



Industrial Ecology and Sustainable Management of Materials

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Content

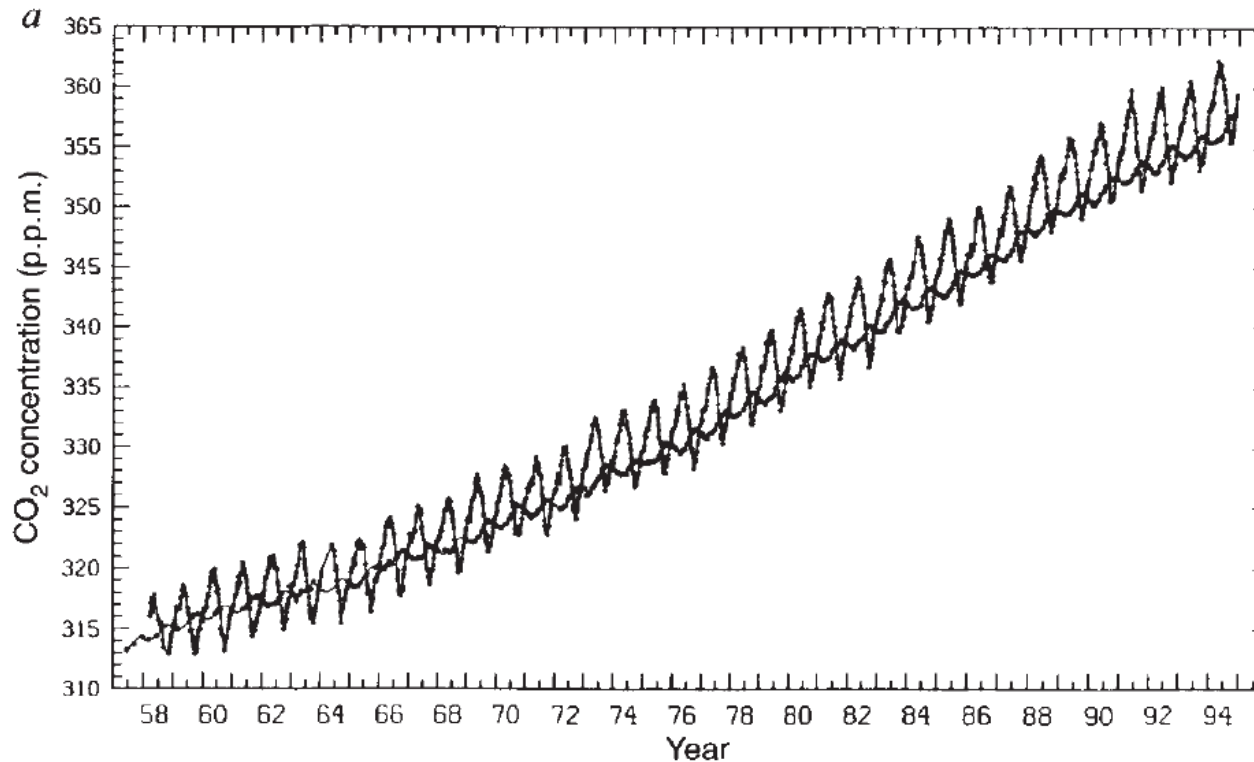
- Background
 - Anthropogenic materials and energy flows
- Industrial ecology
 - Loop closure, stocks and flows
- Future challenges and the role of engineers
 - Designing the future

Background

Anthropocene

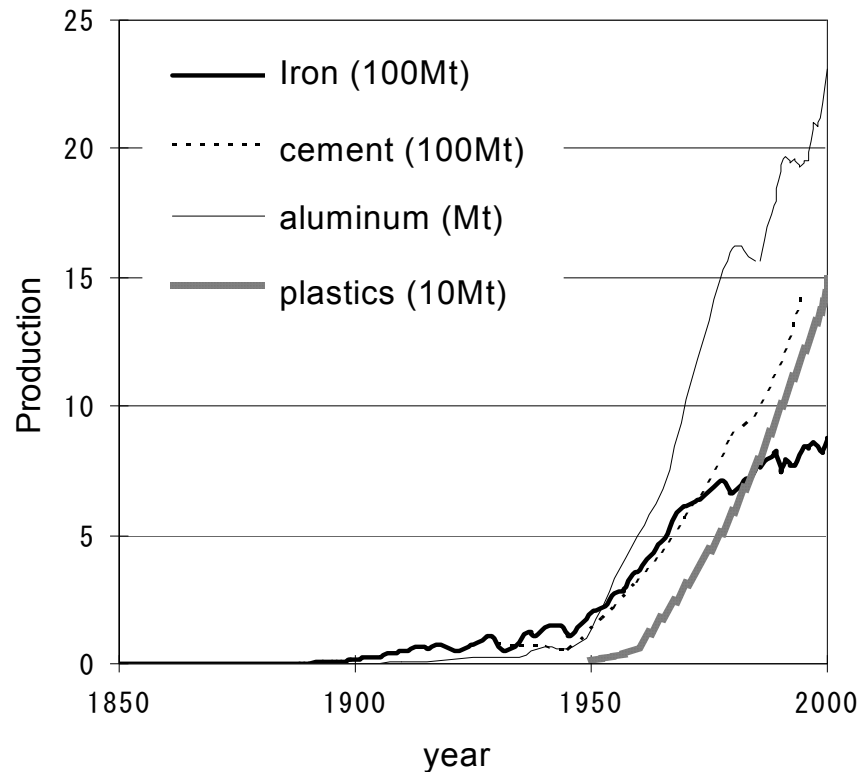
- Proposed by Crutzen and Stoermer (2000)
- A new epoch characterized by human domination
 - Composition of the atmosphere / stratosphere
 - CO₂, O₃
 - Alteration in biophysical cycles
 - Nitrogen, Phosphorus, Carbon, Water
 - Flora and fauna
 - NPP under human influence, biodiversity

CO₂ concentration



Keeling, C.D., Whorf, T.P., Wahlen, M., Plicht, J. (1995) Interannual extremes in the rate of rise of atmospheric carbon dioxide since 1980, *Nature*, 1995

Human use of materials

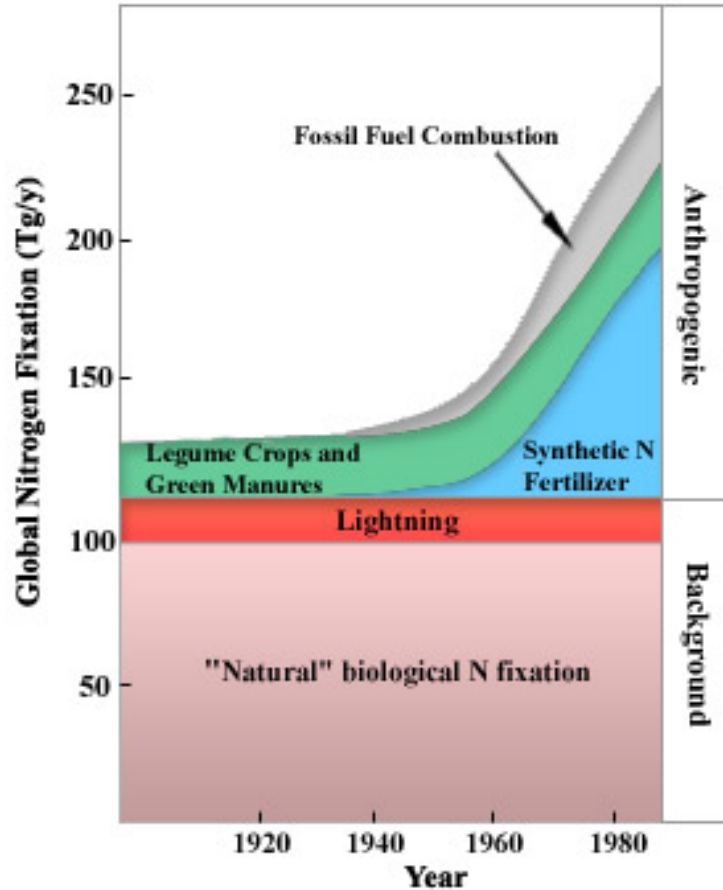


Source: Halada (2006) *Hidden material flow of metal behind economics*, Tokyo, Japan.



How much is 75 million barrels of daily crude oil production?

Nutrient flows and hypoxia



Source: Vitousek, P. M., Matson, P. A. (1993) Agriculture, the global nitrogen cycle, and trace gas flux. The Biogeochemistry of Global Change: Radiative Trace Gases. R. S. Oremland. New York, Chapman and Hall

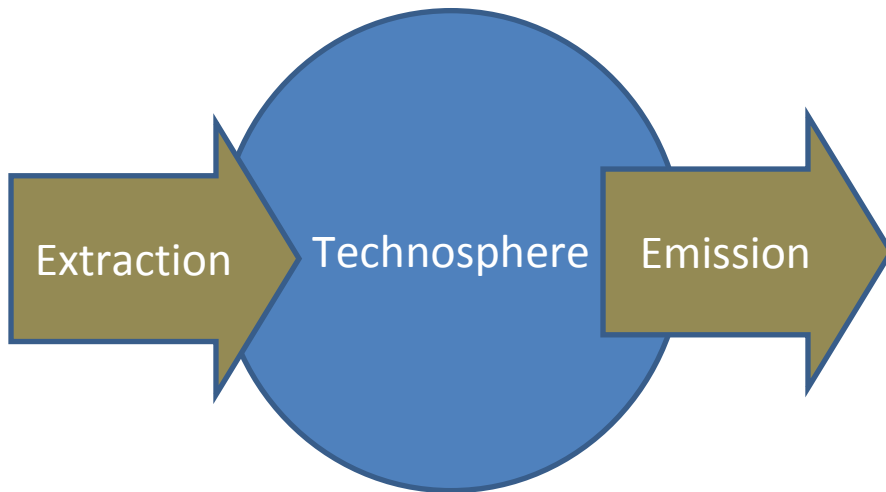
Industrial ecology

Industrial ecology

- Derived from “industrial ecosystem” coined by Frosch and Gallopoulos (1989).
- Field of study concerns stocks and flows of materials and energy in human-nature complexity.

Industrial Ecology: closing the loop

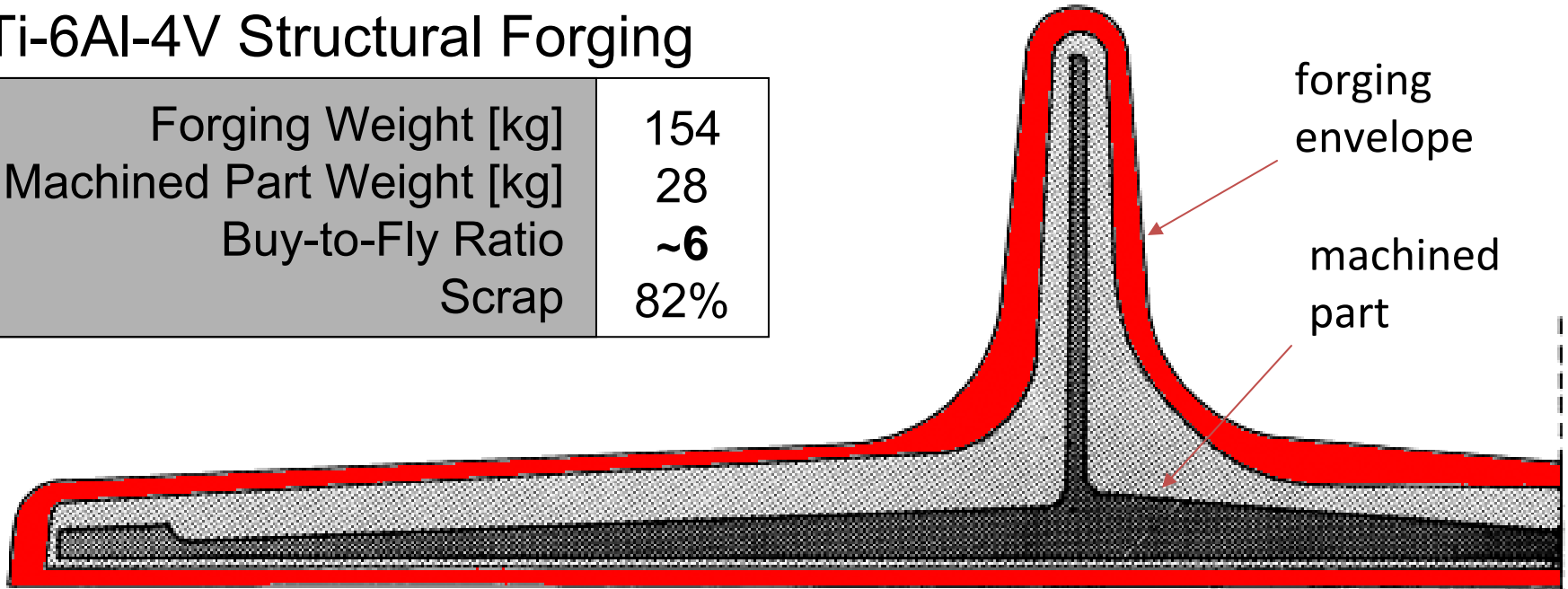
- In principle, adverse impacts by humans can be prevented from the source by closing the materials cycle within the technosphere.



The “Buy-To-Fly” Problem

Material Utilization Case Study: Ti-6Al-4V Structural Forging

Forging Weight [kg]	154
Machined Part Weight [kg]	28
Buy-to-Fly Ratio	~6
Scrap	82%



Source: Sanjay Shah, “Isothermal and Hot-Die Forging,” ASM Metals Handbook, Vol.14 (Forming and Forging), 2nd Ed., ASM International, 1998.

Most of the input mass is lost to scrap

Urban mining



1 ton

=



150 g



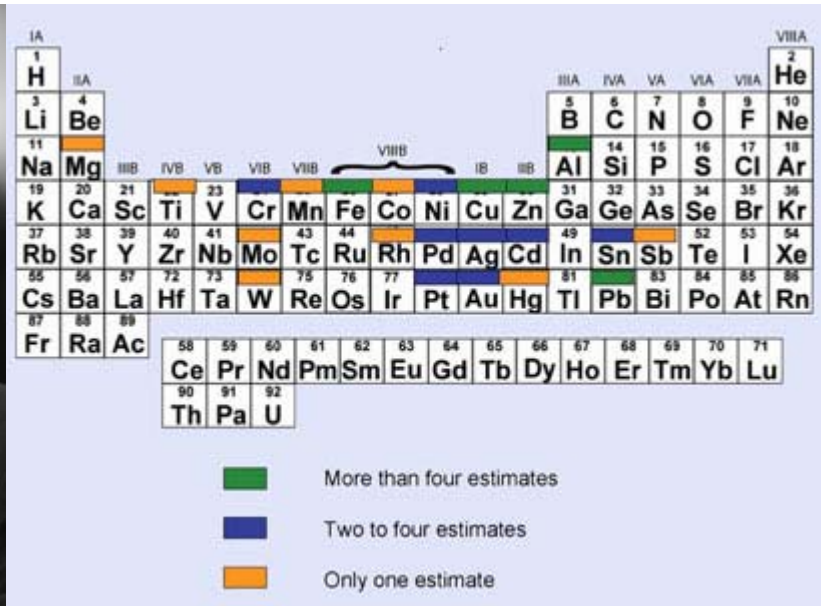
100 kg

Recycling rate

- Little is known
- Only a few metals exceed 50%, many <1%



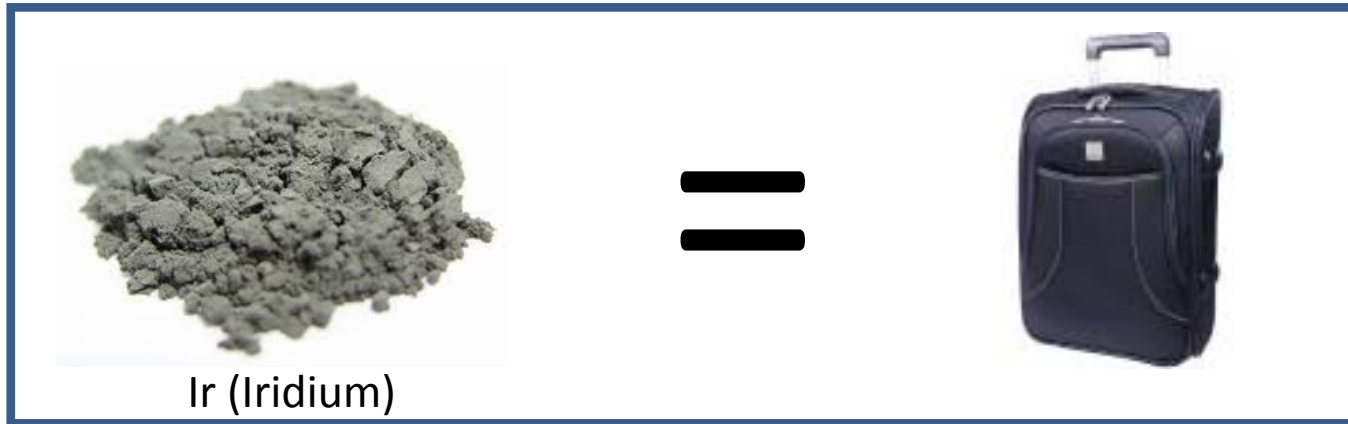
International Panel
for Sustainable
Resource Management



Graedel, T. et al. (2010) Metal stocks in society and recycling rates, International Panel for Sustainable Resources Management, UNEP, Paris, France.

Future challenges and the role of engineers

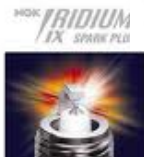
Technology-material interaction



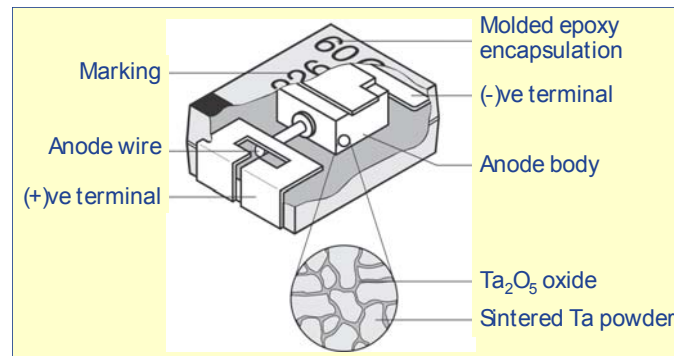
VOLKER IRIIDIUM
Twin-tip Technology



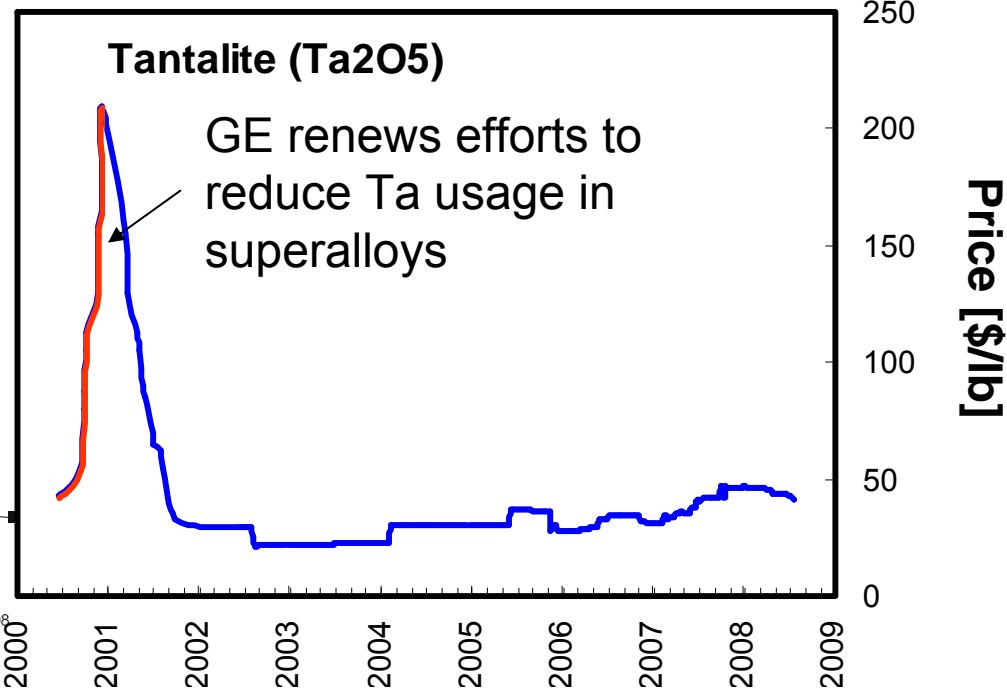
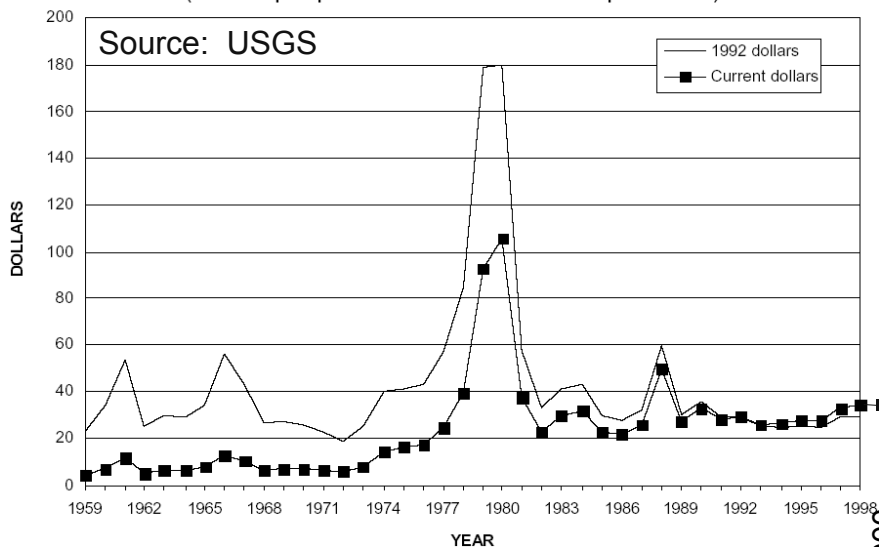
Center electrode
Ø 0.5 mm
SUPER IRIIDIUM
Ground electrode
Ø 1.0 mm
PLATINUM tip



Tantalum Price



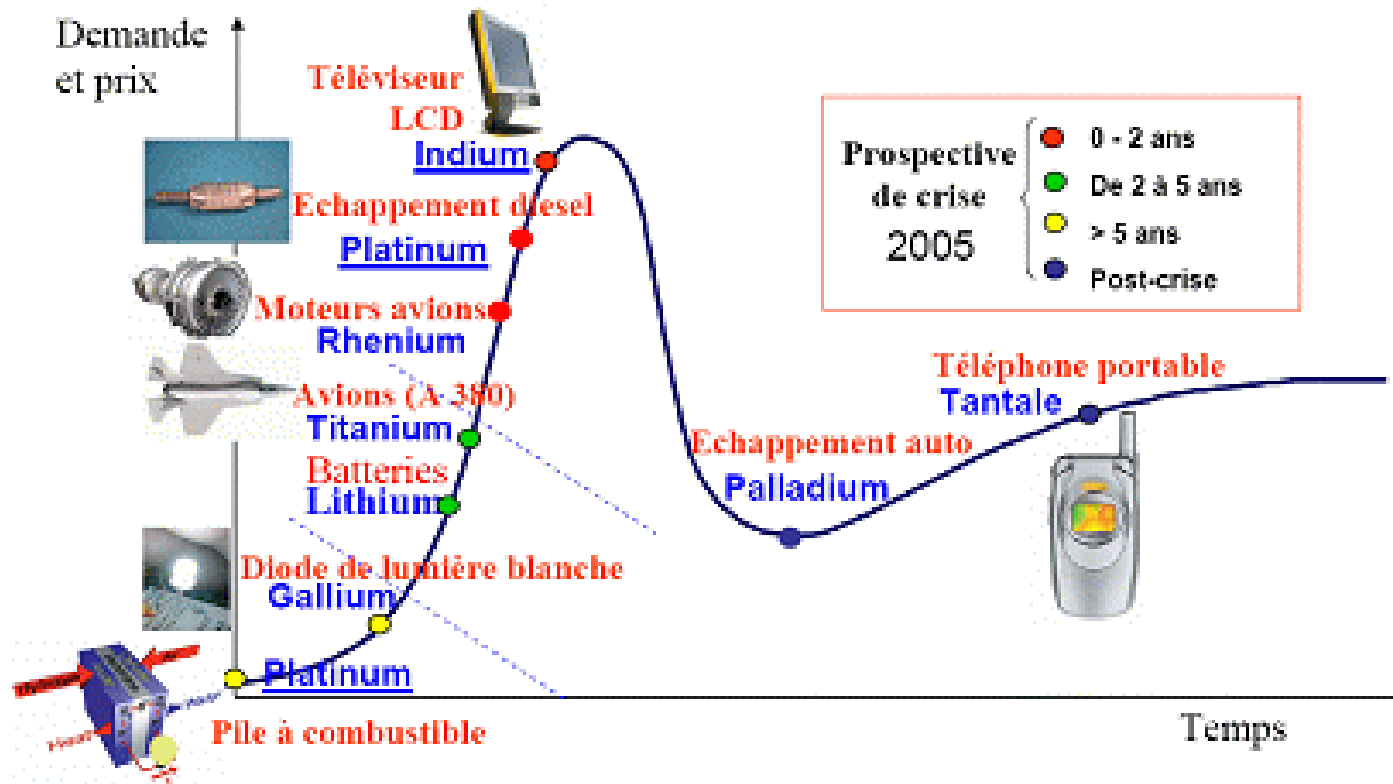
Yearend Average Tantalum Concentrate Price
(Dollars per pound contained tantalum pentoxide)



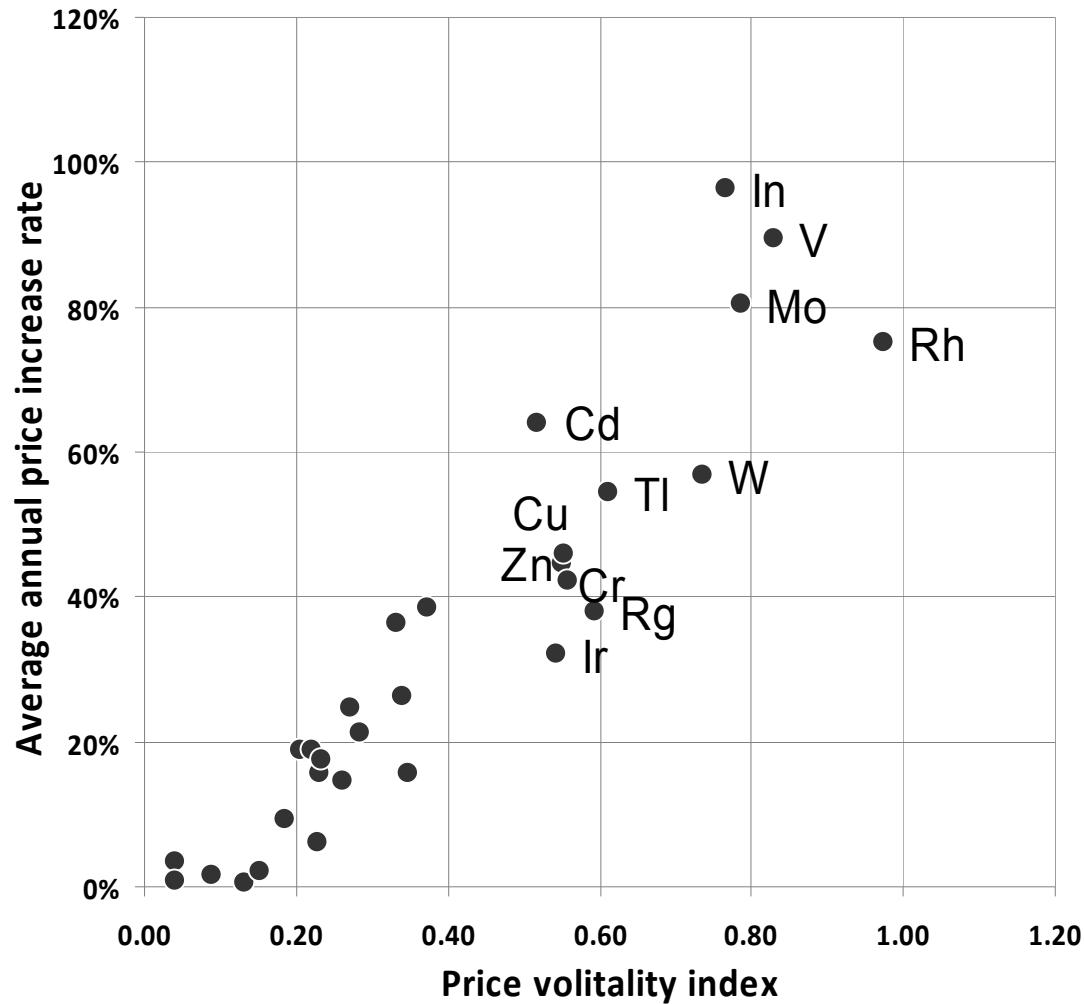
From: Don Lipkin (GE Global Research): *personal communication*

Industrial cycles and resources crises

- More waves to come



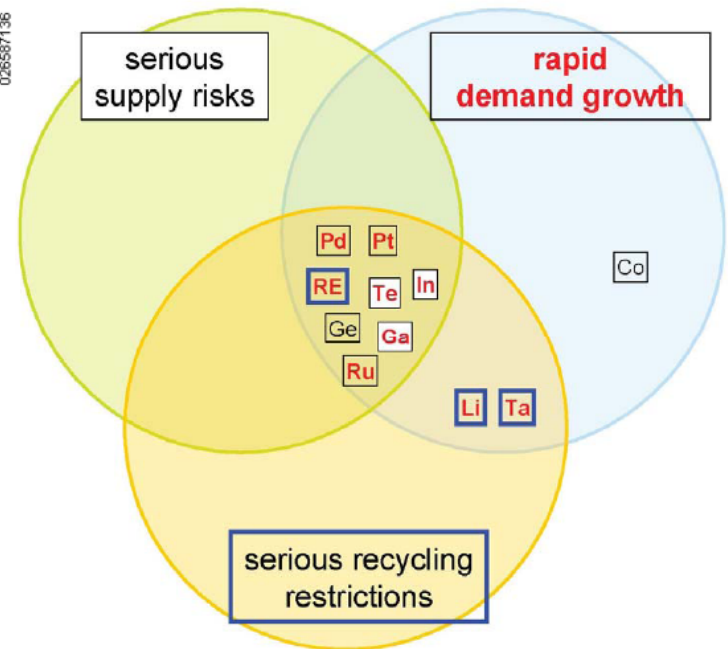
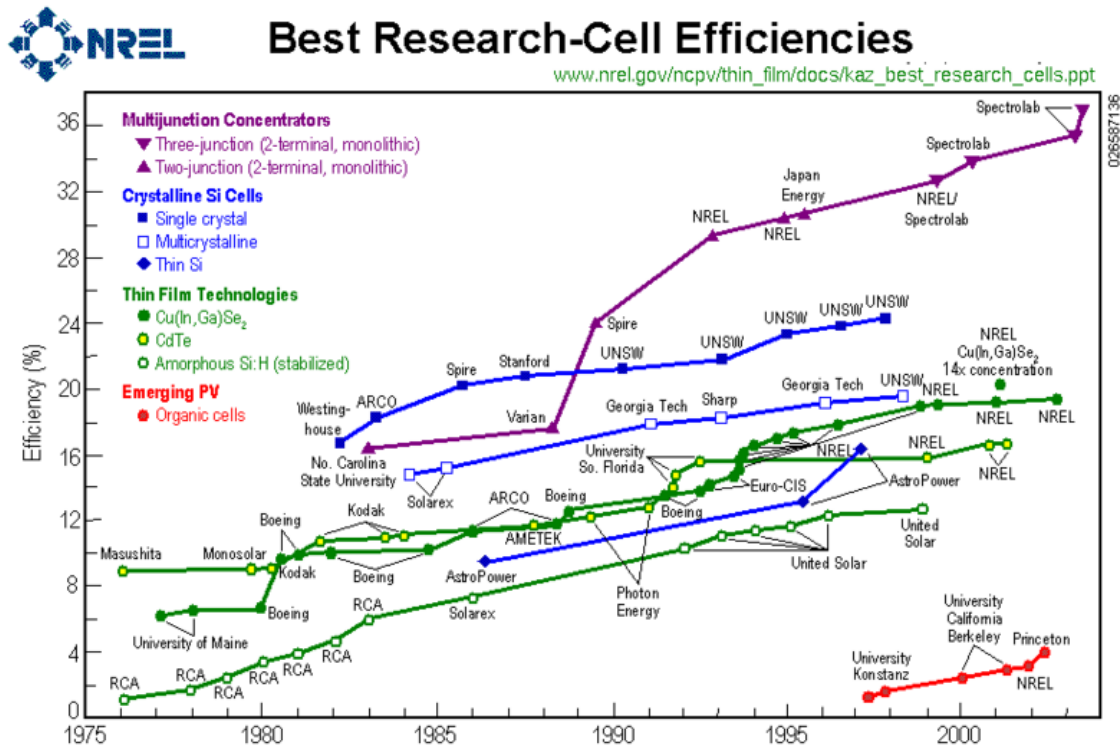
Metal price trend



Source: Suh, S. (2008): Natural resources and sustainable industrial development, Sustainable Industrial development, 28-41

Energy-materials nexus

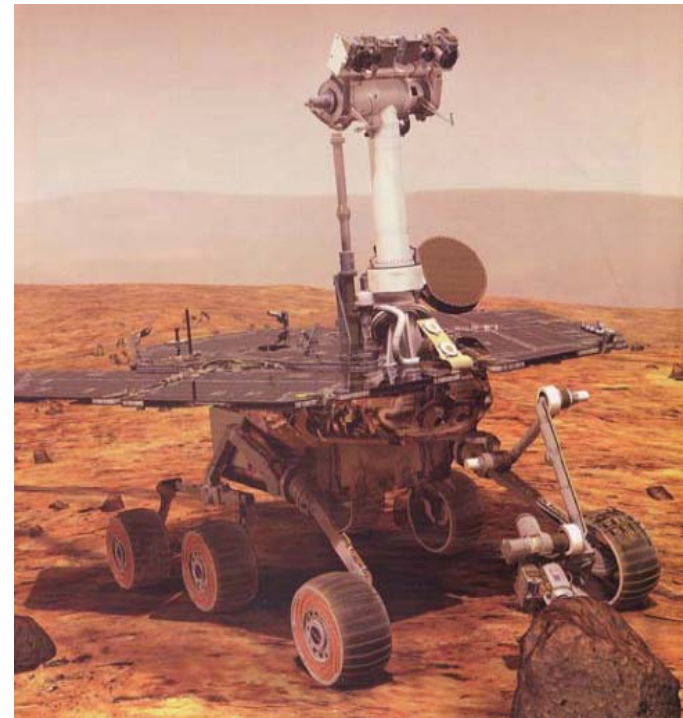
- Energy efficiency v.s. materials efficiency/availability



Öko-Institut (2008): *Critical metals for future sustainable technologies and their recycling potential*, Freiburg, Germany.

Scale of application

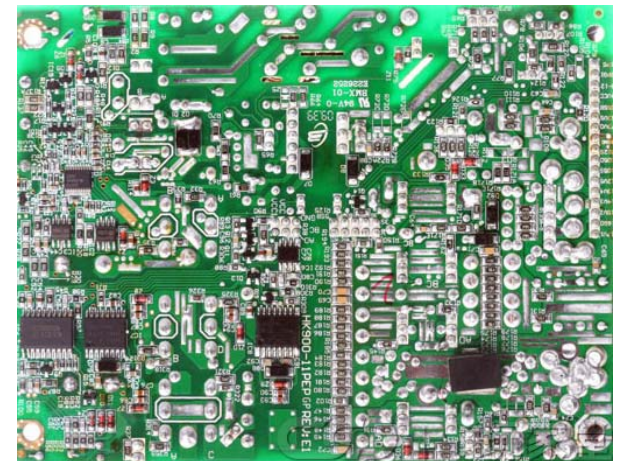
- Hypergreen (La Défense, France)
 - 3000m² PV



Lead-free soldering



From: Whittome, C. (2008) Mountain of waste and suffering in Guiyu, China
Filed Under (recycling)



The role of engineering and innovation

- Closing loops within the technosphere is not only about doing more EOL recycling.
- Innovative design throughout the life-cycles of products and services is essential.
- Connections between materials, energy and water become increasingly complex.
- Industrial ecology helps see the linkages from a systems perspective.

Thank you!

- Questions, suggestions, comments welcomed.
- Contact: suh@bren.ucsb.edu