Center for Industrial Ecology

Yale School of Forestry & Environmental Studies

Is Sustainable Resource Management Possible?

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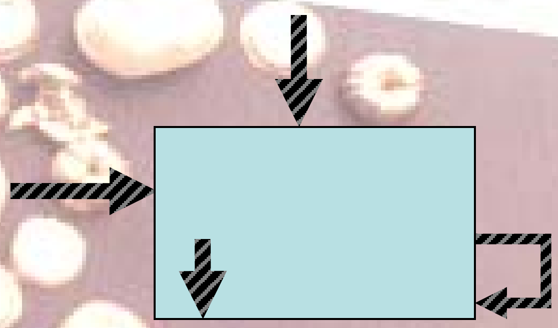
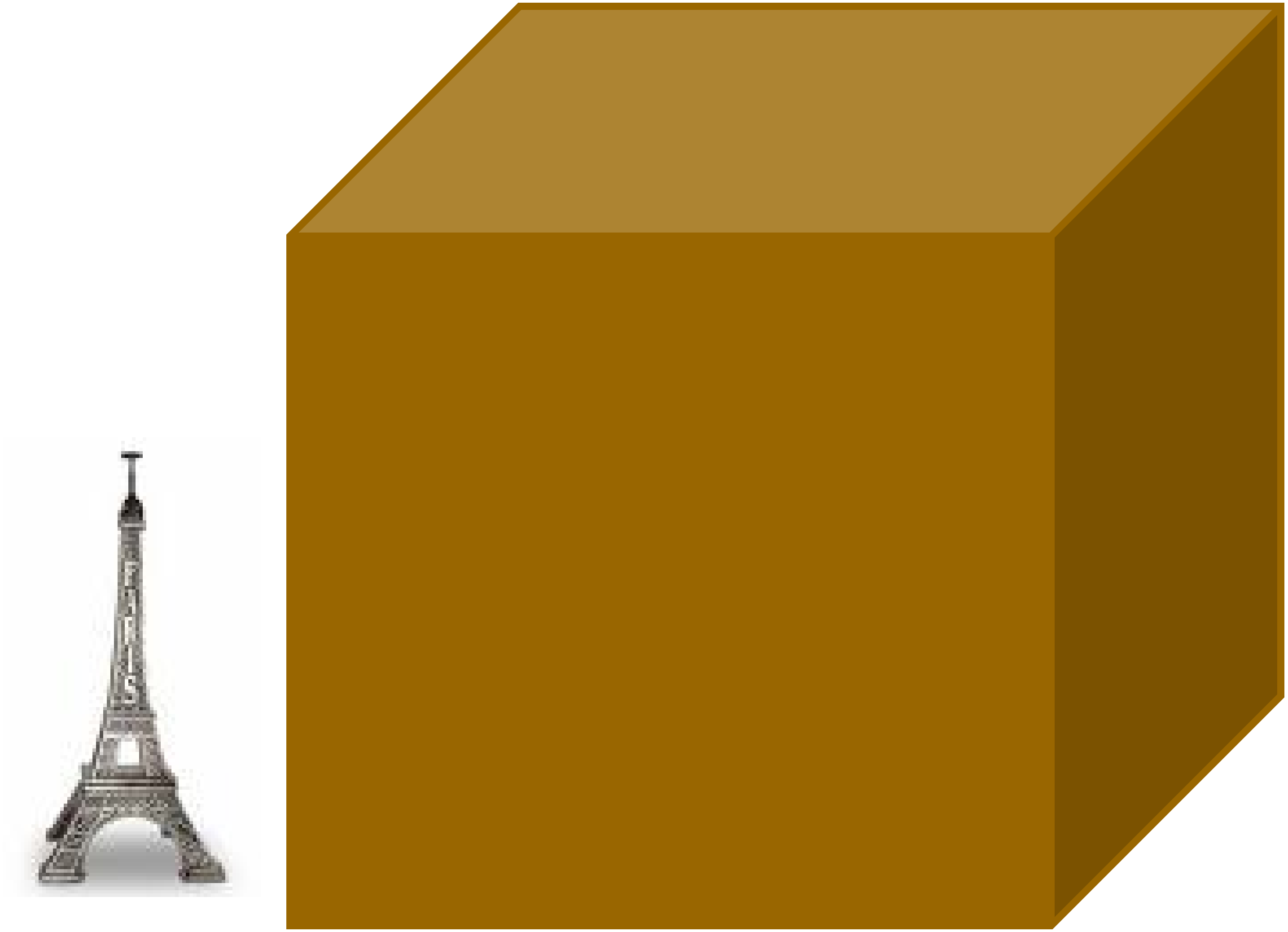
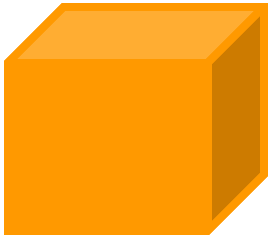


The World’s Annual Production of Iron



940 million
metric tons

The World's Annual Production of Copper

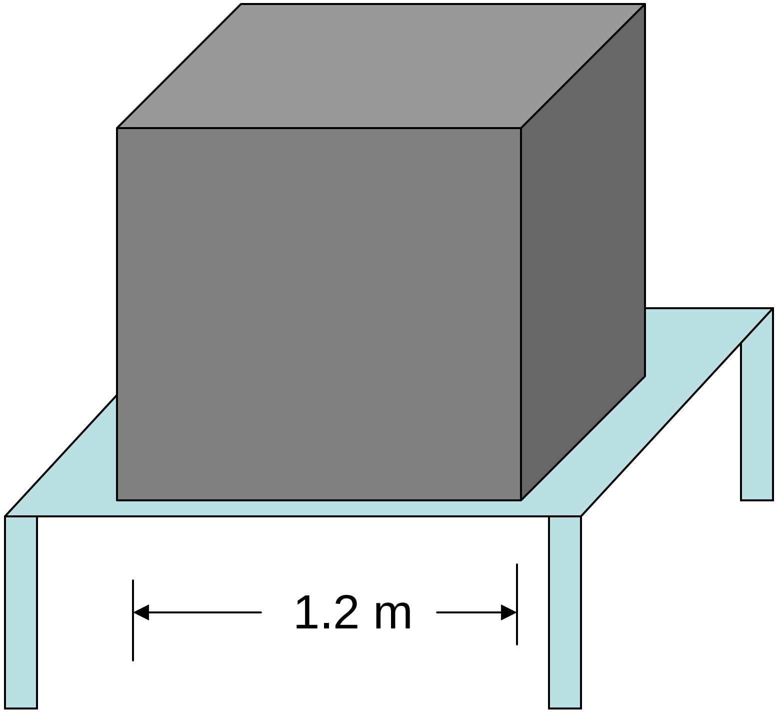


15.6 million
metric tons

The World’s Annual Production of Tungsten

90 thousand
metric tons

The World's Annual Production of Rhenium



Aircraft Engine Combustors

Aircraft Engine Combustors

Rhenium: Only element whose alloys can withstand modern combustor temperatures

UNEP

International Panel for Sustainable Resource Management

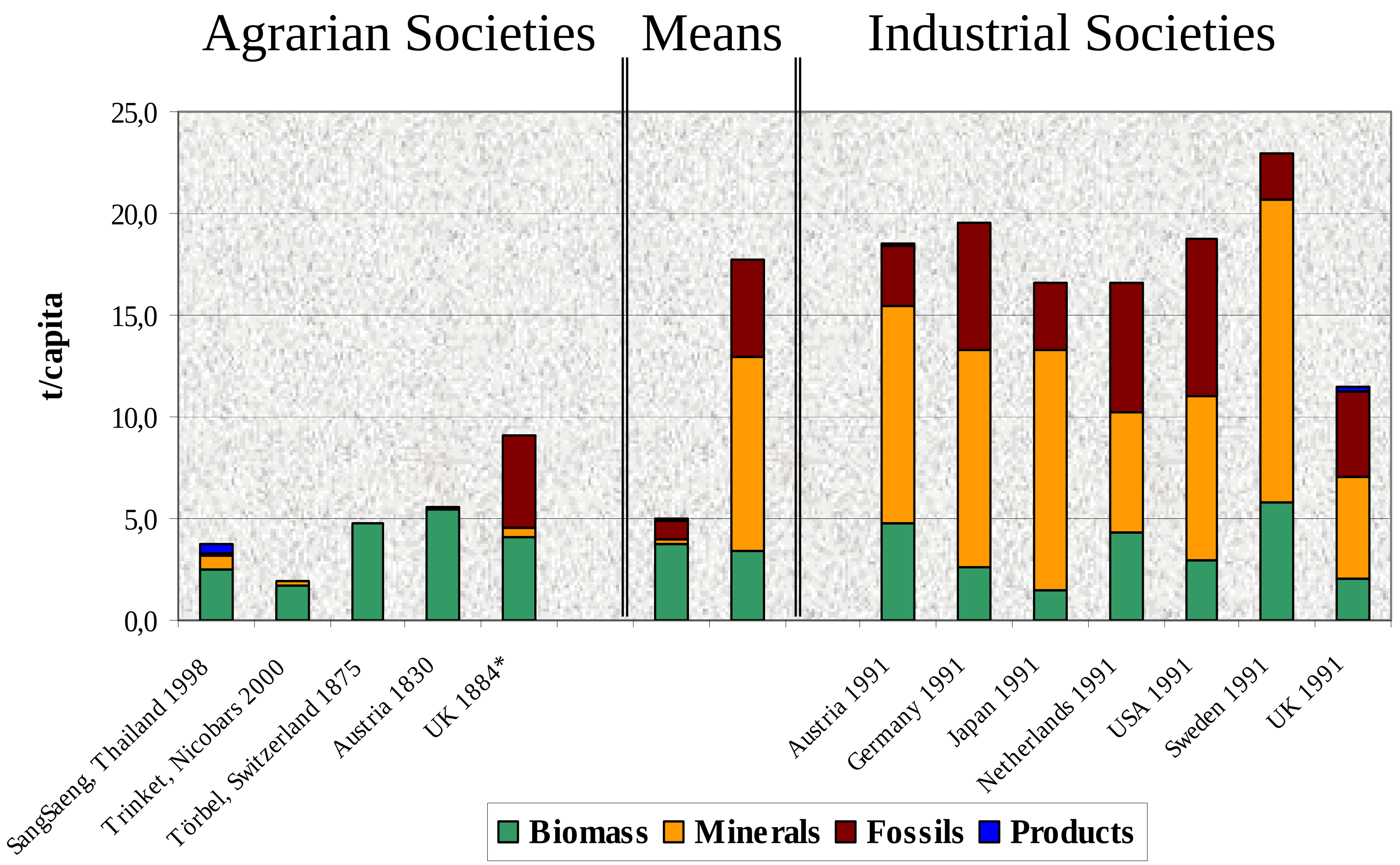
Mission of the Panel

To provide independent scientific assessments on the sustainability of resources and on the environmental impacts from the use of resources (renewable and non-renewable) over the full life cycle

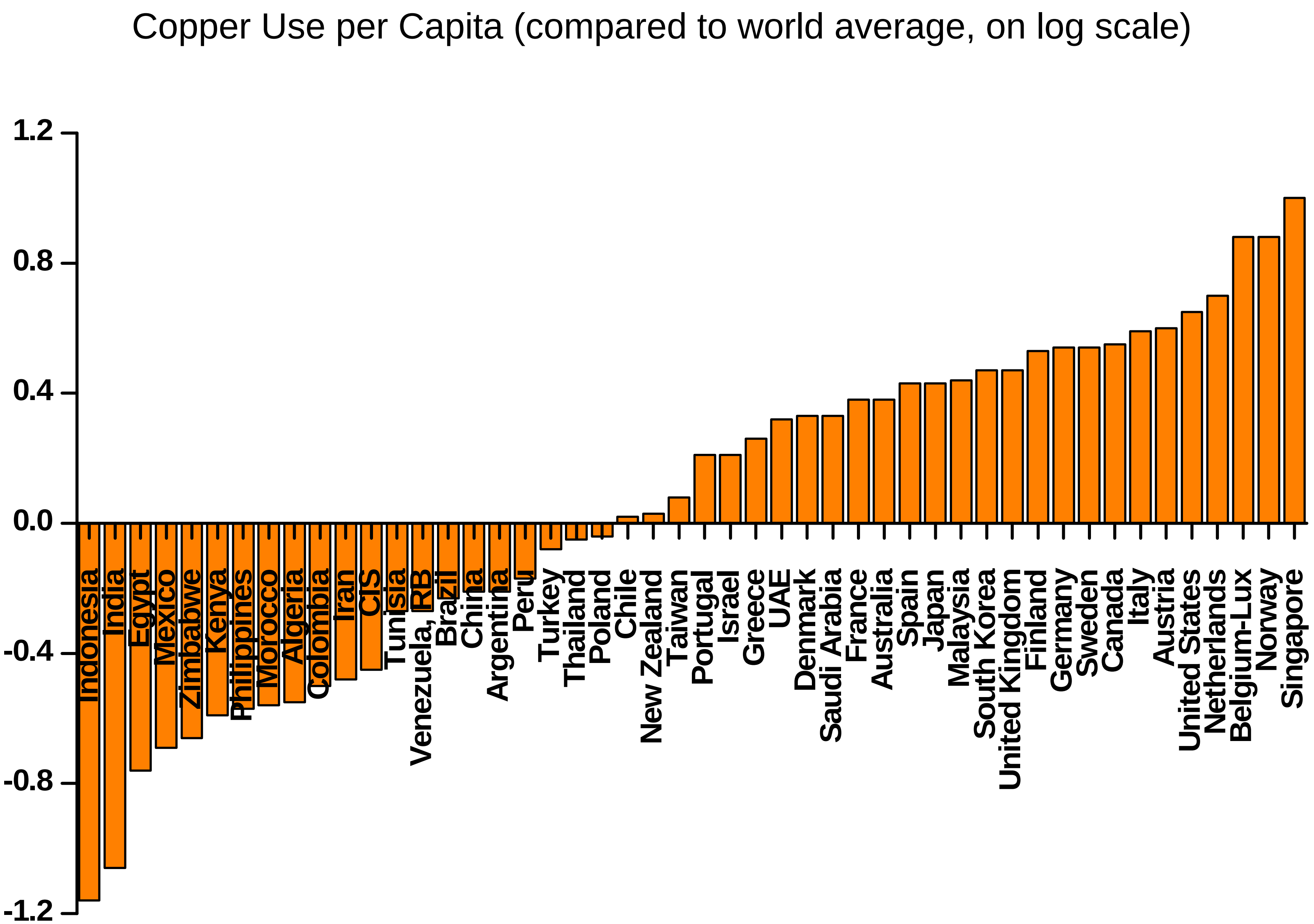
Working Groups of the Panel

- Metal stocks and flows
- Biofuels
- Water supplies
- Prioritization of flows
- Decoupling
- Innovations
- Institution building

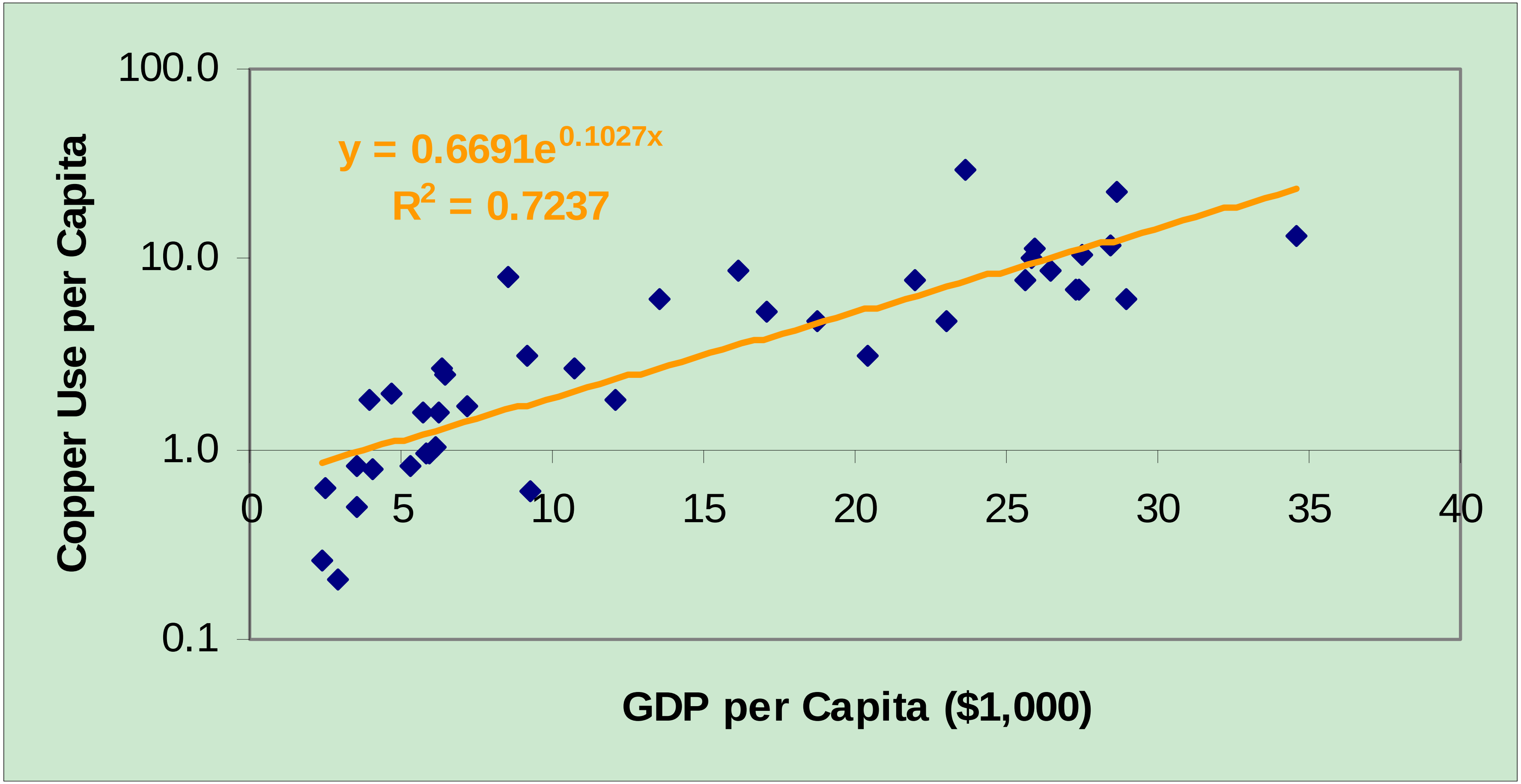
Metabolic profiles by socio-ecological regimes (DMC/capita)



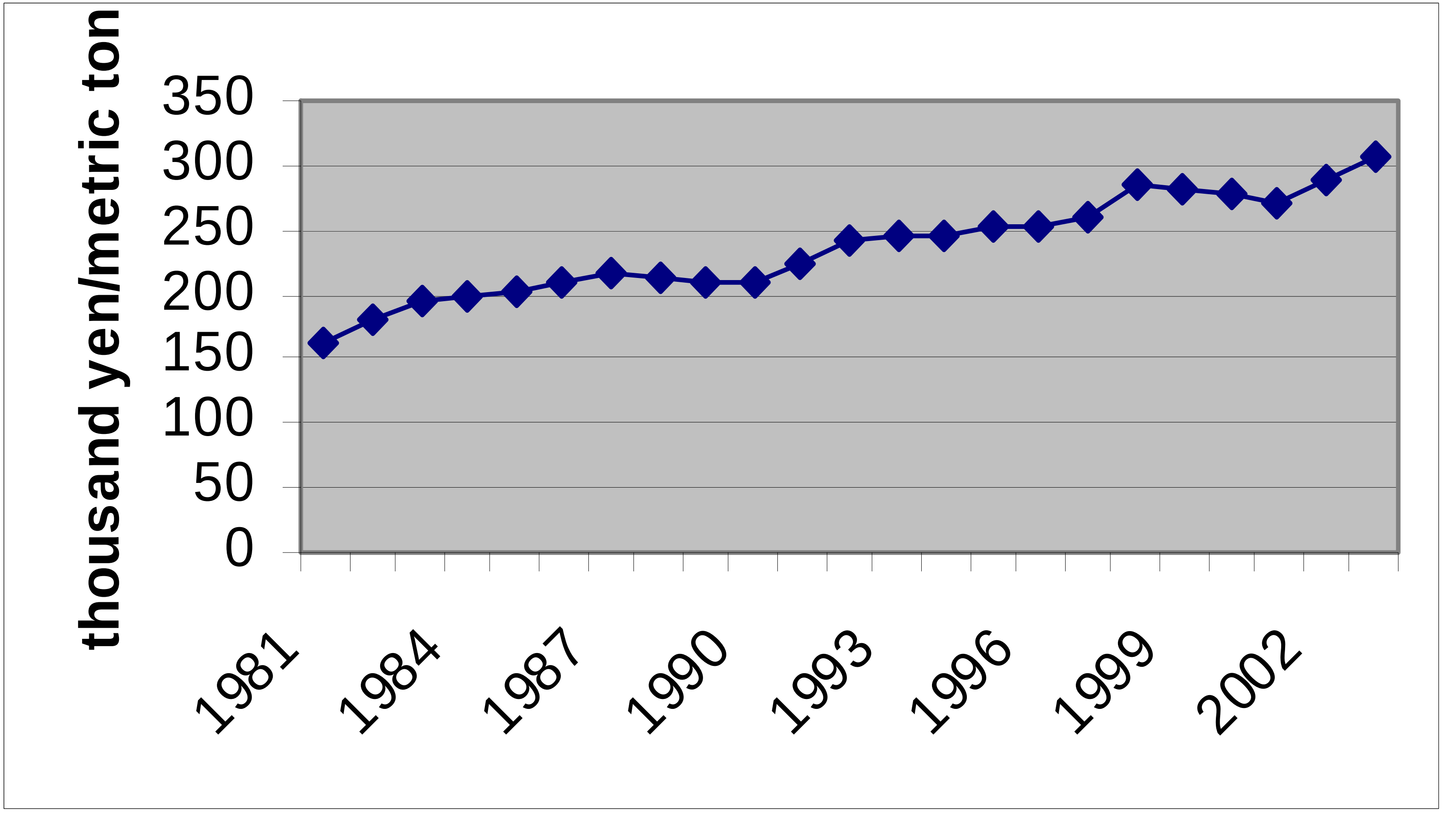
Source: M. Fischer-Kowalski, Vienna


Copper Use per Capita (compared to world average, on log scale)
1.2
0.8
0.4
0.0
-0.4
-0.8
-1.2
Indonesia
India
Egypt
Mexico
Zimbabwe
Kenya
Philippines
Morocco
Algeria
Colombia
Iran
CIS
Tunisia
Venezuela, RB
Brazil
China
Argentina
Peru
Turkey
Thailand
Poland
Chile
New Zealand
Taiwan
Portugal
Israel
Greece
UAE
Denmark
Saudi Arabia
France
Australia
Spain
Japan
Malaysia
South Korea
United Kingdom
Finland
Germany
Sweden
Canada
Italy
Austria
United States
Netherlands
Belgium-Lux
Norway
Singapore

Copper Use per Capita Vs GDP per Capita

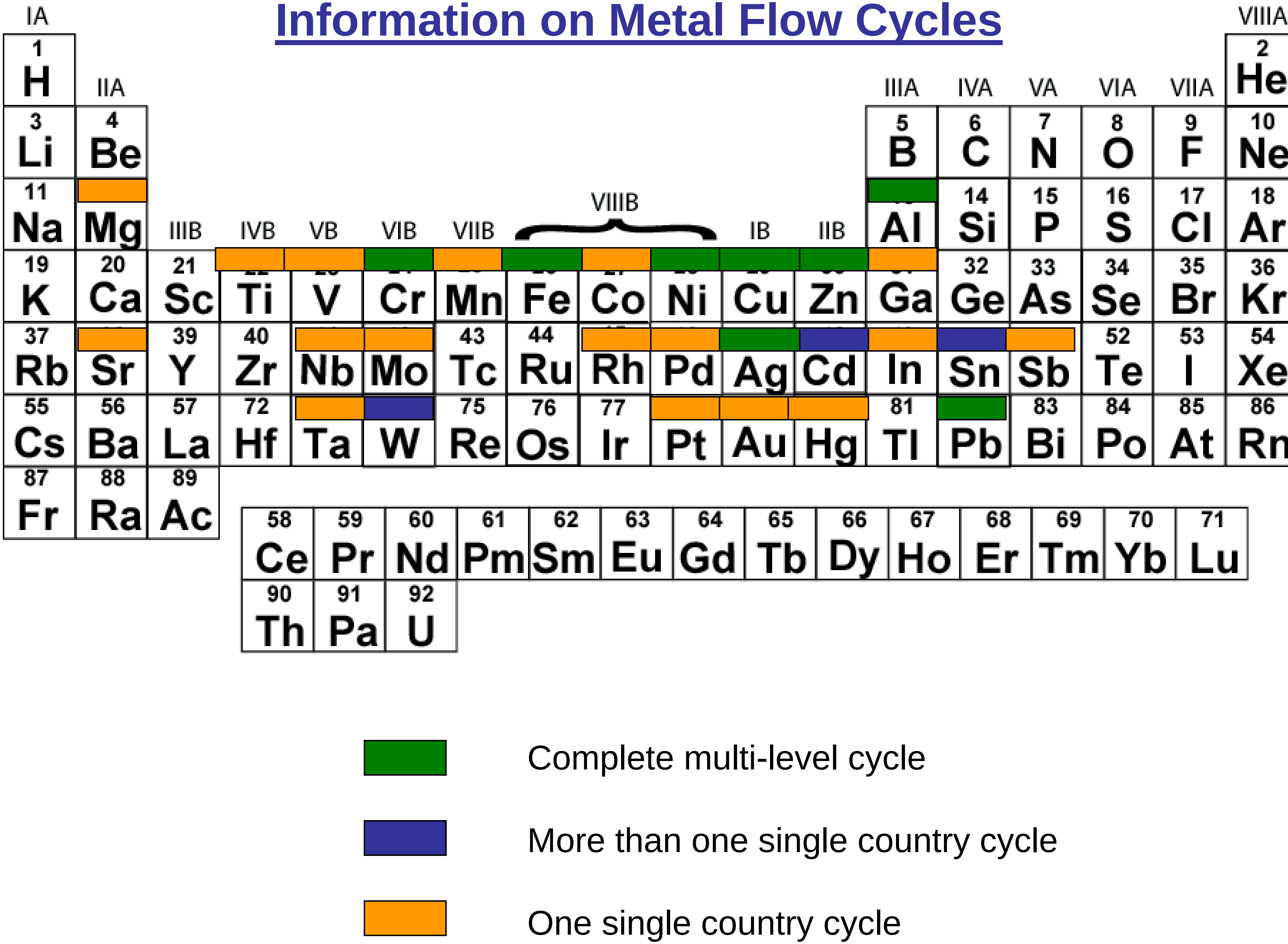


“Resource Productivity” in Japan

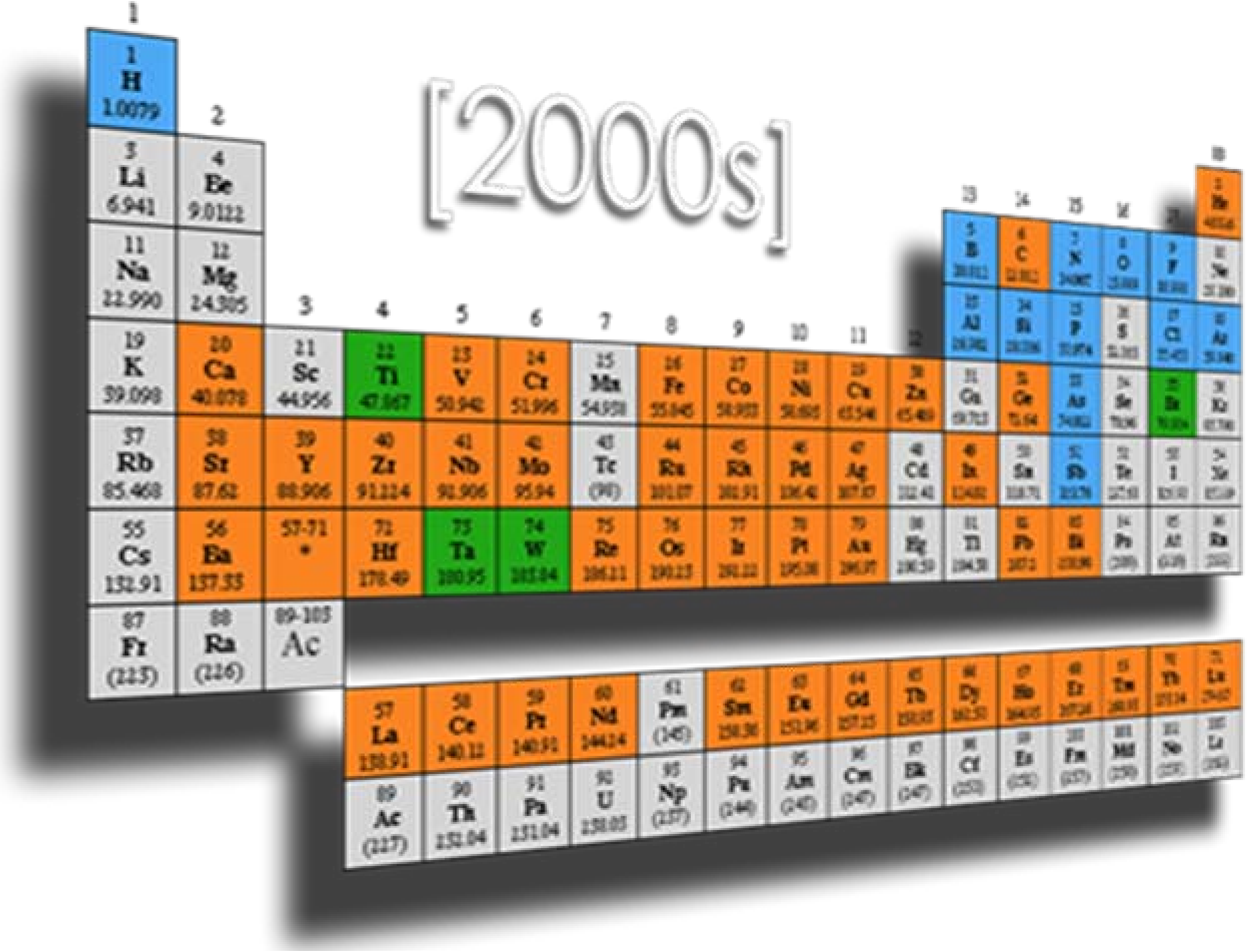


Source: Y. Moriguchi, NIES, Japan, 2008

Information on Metal Flow Cycles



Metal Linkages in the New Mineralogy

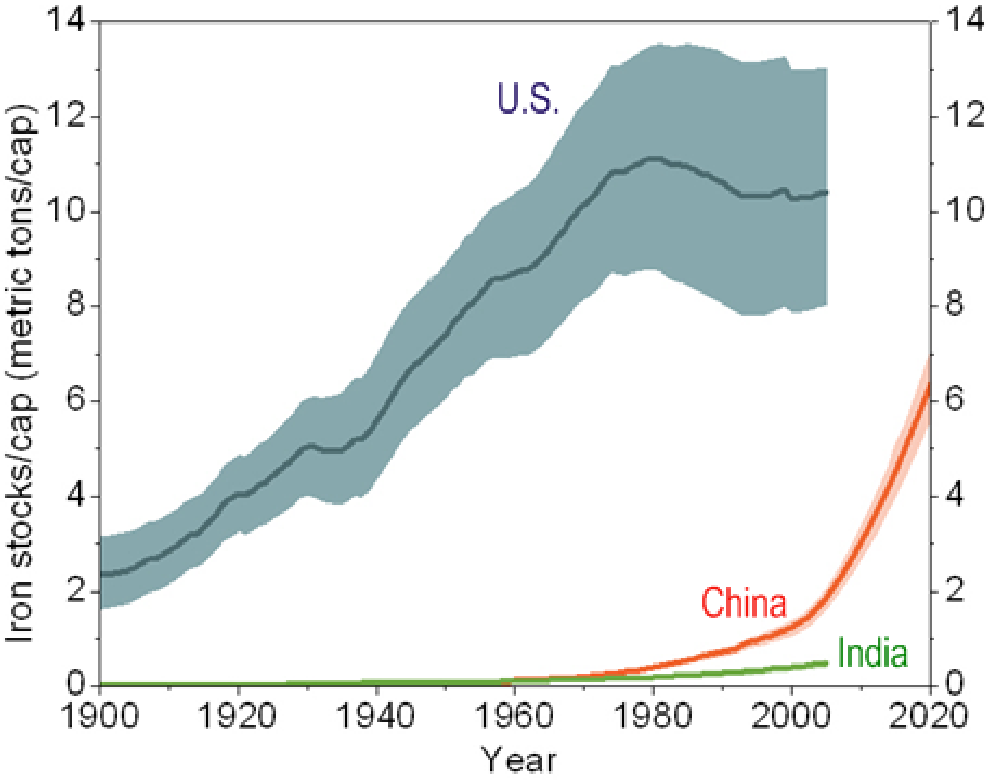


Source: T. McManus, Intel Corp., 2006

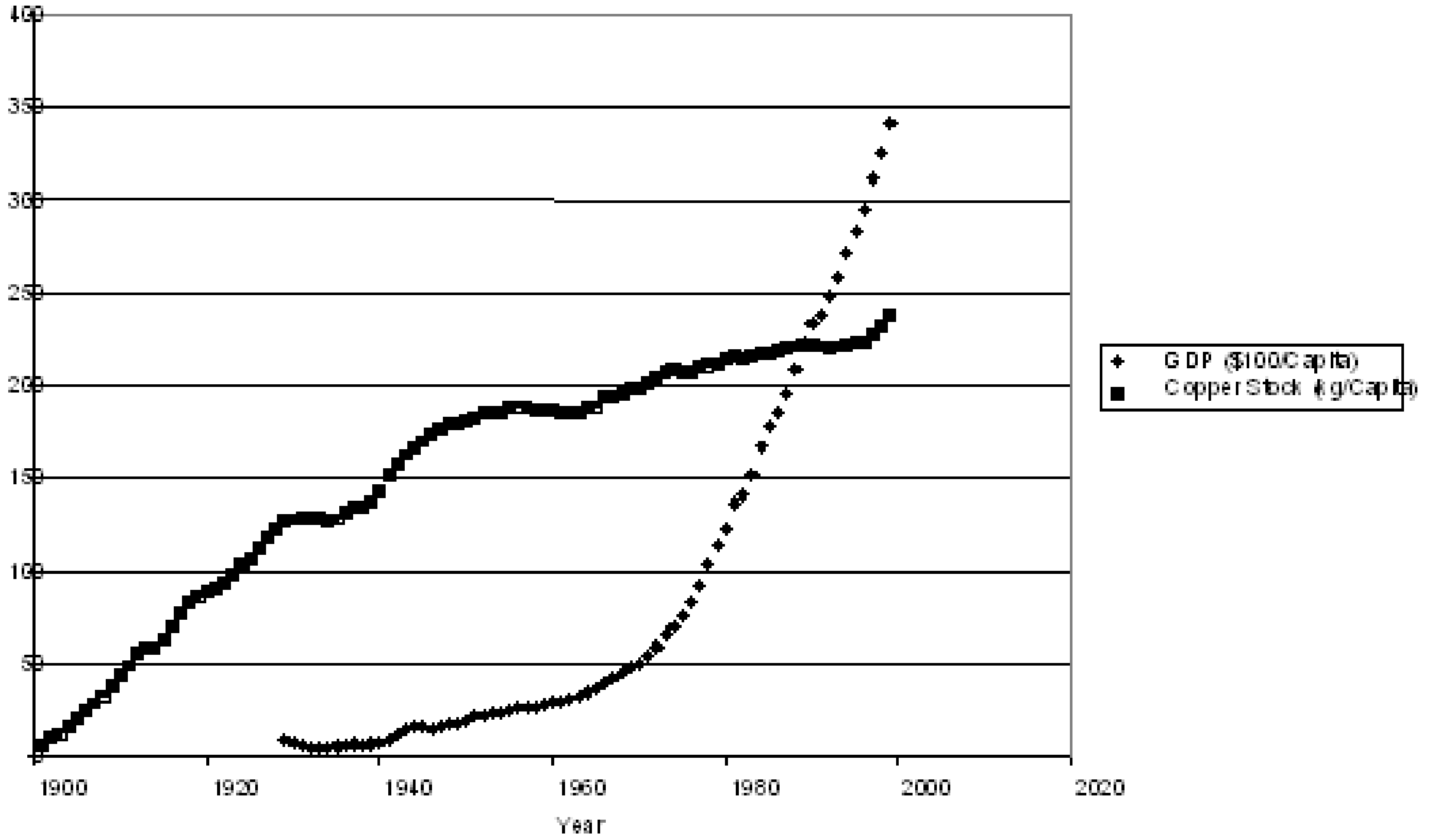
A Key Question for the Future:
How Much Material Will People Use?

Dynamics of in-use stocks provide clues about future iron use

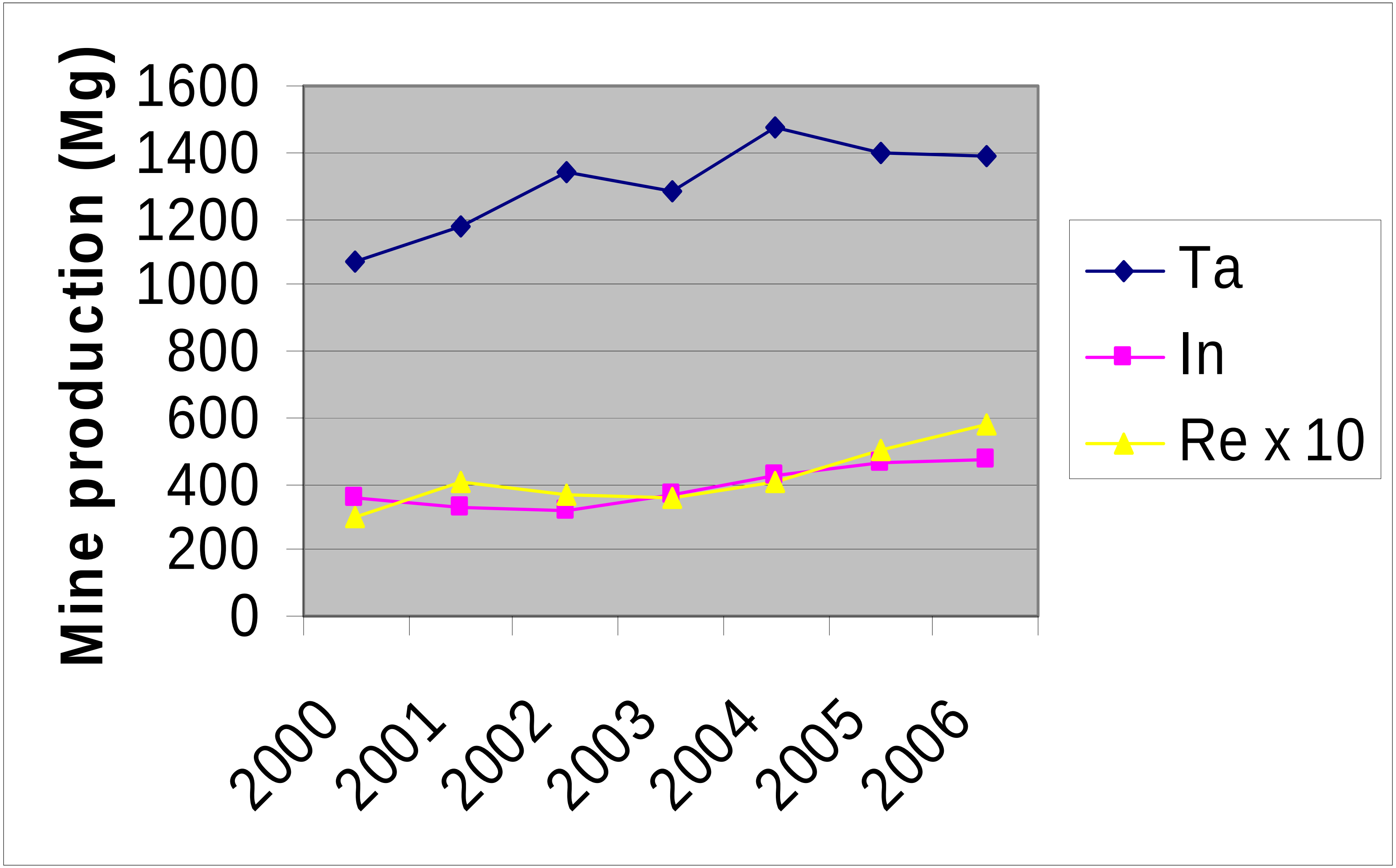
- Saturation hypothesis of in-use stocks proposed by Müller et al., *PNAS*, **44**, 16111-16116, 2006
- Per capita iron stocks in industrialized countries are predictors of metal stock increase and use in developing countries



Copper per capita stock in the US



World Use of Specialty Metals



Data source: U.S. Geological Survey

Summary

- We can probably estimate how much of the base metals (Fe, Al, Cu, Ni, Cr, Pb) we will need in the coming decades
- We do not have the information to do the same for most other resources
- Sustainable resource management required statistics are not yet adequate
- Nonetheless, we suspect that supplies of some widely used materials (Pt, Cu, Co, In?) may be severely challenged in the next decade or two