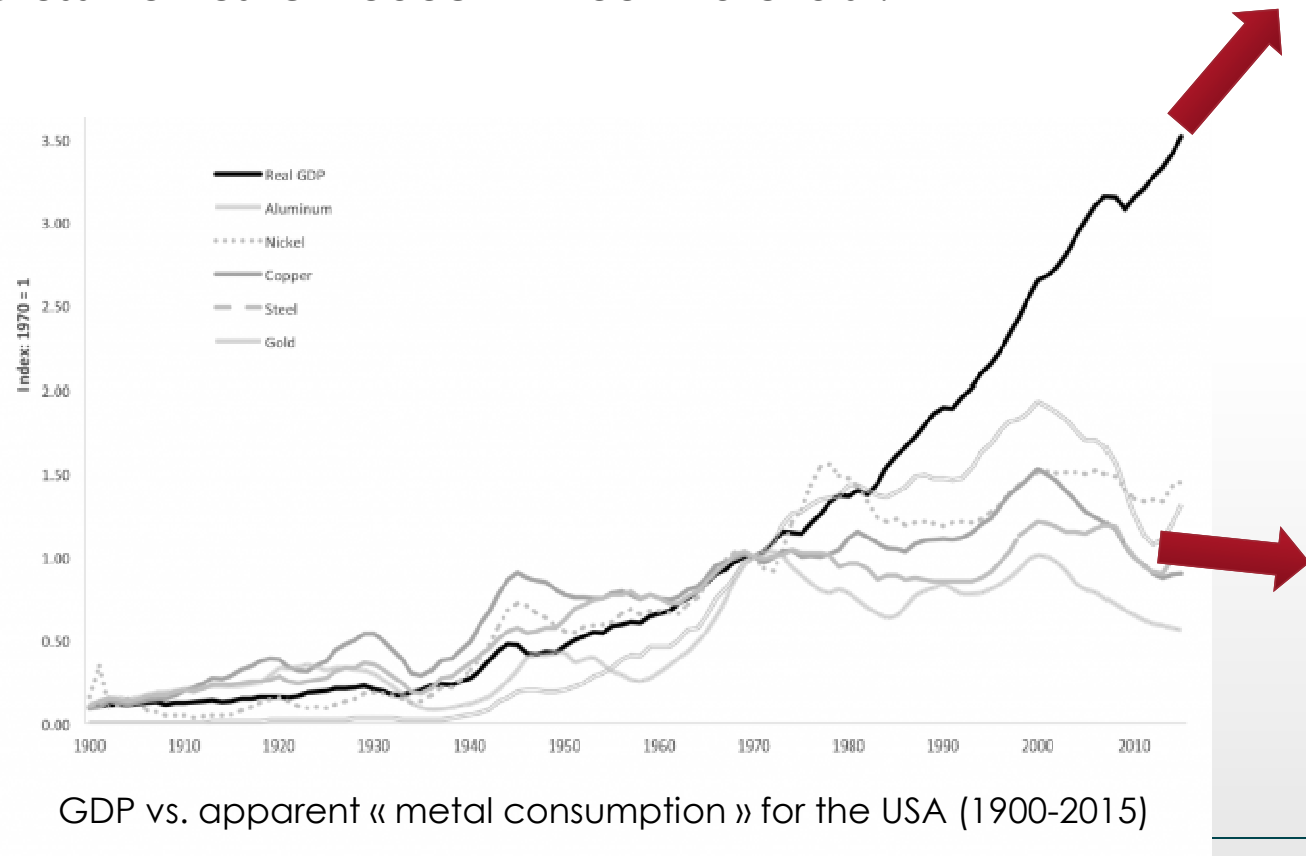
- Products should have very long lifetime
- Urban mines must have high grades
 - Banded Iron Formation (60% Fe)
 - Steel (99% Fe)
- Urban mines must reach large tonnages
- Urban mines should contain a limited diversity of materials
 - Steel
 - 304 vs 316 (2% Mo)
 - Stainless Steel (Cr, Ni,...)
 - MicroAlloyed Steel (Nb, V, ...)
 - < 1% Nb



Green Deal, Dematerialisation and Security of Supply

Green Deal, Dematerialisation & Security of Supply

- Increasing the Gross Domestic Product without Materials ?



Green Deal, Dematerialisation & Security of Supply

- E-mobility and technobesity
 - Mini 1960 (600 kg) – Mini SE 2021 (1440 kg)



1960

2010

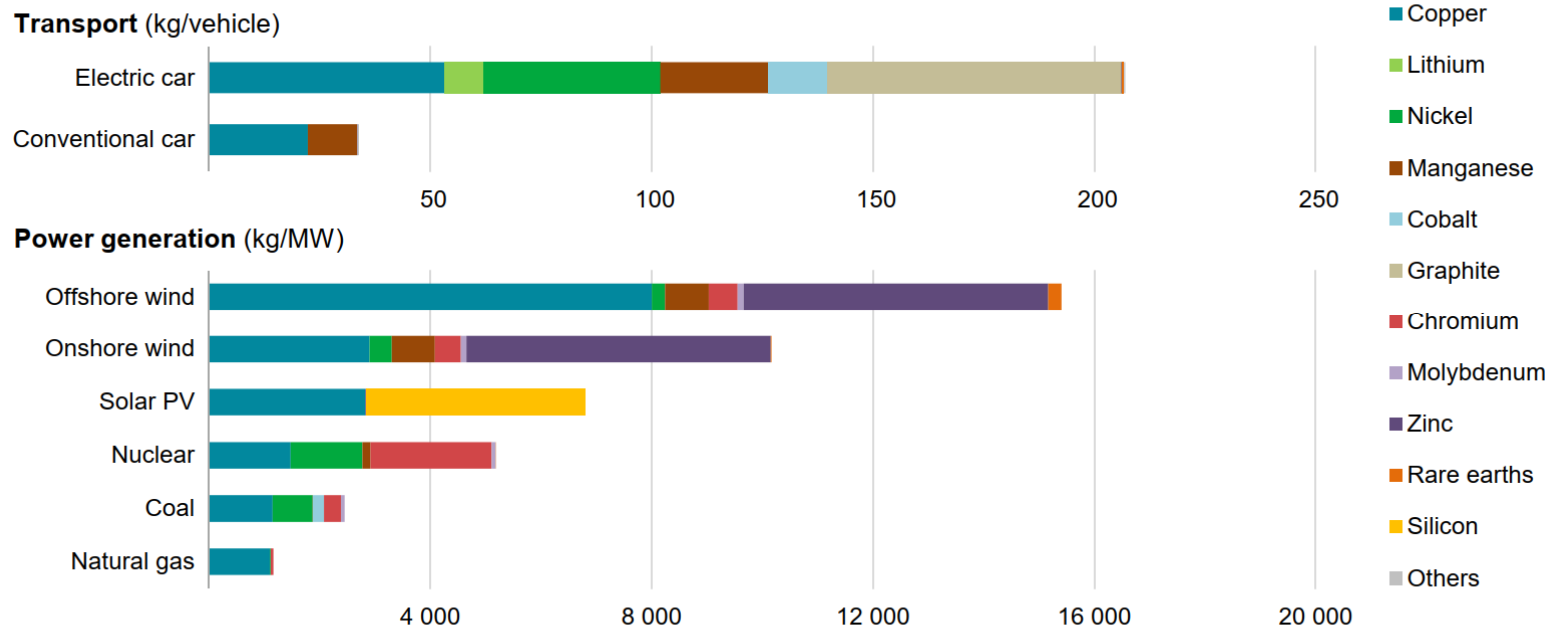
Green Deal, Dematerialisation & Security of Supply

- A green wish ...

The Role of Critical Minerals in Clean Energy Transitions



Minerals used in selected clean energy technologies



Green Deal, Dematerialisation & Security of Supply

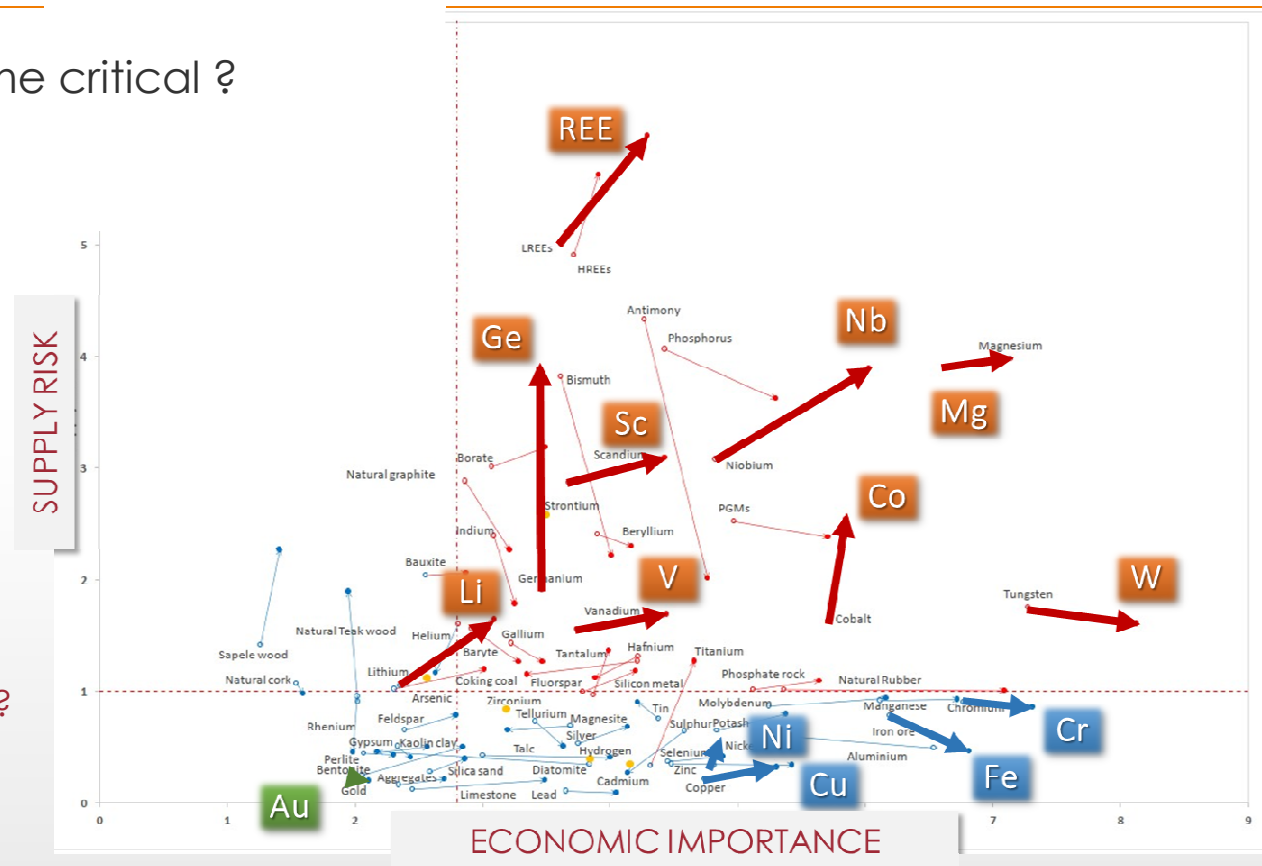
- Our first mission is to feed the loop
 - Recycling alone cannot satisfy our needs...



Feed the Loop

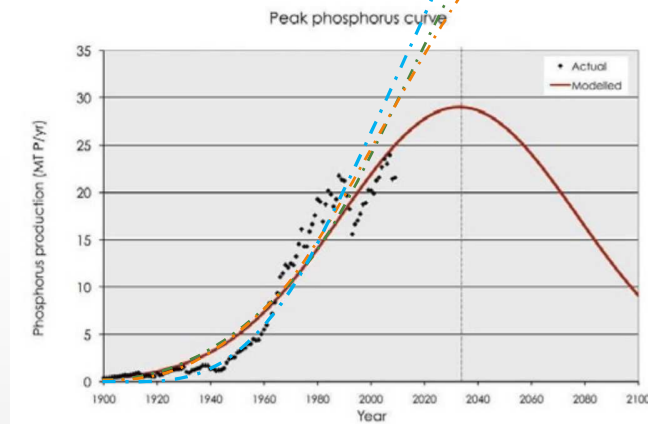
Feed the Loop

- Why did metals suddenly become critical ?
 - Carelessness for decades
 - Mostly geopolitics
 - Willingness to open new mines in EU?
 - Social License to Operate ?



Feed the Loop

- When will we run out of metals ?
 - Peak theories
 - Ill-posed problem
 - No way to know the shape
 - Limited exploration
 - Potential to go much deeper
 - for metals
 - not for sand, clay, etc. !

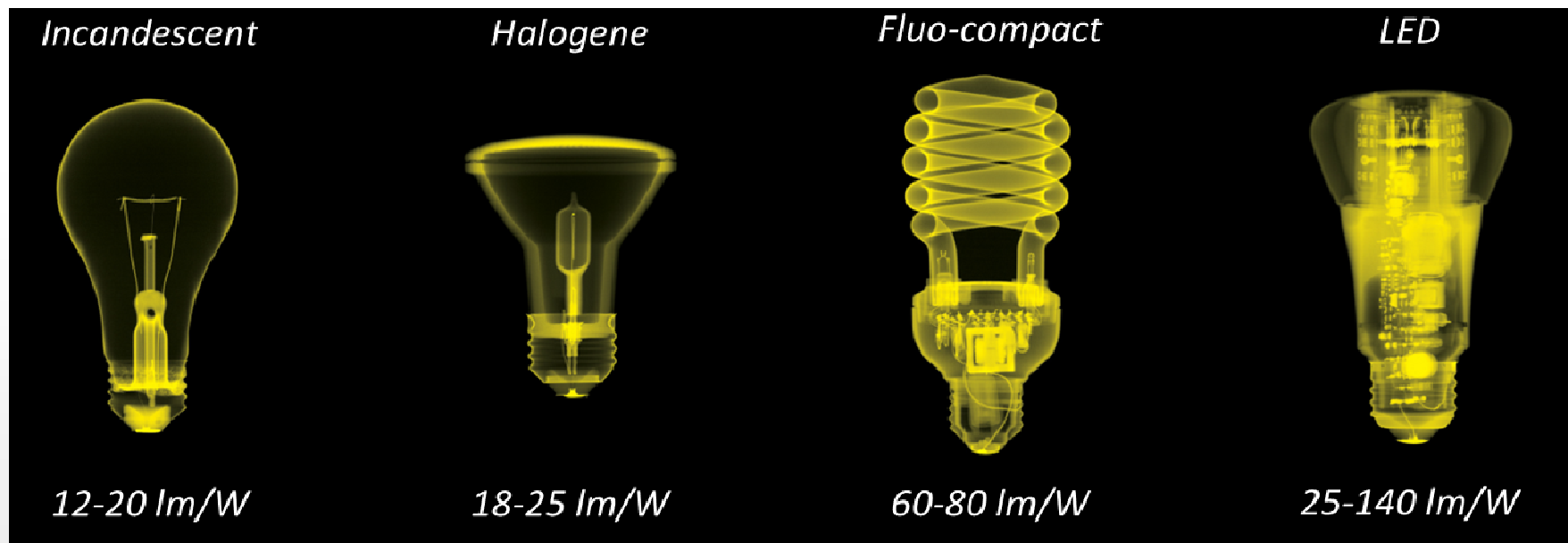


Global Phosphorus Research Initiative

Feed the Loop

Therefore, instead of worrying about reaching “peak” production or “exhausting” a resource, we should instead be more **concerned about what we do with the resource** after it has been extracted.

Meinert et al., 2016, Mineral Resources: Reserves, Peak Production and the Future



Not just the lifecycle analysis of the use phase...

Compromising Circularity

Compromising Circularity

- Compromising actions (Van Oers et al. 2020) (Dewulf et al., 2021)
 - Environmental Dissipation; Tailings
 - Abandoned stock; Hoarded stock; Landfilling
- Mining transfers materials from the geosphere to the anthroposphere
 - Ownership is passed to customers



| | ICE Vehicle |
|----------|-------------|
| Fe | 68 % |
| Polymers | 12 % |
| Al | 7 % |
| Rubber | 4 % |
| Glass | 3 % |
| Zn | 1,5% |
| Cu | 1% |
| Others | 4 % |



| | Smartphone with battery |
|----------|----------------------------|
| Polymers | 19,2 % |
| Glass | 19,4 % |
| Cu | 10,7 % |
| Co | 8,4 % |
| Ni | 1,2 % |
| Li | 0,8 % |
| ... | |

Compromising Circularity

- Compromising actions (Van Oers et al. 2020) (Dewulf et al., 2021)
 - Dispersion in the Anthroposphere
- Enhanced functionality often at the expense of recyclability



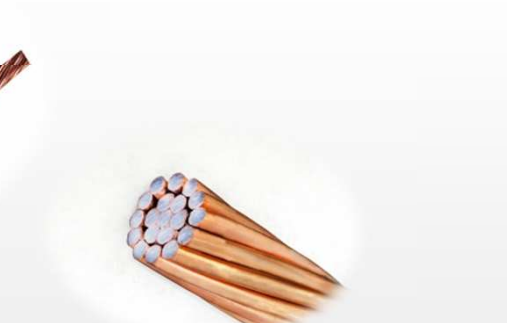
Cu sanitary tubes



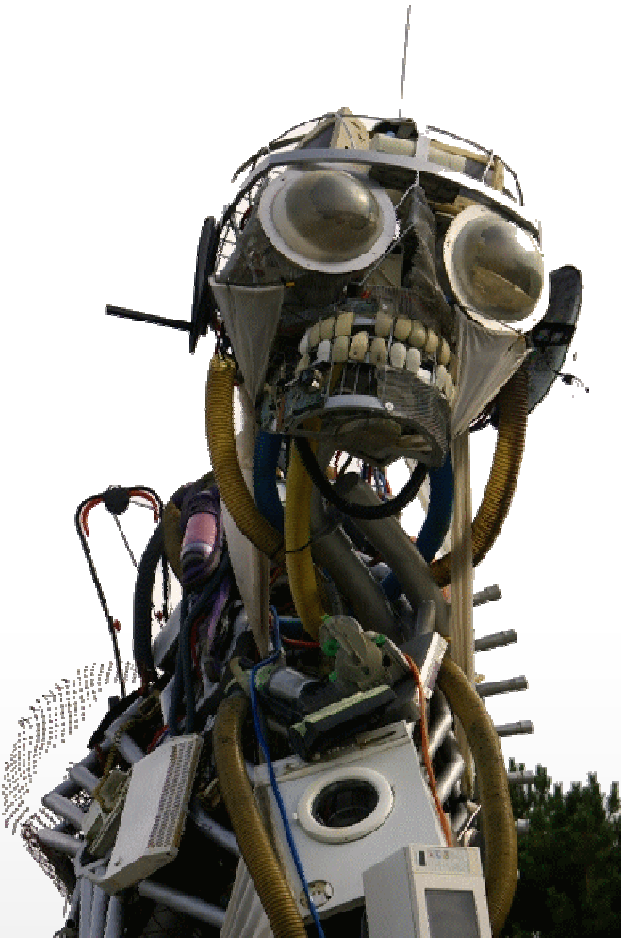
ALPEX tubes



Cu electric cables



Copper Clad Aluminium (CCA) cable



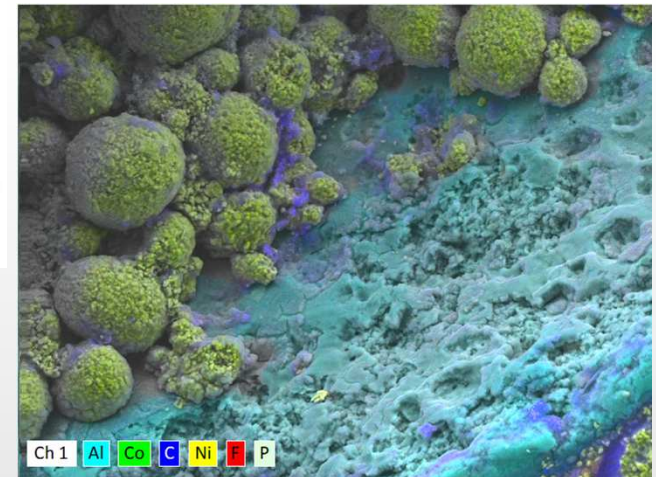
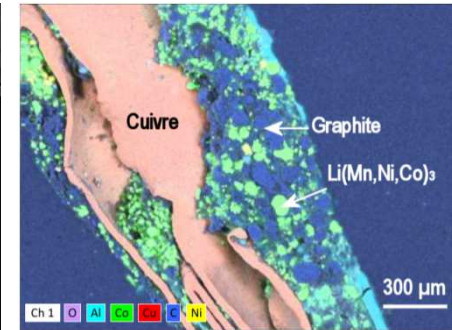
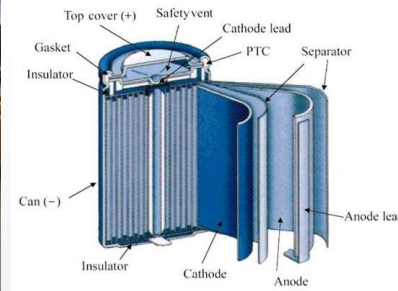
WEEE sculpture (Eden Project, UK)

The art of exploiting urban mines

Closing the Loop

The art of exploiting urban mines

- Dismantling of e-scooter
- Electrodynamics fragmentation of Li-ion batteries
 - Black mass binder (PVDF); Adhesion to Cathode;...



The art of exploiting urban mines

- Dismantling and Shredding of end-of-life hybrid plug-in vehicles
 - 7 000 CV (5 cars/min)



The art of exploiting urban mines

- Pre-Processing

Technical sand



Plastic



Ferrous

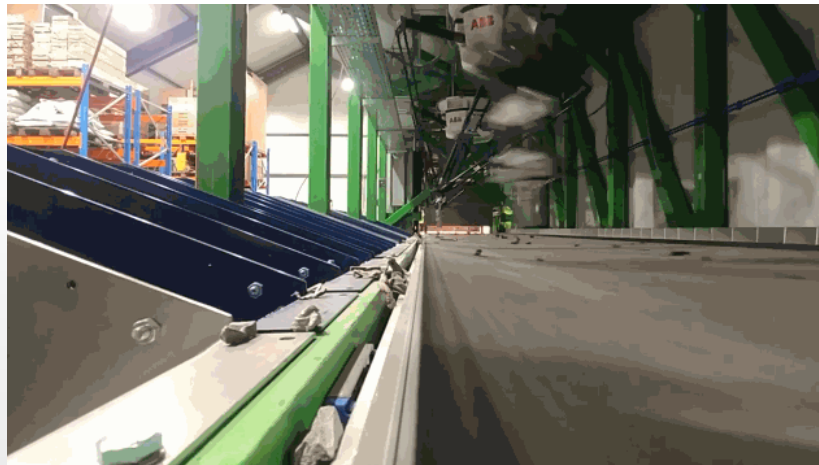
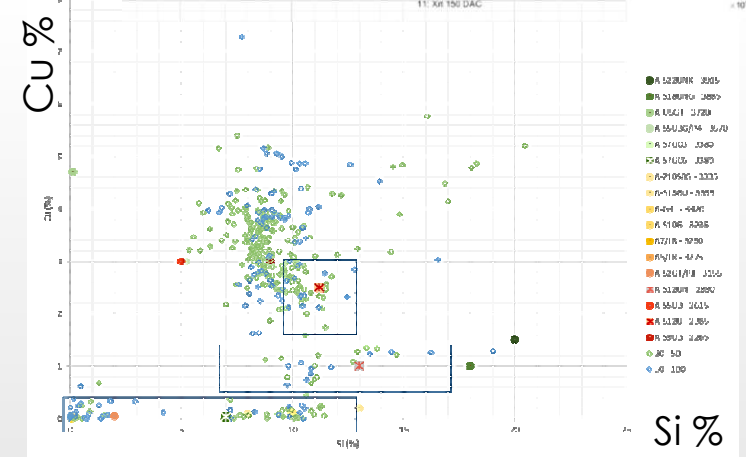
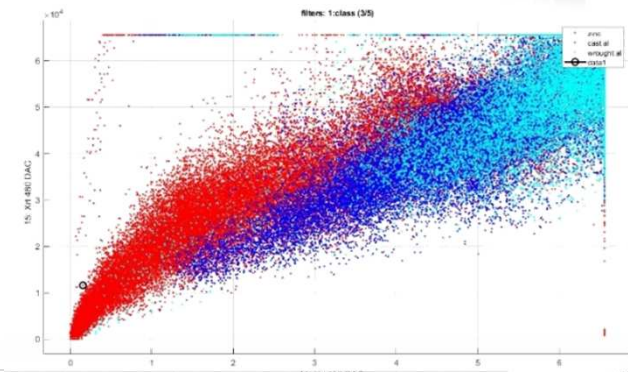


Non-Ferrous Scraps



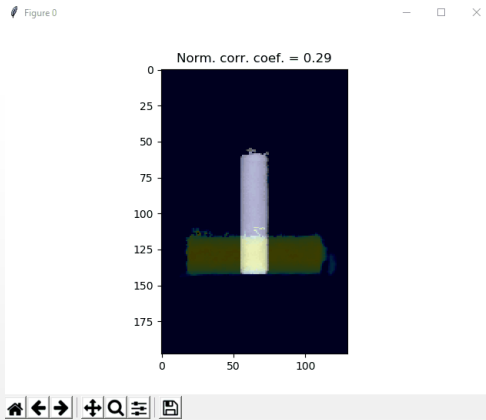
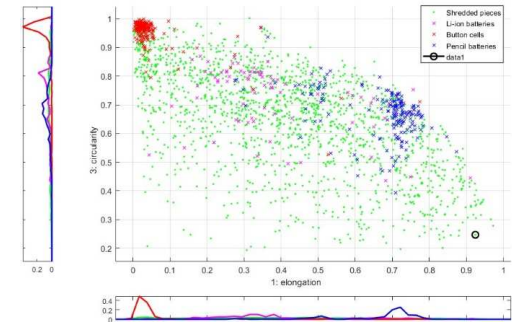


- Real-time identification of scraps (10^9 pcs/yr)
 - Multiple **sensing** (3D, VNIR, XRT, LIBS,...)
 - **Deep learning** algorithms
- Functional recycling (6 t/h)
 - Grouping specific alloys into **multiple bins**
 - Delta **robots**



Transportable sorting plant – 5 robots

- Real-time sorting of batteries recovered from shredded WEEE
 - Using shape descriptors: low precision in concentrate
 - Using template matching: acceptable results, but room for improvement

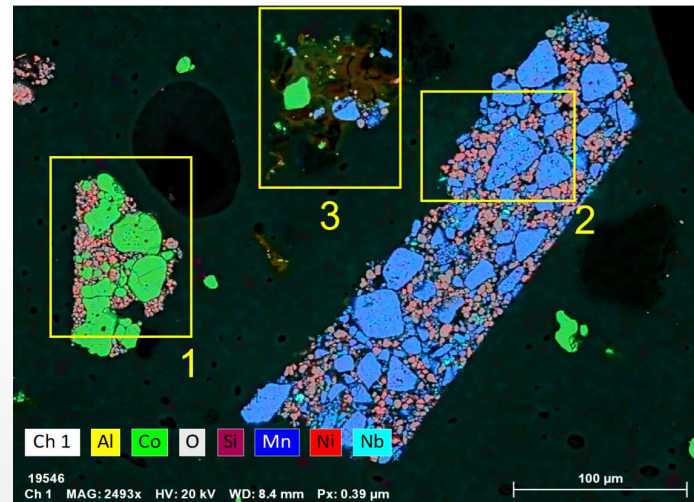


| | Masse (Kg) | Pourcentages | |
|--------------------------------|--------------|--------------|------------------------------------|
| Déchets | 6.87 | | |
| Piles dans déchets | 0.215 | 3.0% | % piles éch. dans déchets |
| Concentré piles | 6.46 | 91.1% | % piles éch. dans concentré |
| Déchets dans concentré | 0.41 | 6.0% | pollution du concentré |
| Déchets dans: trier à la main | 1.54 | 5.9% | % piles éch. dans classe 4 |
| Piles dans: trier à la main | 0.415 | | |
| Total masse échantillon | 15.91 | | |

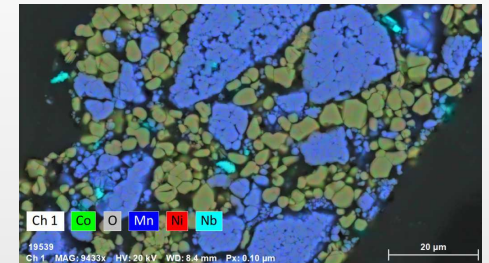


The art of exploiting urban mines

- Exploring metal deportment in WEEE
 - Phase mapping using SEM-EDX automated microscopy

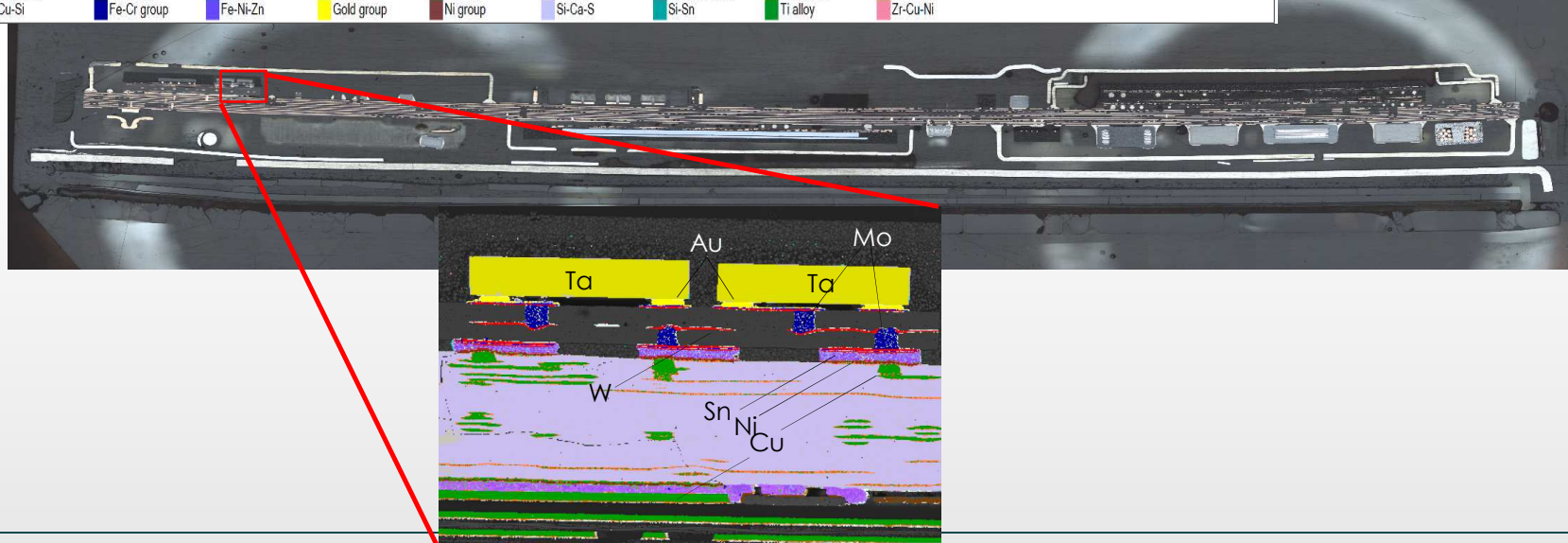
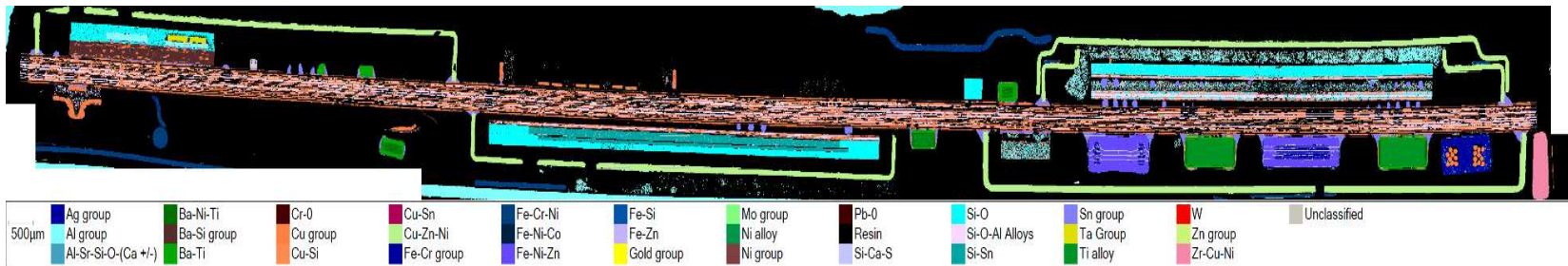


Exploring the Black Mass in LIBs



The art of exploiting urban mines

- Exploring metal deportment in Smartphones



The art of exploiting urban mines



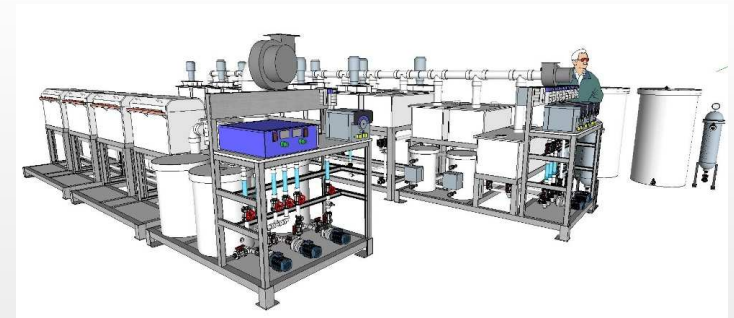
- Recovering copper by dissolution of complex copper-bearing phases



Hydrometallurgical pilot facilities @ULiege



Leaching, solvent extraction and electrolysis to obtain a 99,98% Cu cathode @ULiege



3D model of the solvent extraction facility

The art of exploiting urban mines



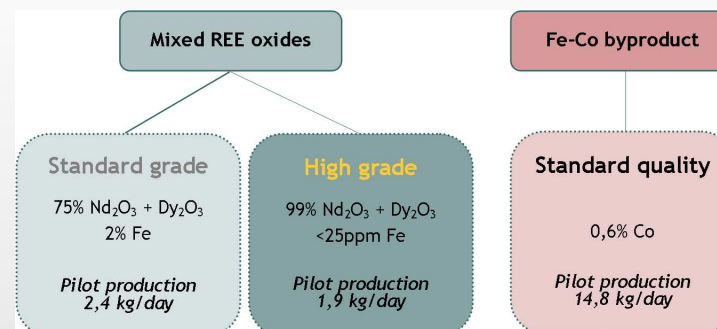
- Manual dismantling of supermagnets
 - 1,2 kg of REE in the rotor segments of the electrical engine

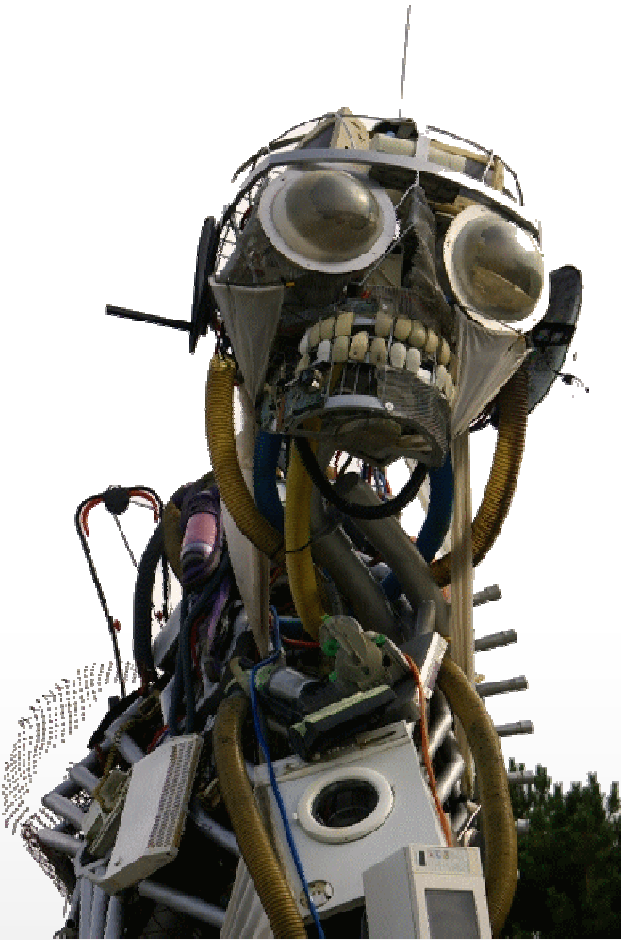


Manual dismantling and recovery of NdFeB magnets after thermal demagnetization



- Extractive metallurgy of Nd
 - 4 stage low T° ($< 80^{\circ}$)
 - 95 % recovery
 - Mixed REO & Fe-Co byproduct





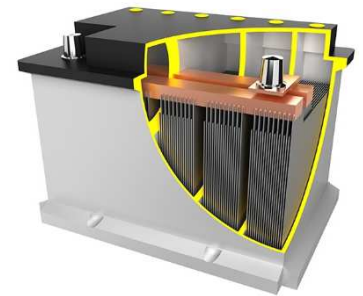
WEEE sculpture (Eden Project, UK)

A Circular Economy Finally ?

Still a long way to go

A Circular Economy Finally ?

- Tonnage
 - Limited physical dispersion - Capacity to transport and collect back
- Grade
 - Privilege massive materials vs. composites. Limit dispersive use (filler, coating, ...).
- Metal department
 - Stable and mature technologies. Identification for sorting/grouping
- Liberation
 - Limit electronics, sensors, nano-microassemblages. Facilitate dismantling. Removable binders



A Circular Economy Finally ?

- Keep in mind
 - 95% recovery leaves only 50% after 14 cycles



Thank You