



Université  
de Liège



**GeMMe**  
Minerals Engineering, Materials & Environment

*Sustainable resource availability.  
Ge, Ni, Al three contrasting stories*

**Eric PIRARD**



# GeMMe

## Minerals Engineering, Materials & Environment

GeMMe operates on the characterization, valorization, transformation, use and recycling of mineral materials at any stage of their life cycle.



- 3 research units – 40+ researchers
  - Building materials
  - Minerals engineering & recycling
  - Georesources & Geo-Imaging
- 2.5 M€ annual turnover
  - 40% contracts with private partners

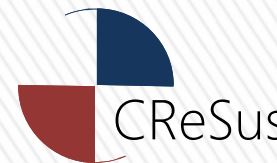


EDUCATION



**EMERALD**  
ERASMUS MUNDUS MASTER  
IN GEORESOURCES ENGINEERING

RESEARCH & INNOVATION



**Centre for Resource Efficiency  
and Sustainability**  
(Regional Gvt : 40 M€)



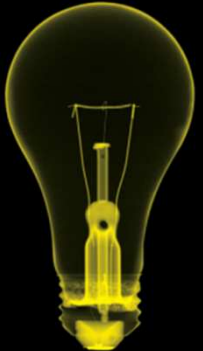



Université de Liège - GeMMe - Génie Minéral, Matériaux & Environnement





# What is progress ?

Future products will not only be optimized with regard to their *functionality* but also their *recyclability* and the *sustainable availability* of resources

<i>Incandescent</i>	<i>Halogene</i>	<i>Fluo-compact</i>	<i>LED</i>
			
<i>12-20 lm/W</i>	<i>18-25 lm/W</i>	<i>60-80 lm/W</i>	<i>25-140 lm/W</i>
Tungsten Glass,...	Tungsten Iodine, Bromine, ... Glass,...	Tungsten Mercury, Rare Earths, ... Glass, Plastics,...	Gallium Indium, Cerium, Yttrium, Copper, Silver, Silicium, ... Plastics, ...







# *Resource Availability*

*A sudden awakening*



# Resource Availability

*A sudden awakening*

- < 1985
  - **Compilation of Mineral/Metal Statistics**
    - Market vs. Non-market driven economies
- 1985-2008
  - **Complete disinterest**
    - Minimum data through USGS Mineral Commodity Summaries
- > 2008
  - **China declares REE export quota**
    - EU Raw Materials Initiative (2009)
    - Minerals, Critical Minerals, and the U.S. Economy (NRC, 2008)
    - Critical Raw Materials for the EU (2010)
    - JPN-EU-US Trilateral conference on critical materials (2011, 2012, 2013)

**Critical**

**Scarce**

**Strategic**

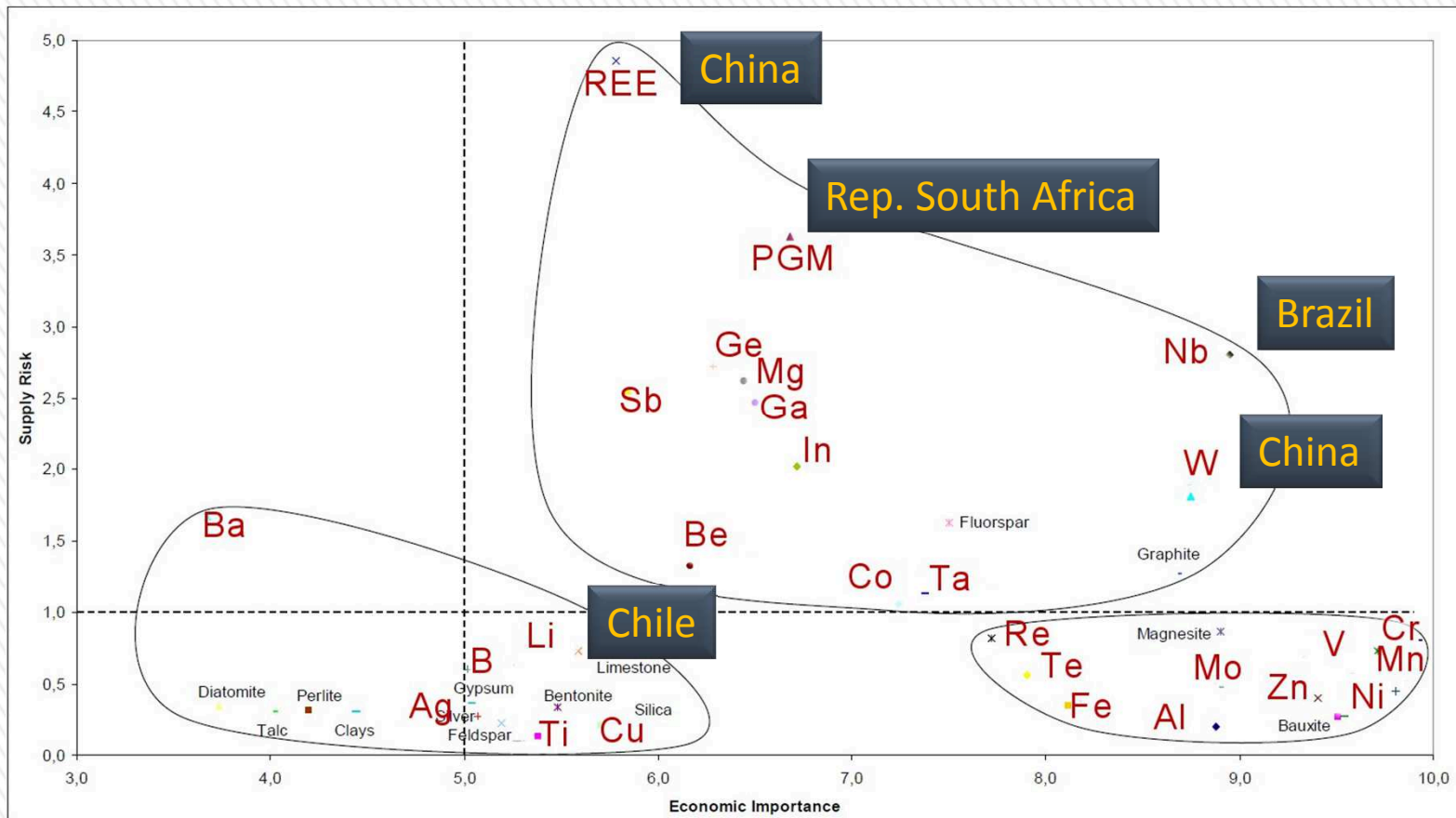
**Rare**



# Resource Availability

Criticality

- Supply Risk vs. Importance in Use
  - 14 metals list (2010 snapshot!)

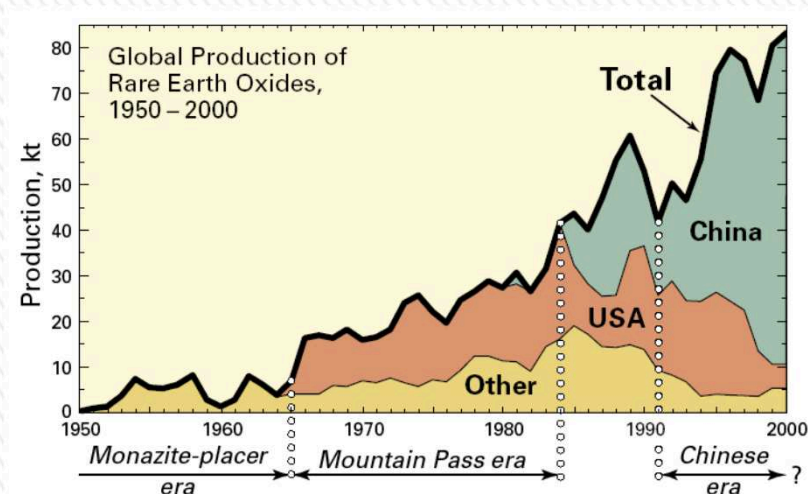
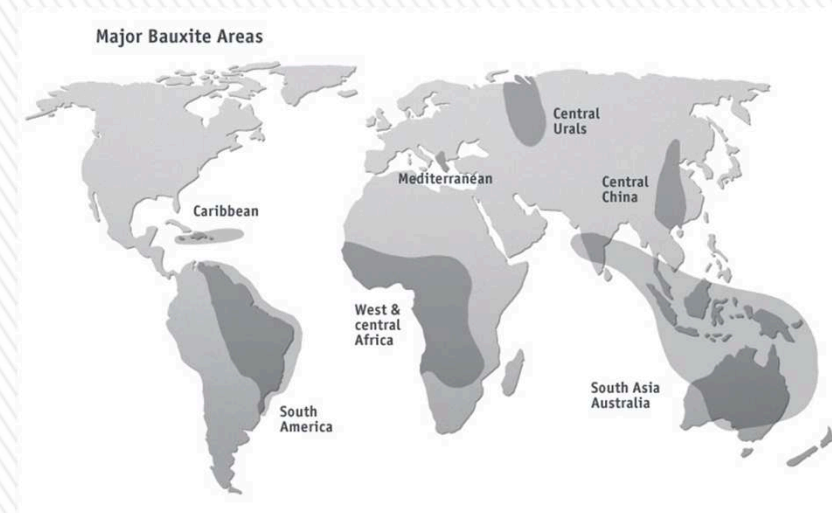




# Resource Availability

*Criticality*

- Components of Supply Risk
  - Geological, Technological, Economic (Graedel et al., 2012)
  - **1. Spatial Component**
    - Variable geological environments
      - ✓ Bauxite distribution
    - Geopolitical strategies
      - ✓ Not in My Continent





# Resource Availability

## Criticality

- Components of Supply Risk
  - 2. Geological Component
    - Average abundance in earth crust
    - Existence of deposits

Metal	Grade (ppm) earth crust	Concentration factor in ores
Al	78 000	3 x
Fe	36 000	7 x
Ti	4700	20 x
Cr	70	1000 x
Ni	44	100 x
Cu	30	100 x
Li	30	150 x
Sn	3	600 x
Ge	1,7	100 x
Au	0,002	1250 x

In **Bauxite** as  $\text{Al}(\text{OH})_3$

In **Massive Sulphides** as  $(\text{Fe},\text{Ni})_9\text{S}_8$   
In **Laterites** as  $(\text{Mg},\text{Fe},\text{Ni})_3\text{Si}_2\text{O}_5(\text{OH})_4$

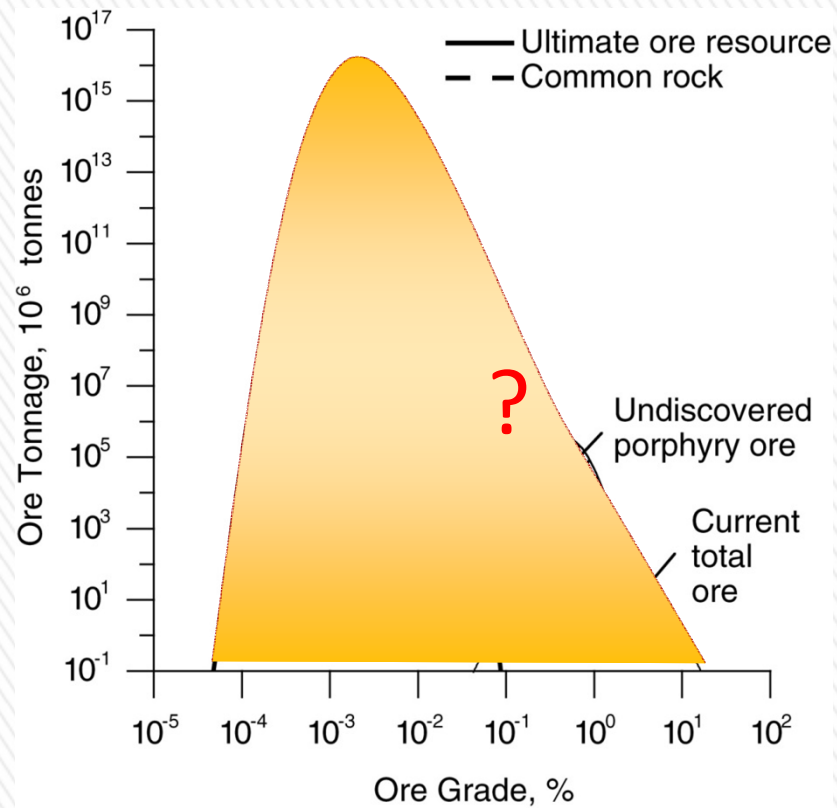
As by-product in **Pb-Zn-Cu** deposits  
As by-product in **coal** seams...



# Resource Availability

*Criticality*

- Components of Supply Risk
  - 2. Geological Component
    - Hypothetical Grade/Tonnage distribution (Bimodal or Lognormal ?)



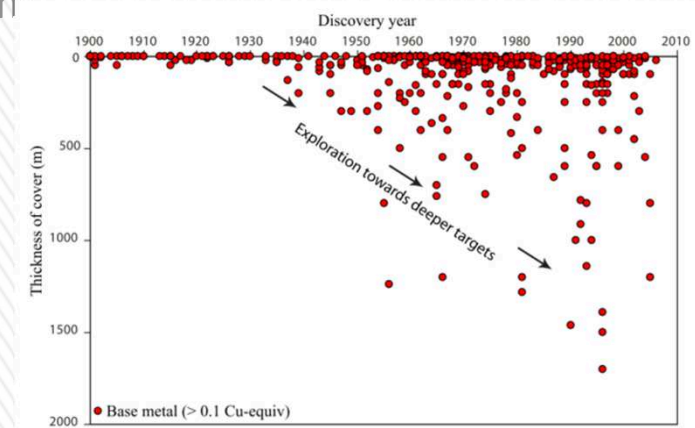
Gerst, 2008, Economic Geology  
Yale Center for Industrial Ecology



# Resource Availability

*Criticality*

- Components of Supply Risk
  - 3. Technological Component
    - Innovation in mineral processing
      - ✓ New technologies make new resources available
      - ✓ Bioheapleaching in Talvivaara (FIN)  
1.3 Mt @ 0,23 % Ni ; 0,02% Co; 0,13 % Cu; 0,5 % Zn
    - Innovation in deep exploration (> 300m)
      - ✓ Potential increase in Ni sulphides deposits and expected higher Ge grades with depth

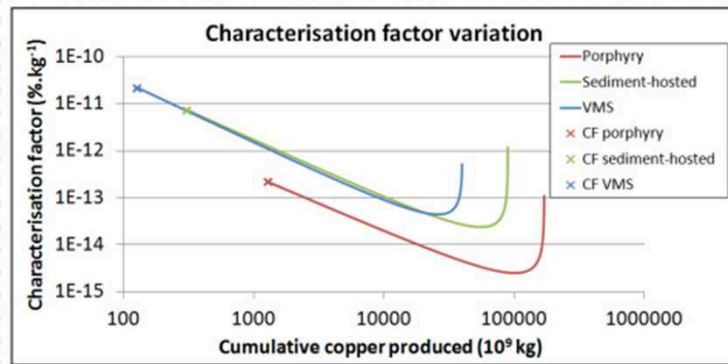




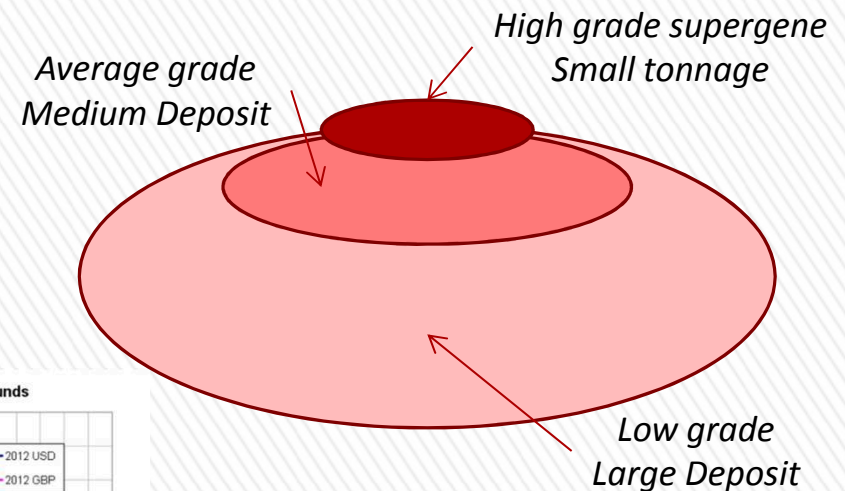
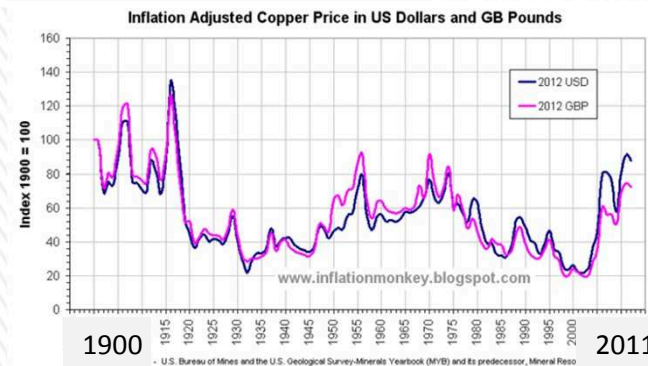
# CF for Resource Availability

*How to build them?*

- Characterization Factors for LCA
  - # Metal price (Krautkraemer, 1998)
  - # Ore grade (Vieira et al., 2012; Swart et al., 2013)
    - Ore grade, metal price and extraction costs are intimately linked



(Vieira et al., 2012)







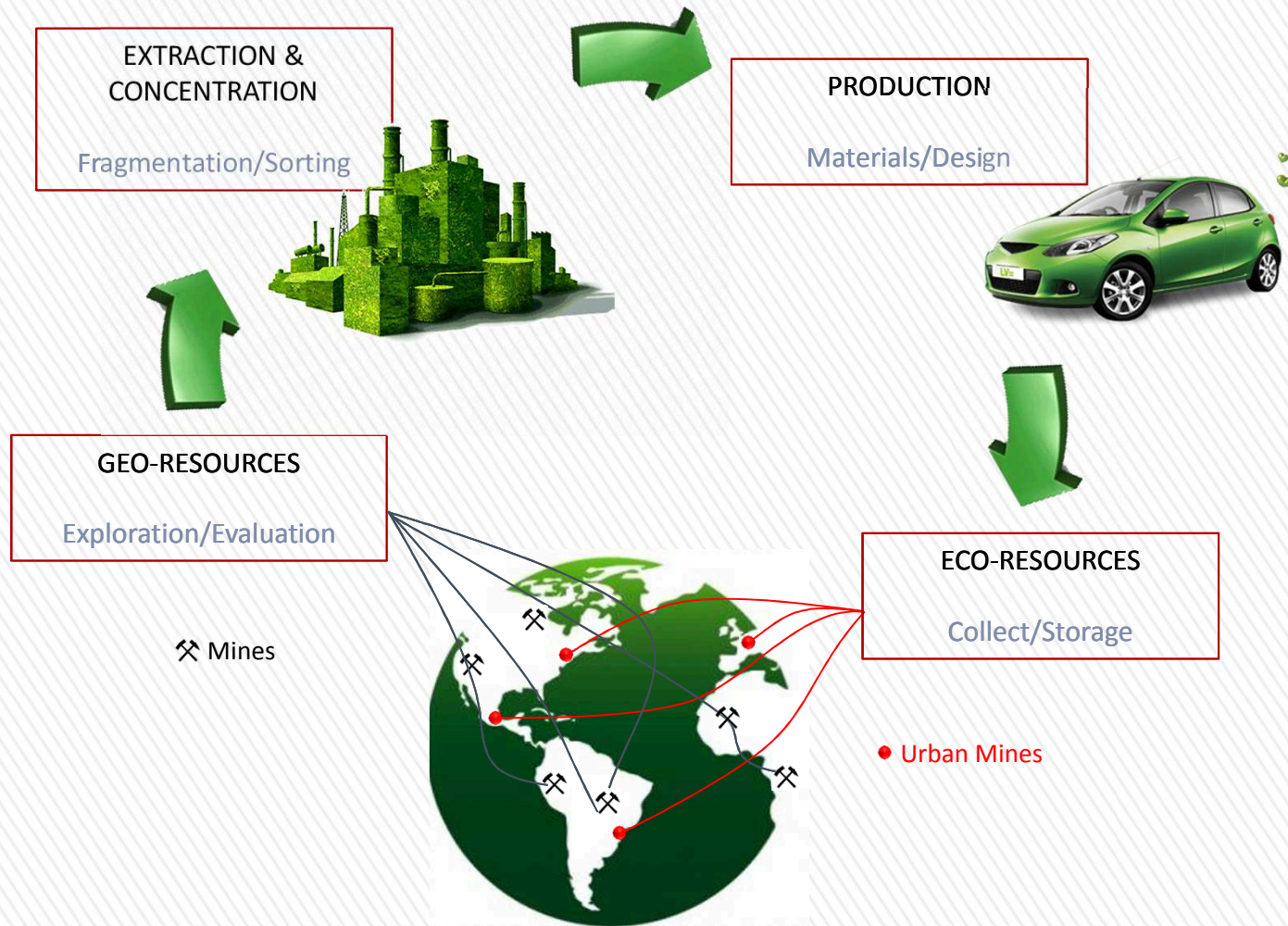
# ***Sustainable*** ***Resource Availability***

*A glimpse into circular economy*



# Sustainable Resource Availability

*Towards a circular economy*





# Sustainable Resource Availability

*Towards a circular economy*

- Promote Best Mining Practices
  - Major mining operations meet strict guidelines
    - ✓ Rehabilitation; Biodiversity; Tailings monitoring;...
    - ✓ Social responsibility;...
  - Indicators to reflect environmental impact
    - NORILSK (RUS) 1,5% Ni
      - ✓ Above Arctic Circle
      - ✓ Underground – Grinding
      - ✓ Pyrometallurgical process
      - ✓ Ni sulphides (SO<sub>2</sub>)
      - ✓ Cu, Co, PGE as byproducts





# Sustainable Resource Availability

*Towards a circular economy*

- Promote Best Mining Practices
  - Major mining operations
    - Meet strict guidelines
      - ✓ Rehabilitation; Biodiversity; Tailings monitoring;...
      - ✓ Social responsibility;...
  - Indicators to reflect environmental impact
    - TIEBAGHI (N CAL) 1,5% Ni
      - ✓ Tropical Ecosystem (Coral Reefs)
      - ✓ Surface Mining (Land Use)
      - ✓ Ni silicates
      - ✓ Pressure Acid Leaching

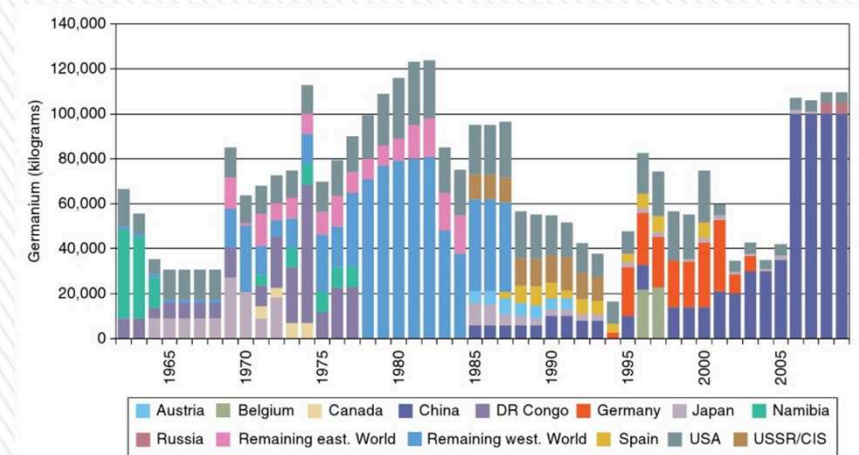




# Sustainable Resource Availability

*Towards a circular economy*

- Promote Shorter Supply Circuits
- Promote by-production
  - Privileged source for Germanium
    - CHINA
      - ✓ Ge in coal seams
      - ✓ Leaching from power plant residual ashes
    - EUROPE
      - ✓ Ge from lignite or zinc deposits
      - ✓ Poorly documented resources
      - ✓ No incentives for extraction



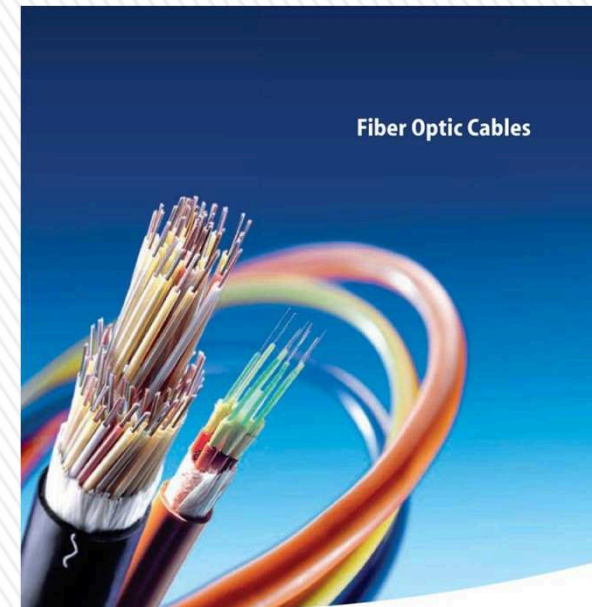
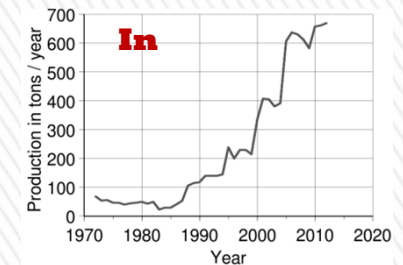
Gunn, 2014



# Sustainable Resource Availability

*Towards a circular economy*

- Help closing the Loop
  - Put enough material in the loop
    - ✓ 4000 t of Ge in cycle
  - Limit dispersive uses
    - ✓ Ge as a catalyst of PET
  - Collect end-of-life products
    - ✓ Collection of Ge doped optical fibers (14mg/km)
  - Build optimal urban mines





# Sustainable Resource Availability

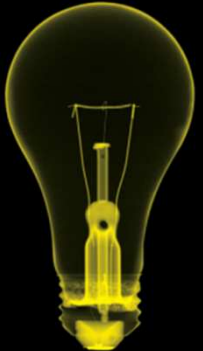



*Towards a circular economy*

- Building Mines for the Future
  - 1. Metal concentrations
    - Maintain grade above a technological cut-off
      - ✓ Often only precious metals (Au, PGM) pay for recycling
  - 2. Metal speciation
    - Metal, alloy, salt, organic compound, ...
      - ✓ Wide variety of Ni, Al alloys
  - 3. Metal paragenesis
    - Unexpected metal assemblages, ..., contamination
      - ✓ Copper coated aluminium wires
  - 4. Textural assemblage
    - Liberation and dismantling
      - ✓ Separate core from cladding and jacket in optical fibers
  - 5. Volume of mine
    - Make sure large enough quantities can be collected
  - 6. Homogeneity
    - Zonation, Blending
      - ✓ Technological evolution with time changes deposit



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