Material Requirements of Energy Technologies

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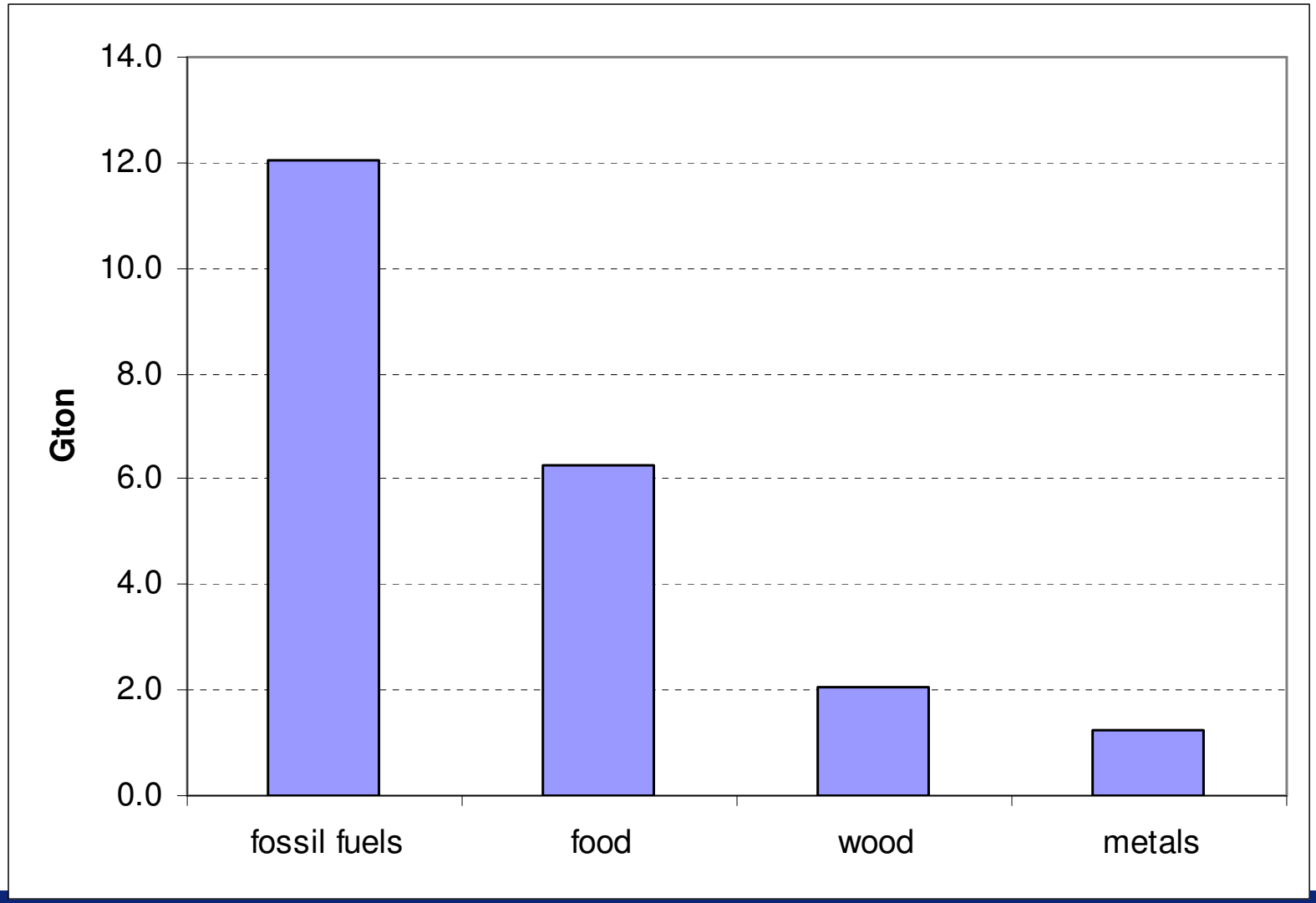
Inventory of material requirements based on current technologies

Current fossil fuel based system

- Fossil Fuels
- Uranium
- Steel: ships, pipelines, mining equipment, power plants refineries, exploration etc.
- Copper: grid, generators, electro motors,
- Aluminum : grid

Annual global material use

excluding water (4500 Gton), oxygen (~40 Gton) and sand/gravel (5-10 Gton)



What would be the impact of a transition to a low-carbon energy system ?

1
Fossil fuel based low-carbon energy system

Low-carbon fossil fuel based system: additional infrastructure & efficiency

- Carbon Capture and Sequestration (CCS):
  - Capture installation, pipelines, injection well, (decreased efficiency = extra capacity): stainless or specialty steel (30-60% extra steel / kWh)
- Highly efficient turbines (jet engines, power plants)
  - Rhenium for special temperature resistant alloys
  - REE as alloy in temperature resistant steel
- Lightweight Mg REE alloys for car engines
- Rare Earth Elements as phosphors in LED and fluorescent lighting (Y, Ce, La, Eu, Tb, Gd, ..)

2
Renewables based low-carbon energy system

Switch to renewables means:

- Switch of energy carrier
  - From fossils to electricity / hydrogen / …
- Increased distance between electricity production and use
  - PV in deserts, off shore wind
- Intermittency -> buffering needed
  - More interconnectivity between grid
  - More redundancy in electricity production
  - Smart grids

Creates a need for:

- Long distance transmission netwerk for 100-1000 EJ
- High Tech (smart) grid
- Electricity or hydrogen based mobility

Renewable based system (collection)

- (direct drive) wind turbines
  - REE: magnets in generator
  - Copper: generator
  - Steel: tower
- PV solar cells
  - Silver: silicon based cells
  - CdTe: Cd, Te ; CIGS: In, Ga ; others (Ge, Ru) in thin film cells
- energy crops
  - Steel: agricultural machines, and for the production of inputs like fertilizers

Renewable based system
(transmission / buffering)

- power lines
  - short distance (<500 km) overhead AC: aluminum (steel for towers)
  - long distance (>500 km) HVDC: copper
- H_2 pipelines
  - specialty steel (embrittlement resistant)
- electrolyzers (PEM)
  - platinum for catalysts

Renewable based system (end-use)

- cars (and other transport)
  - REE in magnets for electric motors
  - copper for electric motors
  - lithium, cobalt, nickel, lanthanum for batteries
  - platinum for PEM fuel cells

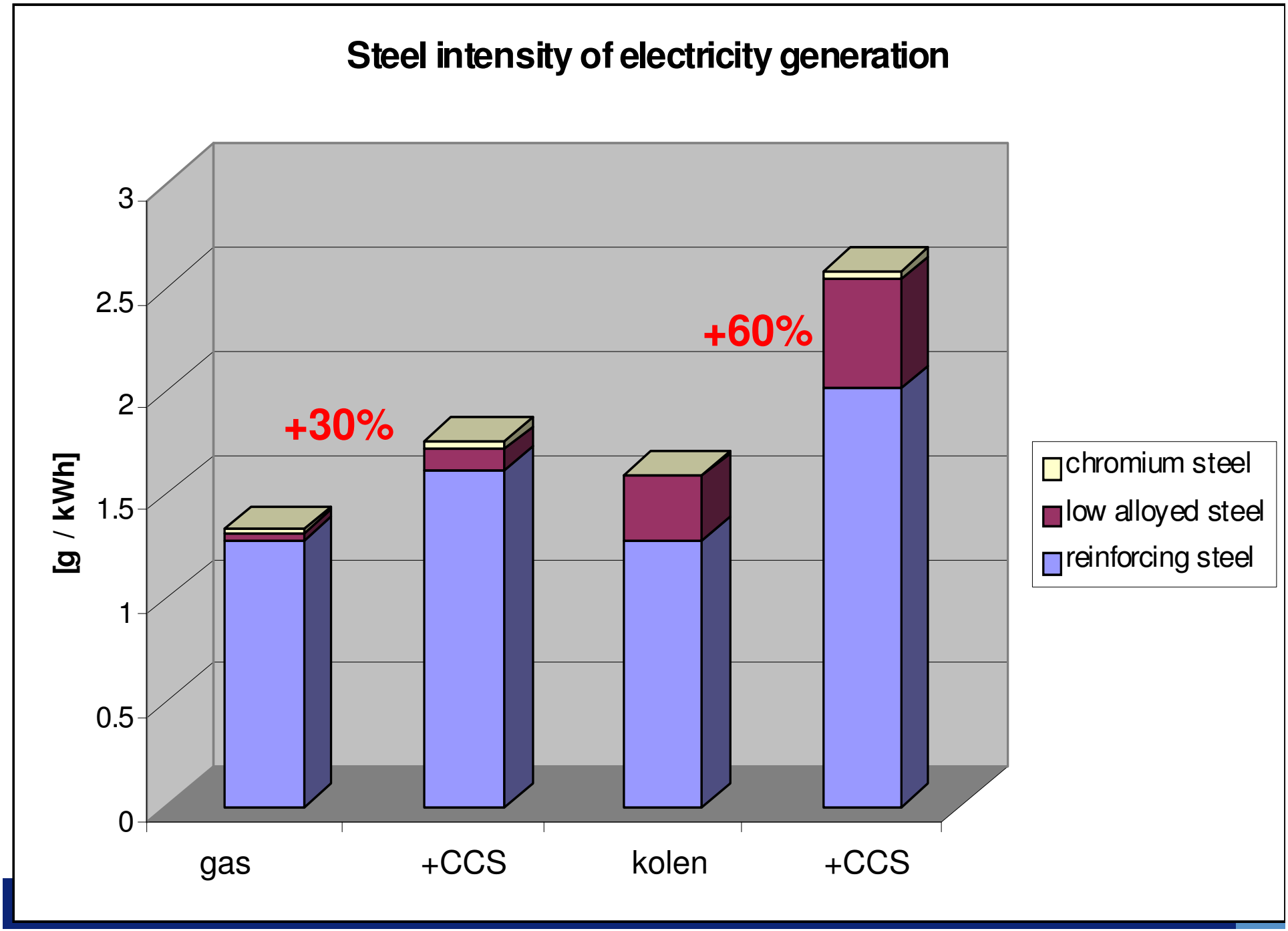
Quantification:

how do these material requirements compare to current production and reserves ?

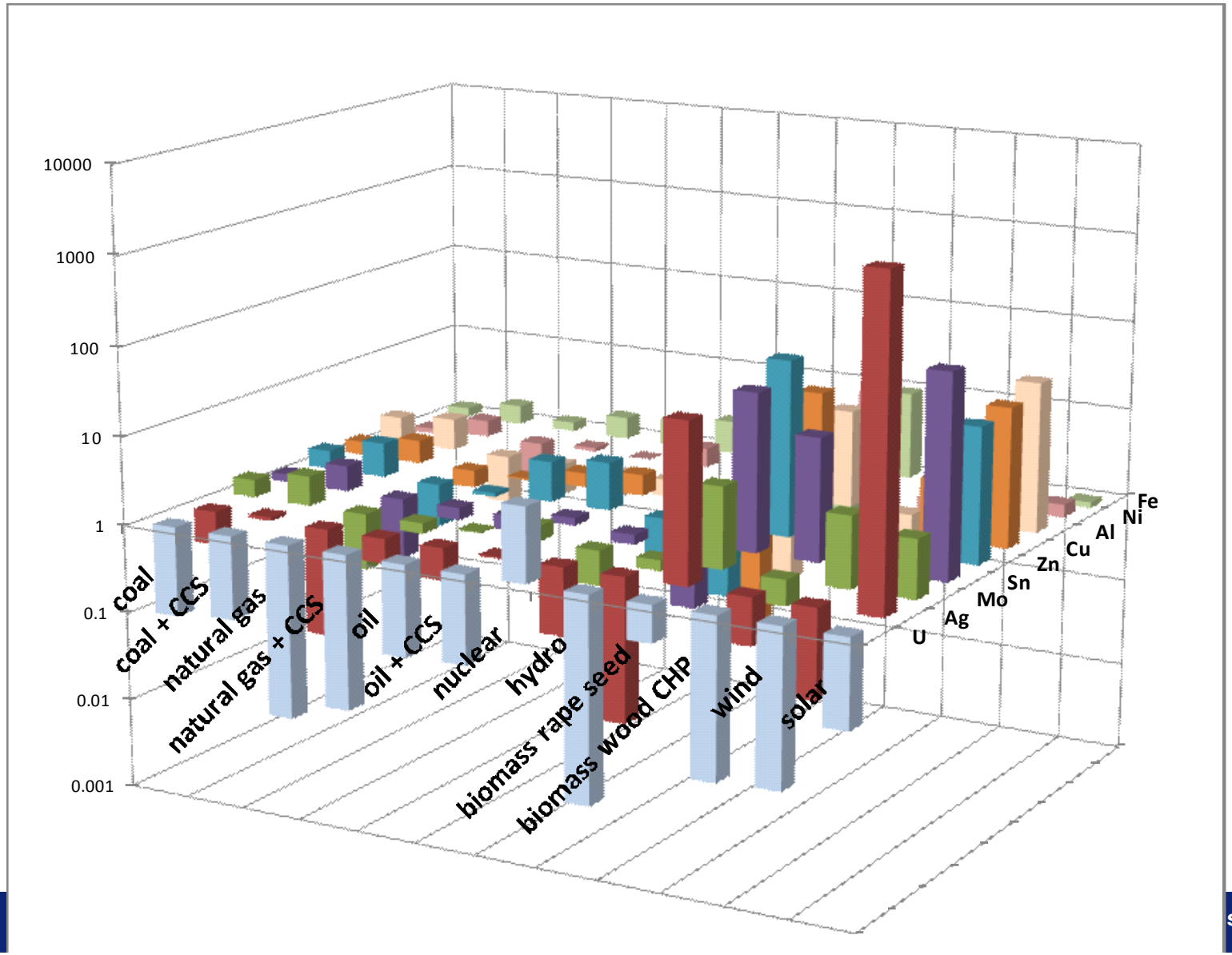
Metals in renewable energy technologies

- Copper in High Voltage DC power lines
  - 1200 MW bipolar cable
  - 28 kg / m
  - 28 ton per km
  - 3000 km > 80,000 ton Cu for one (powerplant size) cable
  - we need thousands of these cables for a worldwide supergrid
  - could add up to a quarter of the known copper resource
  - ...and we need 50 million ton Cu for wind turbines (4x annual production) and more for hybrid and full electric vehicles

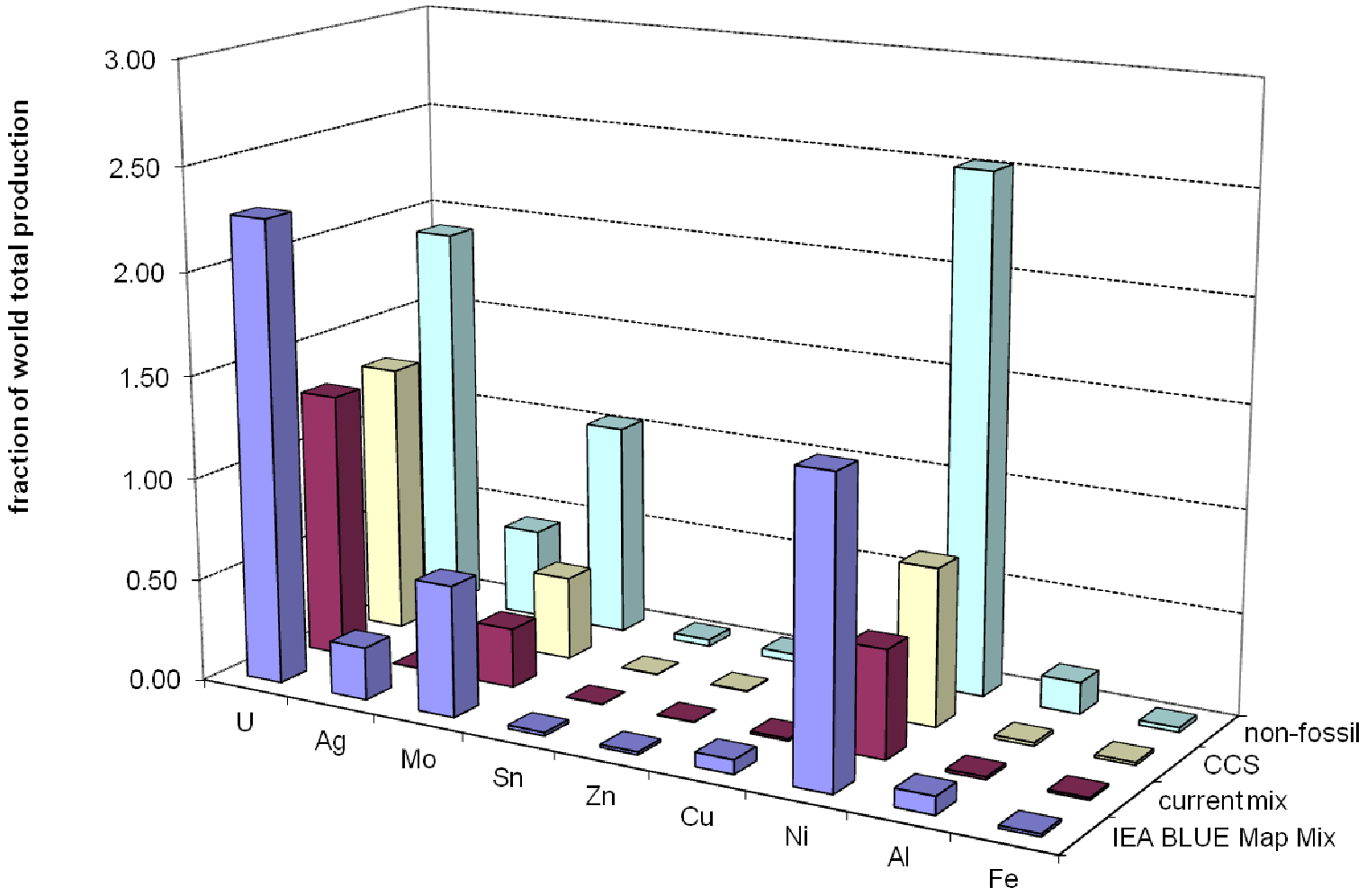
- Steel in wind turbines
  - 140 ton/MWe
  - for 15% of world energy in 2050 ,3 billion ton steel is needed
  - about three times current annual production


Steel intensity of electricity generation
[g / kWh]
3
2.5
2
1.5
1
0.5
0
+30%
+60%
gas
+CCS
kolen
+CCS
chromium steel
low alloyed steel
reinforcing steel

g metal/kWh compared to current mix



Material requirement energy scenarios compared to total annual mine production

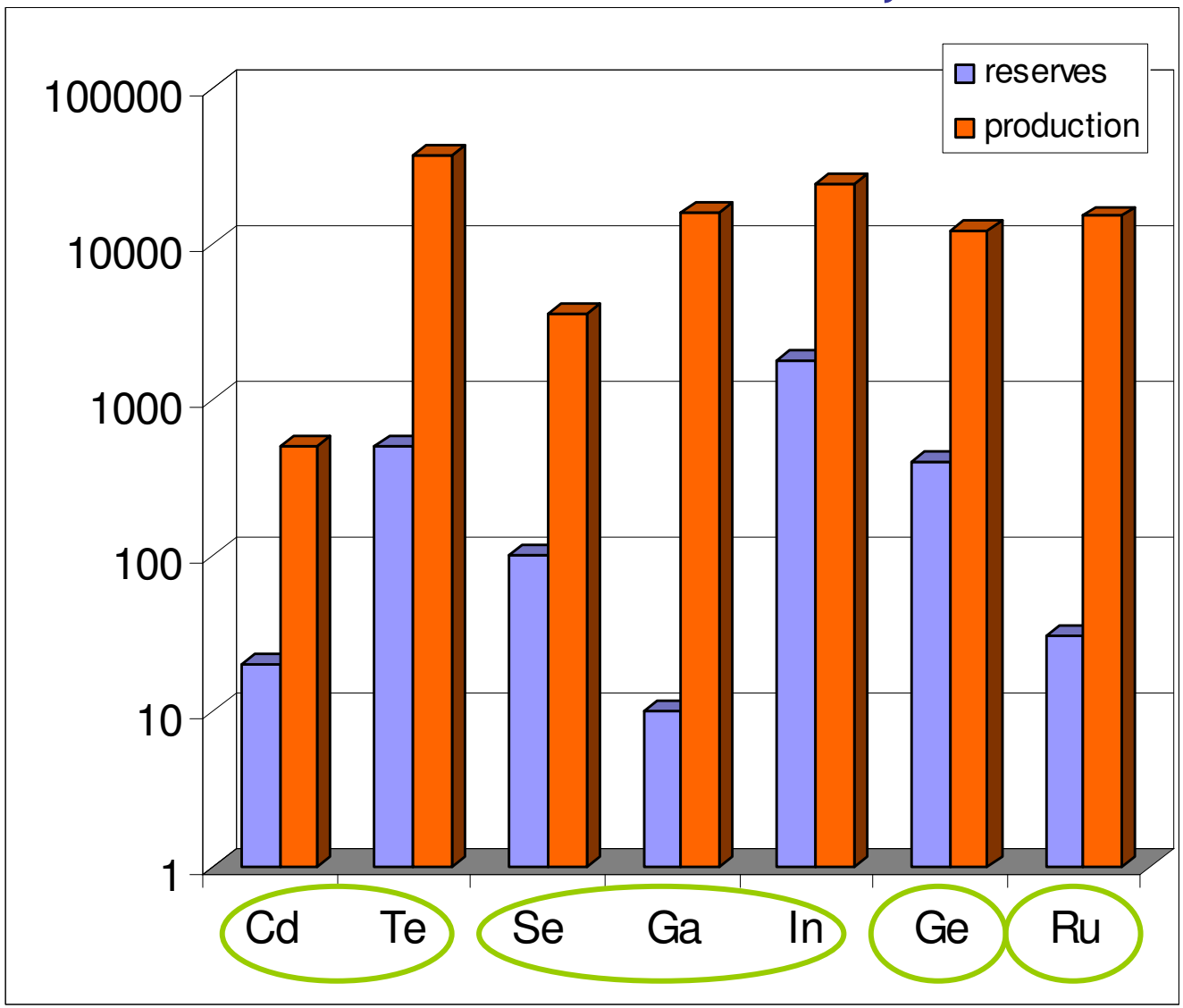


Special metals in sustainable energy technologies

- Wind Turbines
  - one large power plant (1GW) = 1250 - 2500 turbines (2MW)
  - 300 kg neodymium (Nd) per 2 MW turbine
  - 325 – 750 ton Nd for one power plant
  - current annual production 16000 ton (20-50 plants / a)

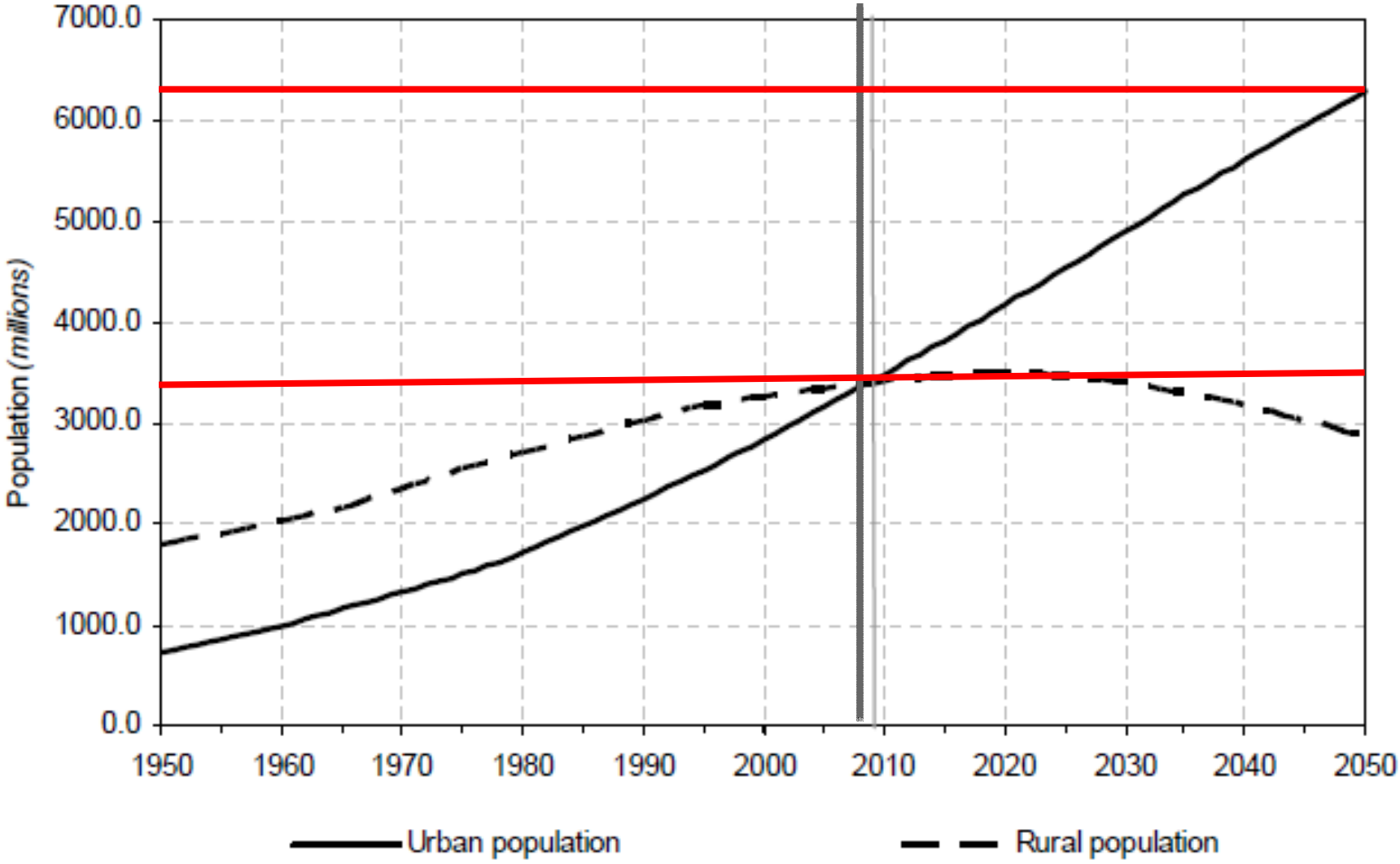
- Cars (50-60 million/a , double in 2050)
  - 0.5 kg neodymium per hybrid (34 million cars / a)
  - 0.5-1 kg lanthanum per hybrid (25-50 million cars/a)
  - 90 g dysprosium per hybrid (550,000 cars /a)
  - 7 kg lithium per electric car (2,6 million cars /a)
  - 10 kg cobalt per electric car (6 million cars/a)

thin-film PV: 2050, 80% PV



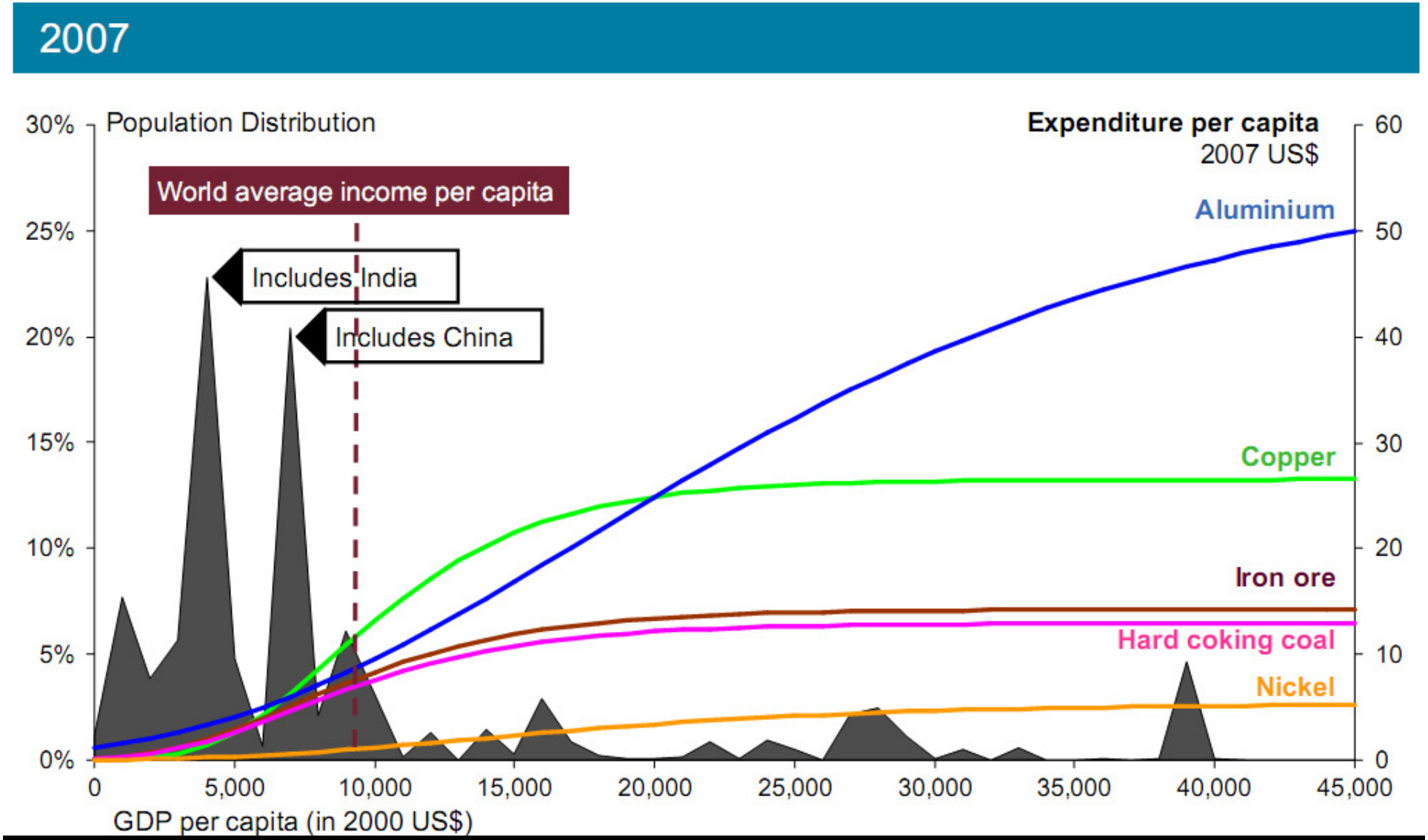
THE SUPPLY OF MATERIALS

Doubling urban population



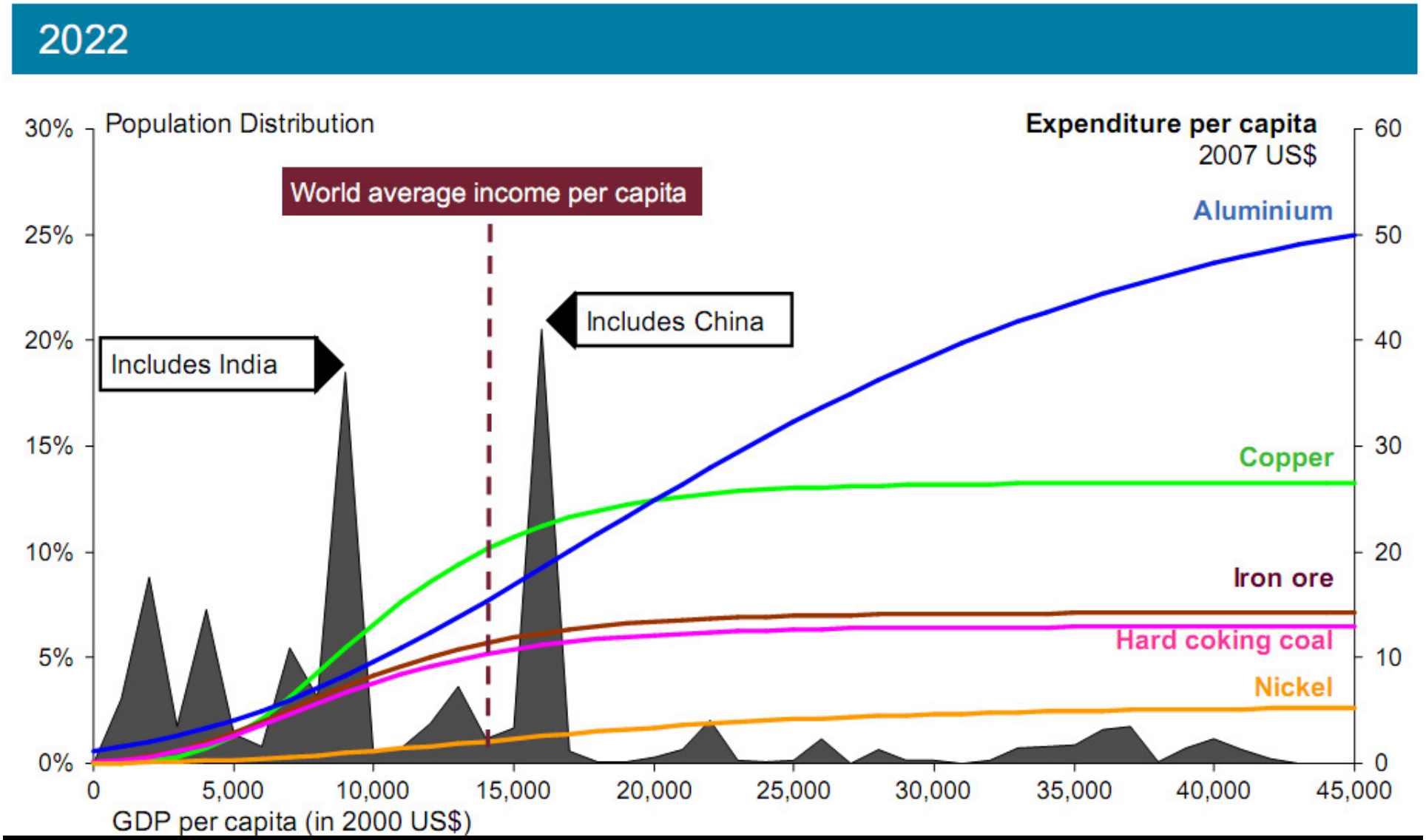
Source: UN World urbanisation prospects 2009

Climbing the materials ladder



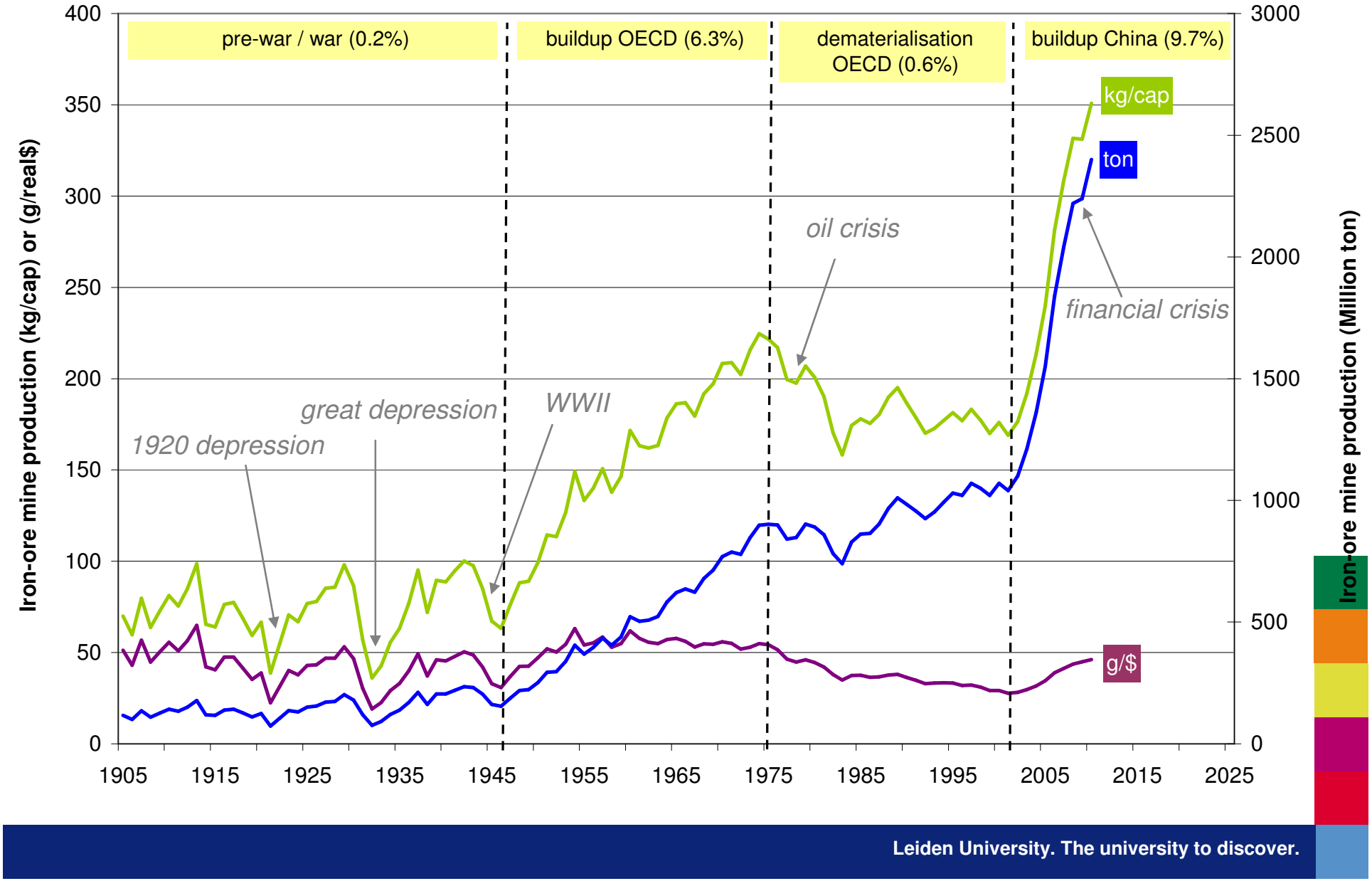
Source: Rio Tinto & Global Insight, 2008

Climbing the materials ladder

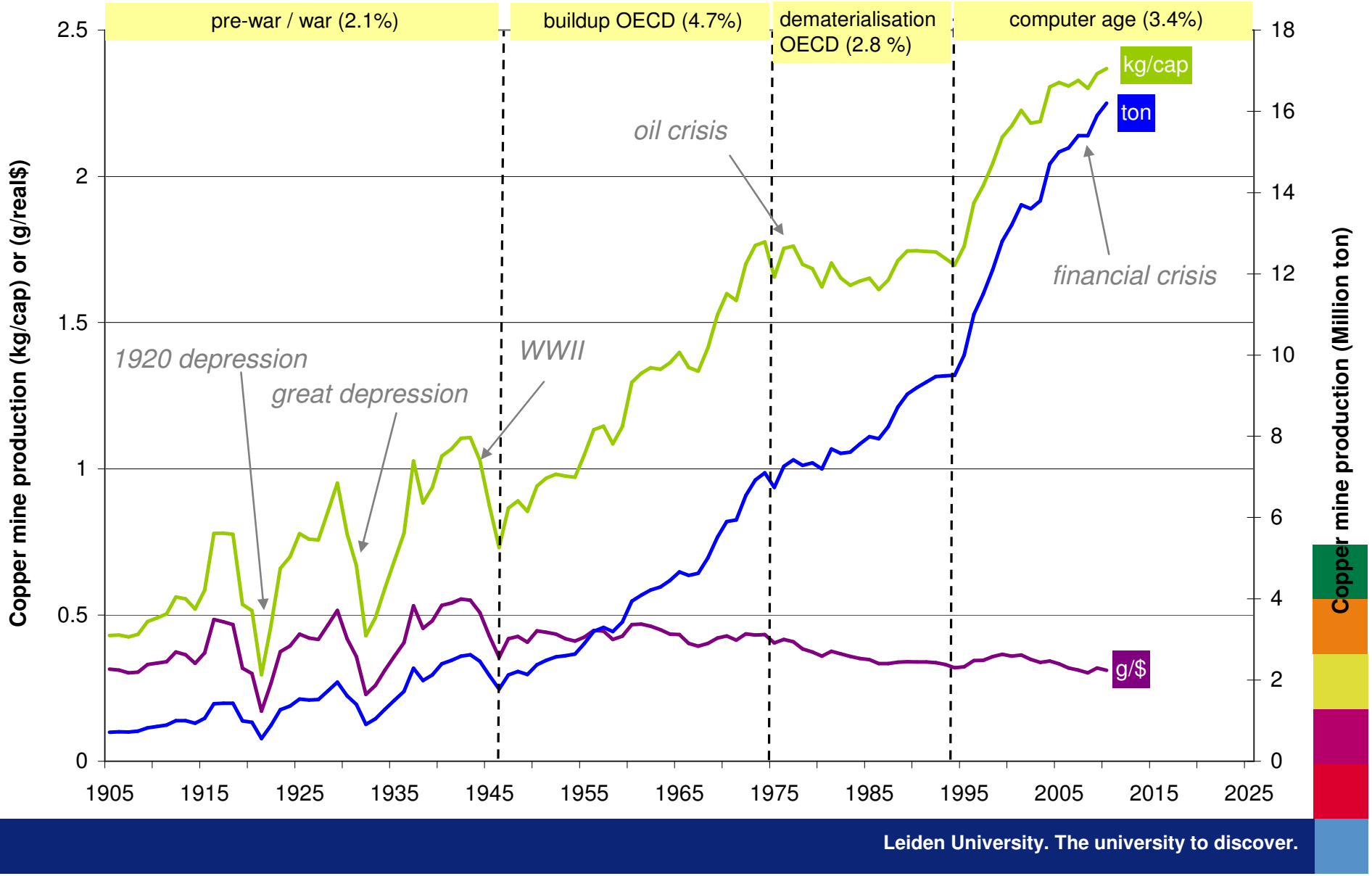


Source: Rio Tinto & Global Insight, 2008

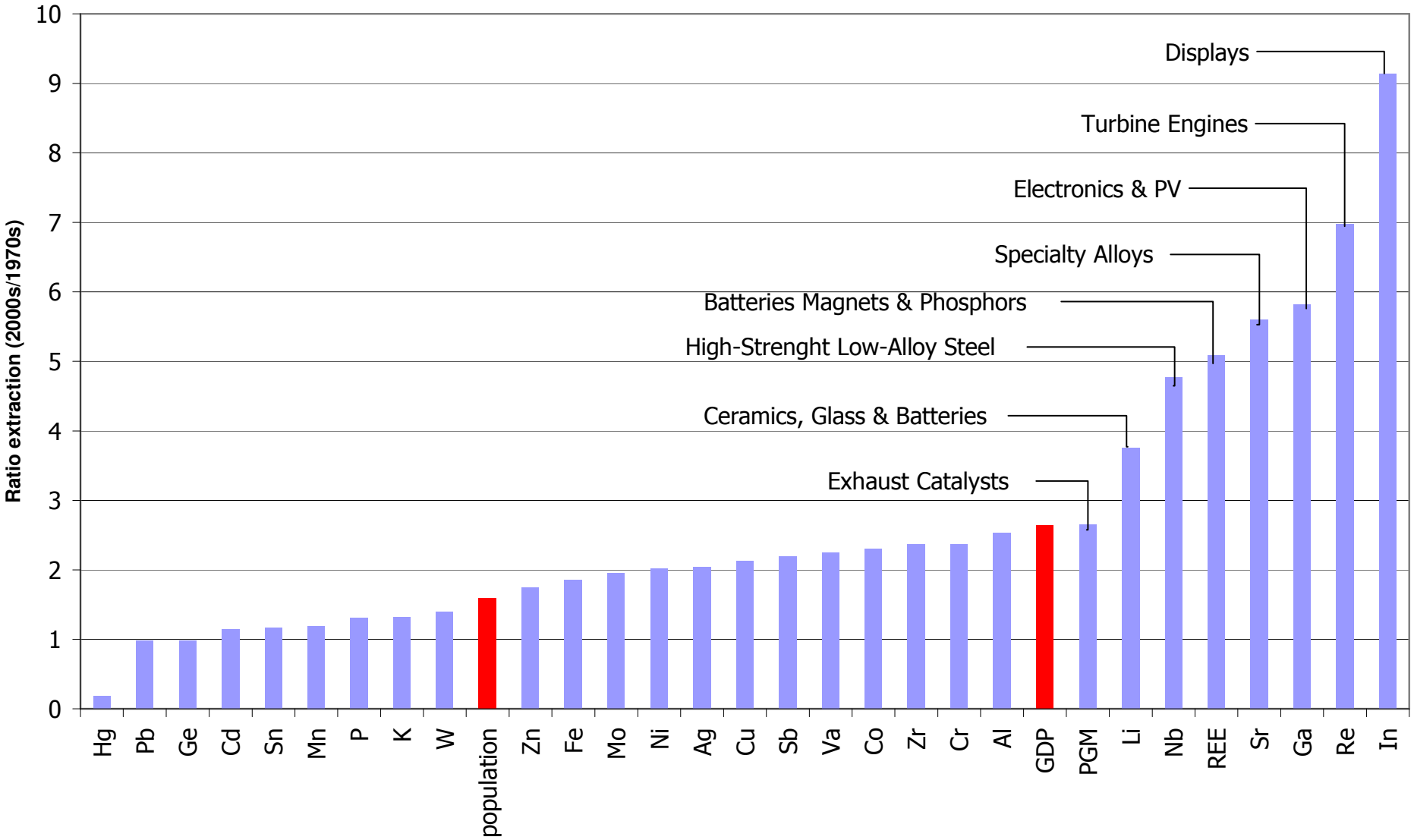
Primary production iron-ore



Primary production copper



Ratio extraction 2000s/1970s



The future:
The supply of materials :

- globalization is a one-off gain
- limits to the scale-up of mining projects
  - smaller deposits
  - deeper deposits
  - back to underground mines ?
  - high-tech mining ?
- efficiency refining is closing physical limits

Two possibilities solutions

- innovation / engineering
  - technologies based an abundant materials
    - Molycorp / Boulder Wind: Dy free wind turbines
    - Enercon: REE-free direct drive wind turbine
    - Toyota et al: PM free induction electric motor
    - FeS_2 thin film solar cell
    - Ni based catalysts fro PEM fuel cells
    - Aluminum for HVDC power lines
    - Concrete for wind turbine towers
- dematerialization / engineering
  - reduce energy (and material) demand
    - efficiency improvement
    - low growth/ stable/ de-growth economies
    - Closing the material loop: recycling, urban mining

Current studies on future metals scarcity do not include a full energy transition

- Based on extrapolations of current trends or optimistic scenarios for market penetration of low-carbon energy
- These trends don't even come close to solving climate change
- We need a complete transition to a low-carbon economy in the next few decades
- Material requirements are therefore gravely underestimated (.. or we don't act...)

Thank you for your attention

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