Global Resource Depletion:

Metal minerals scarcity and the Elements of Hope

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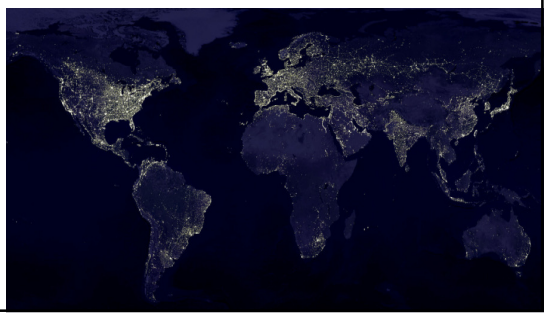


Contents

Exponential growth
"Harvesting speed" versus "ultimate quantity"
Decreasing energy per capita

Energy scarcity means materials scarcity

Metal mineral reserves
Timing of metals scarcity
Geopolitical situation
Consequences of metals scarcity

Solution frameworks
The Elements of Hope

Bottomline

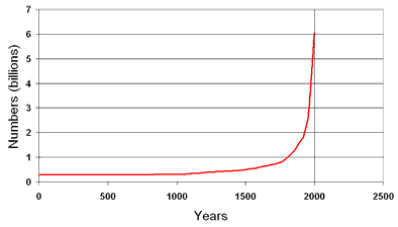
Exponential growth

root cause of global resource depletion

growth rate (% per year)	doubling time (years)
2	36
3	24
4	18
5	14
6	12
7	10
10	7

1900		
1924	1948	
1972		1996
2020		

Past World Population growth



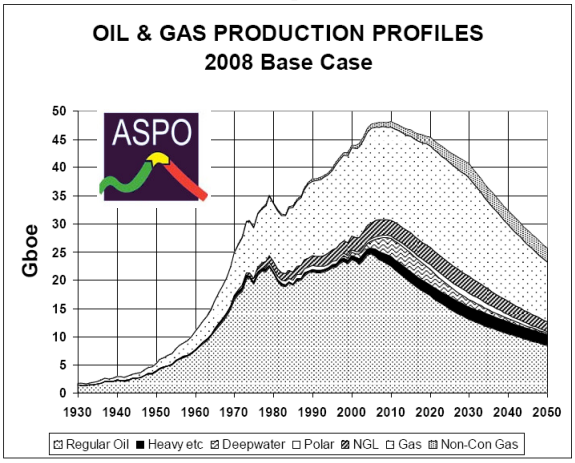
"Harvesting speed" versus "ultimate quantity"

- There is a shortage when supply as a function of time can no longer keep up with demand as a function of time
- The ultimate "recoverable" quantity is irrelevant in this respect *("it is not possible to have a baby in one month with nine women")*
- Examples:
  - fossil fuels (next slide: oil and gas)
  - fresh water
  - road transport and traffic jams
  - "run on the bank"

Decreasing energy per capita

On a global scale “regular” oil has probably peaked, natural gas will follow a decade later

The General Depletion Picture



peak = maximum production rate, when supply can no longer grow

progress in technology → more “efficient” depletion (e.g. North Sea)

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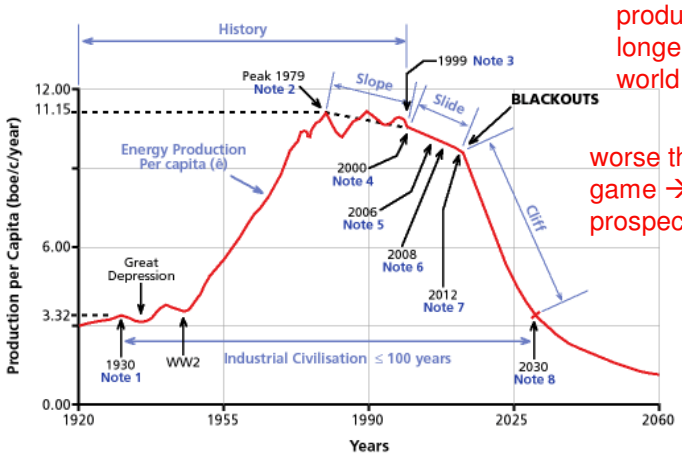
Decreasing energy per capita



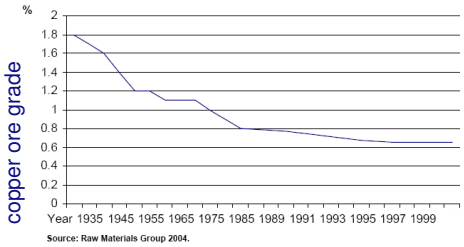
global energy production can no longer carry current world GDP

worse than a zero sum game → increased prospects for conflicts

Original source: The Olduvai Theory by Richard C. Duncan, 1989

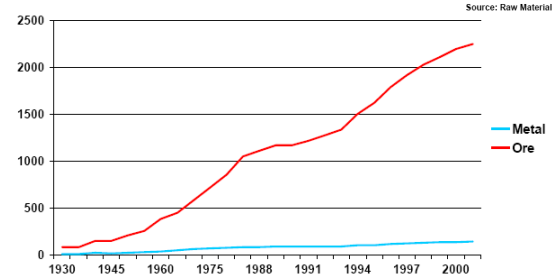
Energy scarcity means materials scarcity

Lower ore grades need exponentially more energy for extraction



Source: Raw Materials Group 2004.

Copper Mt ore/10 x Mt metal



Source: Raw Materials Group, 2004.

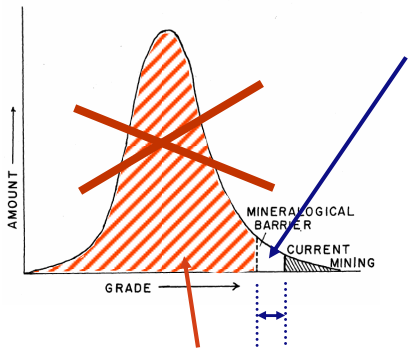
example: copper

The production of 1 tonne of copper produces around 250 tonnes of solid waste with associated energy consumption

(Monash University, 2007)

Energy scarcity means materials scarcity

Mineralogical barrier for elements ≥ 0.1% (mass) earth's crust



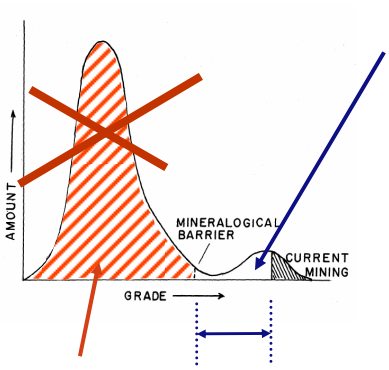
Remaining relevant resources of **aluminum, iron, silicon, magnesium, titanium, …..**

Source: "Exploring the resource base" by Brian J. Skinner, Yale University, 2001

Extremely energy-intensive to extract

Energy scarcity means materials scarcity

Mineralogical barrier for elements < 0.1% (mass) earth's crust



Remaining relevant resources of other minerals

"rare": Cu, Sn, Ni, Sb, Ag, ….

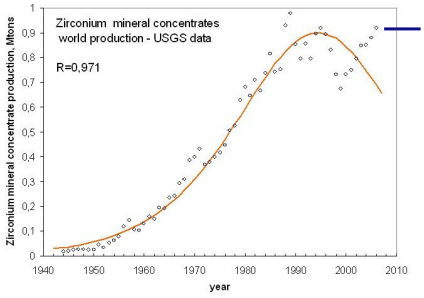
"trace": Pt, In, Se, Ga, ….

Source: "Exploring the resource base" by Brian J. Skinner, Yale University, 2001

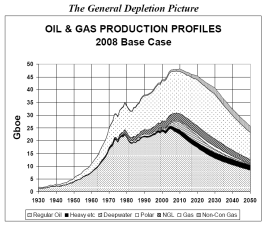
Extremely energy-intensive to extract

Energy scarcity means materials scarcity

Materials scarcity: parallels with "peak oil"



source: Bardi en Pagani, 2007



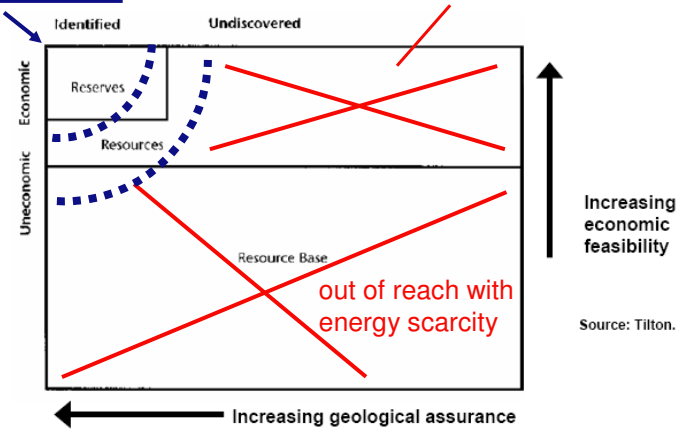
- The time-production profile of large individual mines and of the summation hereof resembles a bell-shaped curve comparable with oil
- The right part of the bell-shaped curve is more difficult to realize because the "low-hanging fruit" has already been harvested
- It takes increasingly more energy to "harvest" the remaining energy and the remaining minerals

Metal minerals reserves

Reserves versus Resources and Resource Base

focus on Reserves!!

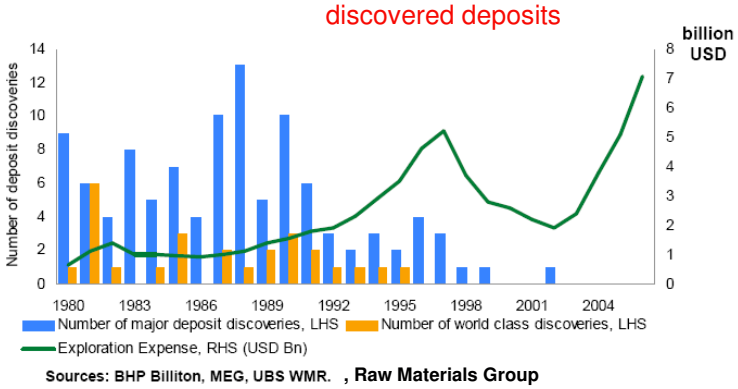
see next slide



Metal minerals reserves

Discovery rate of major mineral deposits

low expectations of yet to be discovered deposits

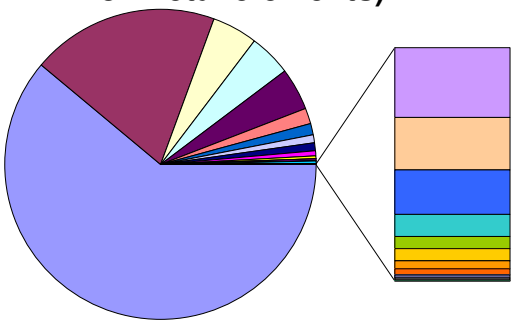


Sources: BHP Billiton, MEG, UBS WMR. , Raw Materials Group

Timing of metals scarcity

Absolute and relative quantities: global reserves

Global reserves excluding magnesium and iron (around 10 billion metric tons of metal elements)



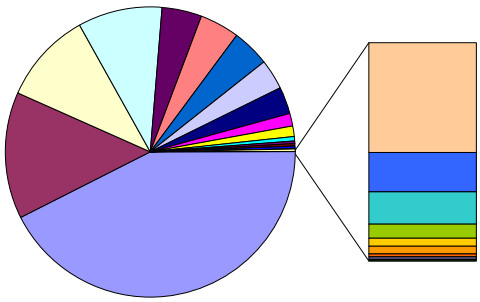
Al Cr
Cu Mn
Ti Zn
Ba Pb
REM Ni
Zr V
Mo Co
Sr Sn
Li W
Nb Sb
As Cd
Y Bi
Ag Ta
Be PGM
Hg Au
Te In
Re Tl

based on USGS

Timing of metals scarcity

Absolute and relative quantities: global production

Annual global primary production excluding iron (around 110 million metric tons of metal elements)

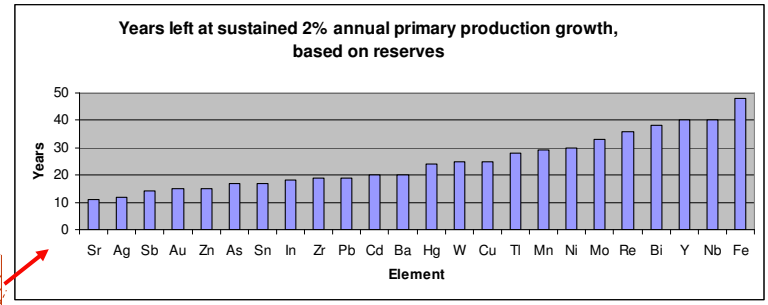


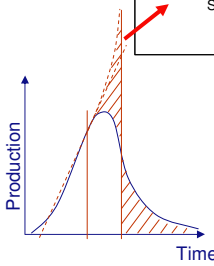
Al Cu
Mn Zn
Cr Ba
Mg Ti
Pb Ni
Zr Sr
Sn Mo
Sb REM
W Co
As V
Nb Li
Ag Cd
Y Bi
Au Hg
Ta In
PGM Te
Be Re
Tl

based on USGS

Timing of metals scarcity

"Years to go" versus bell-shaped curve



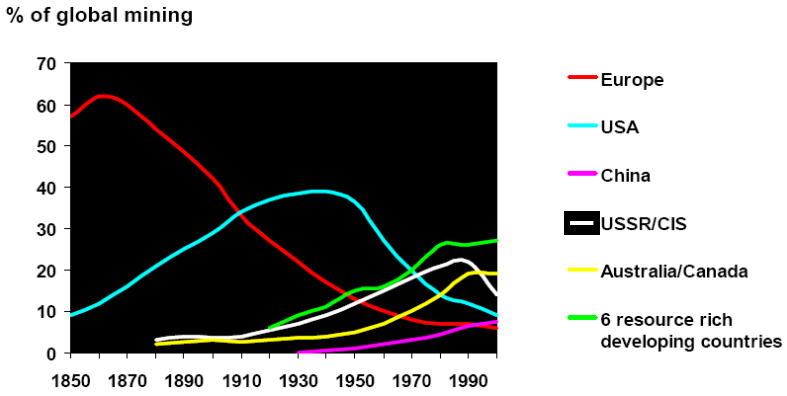


peak date may arrive sooner !!

Source: Dr. A.M. Diederen, ***Metal minerals scarcity: a call for managed austerity and the elements of hope***, March 10, 2009, published at TheOilDrum.com and hcss.nl

Geopolitical situation

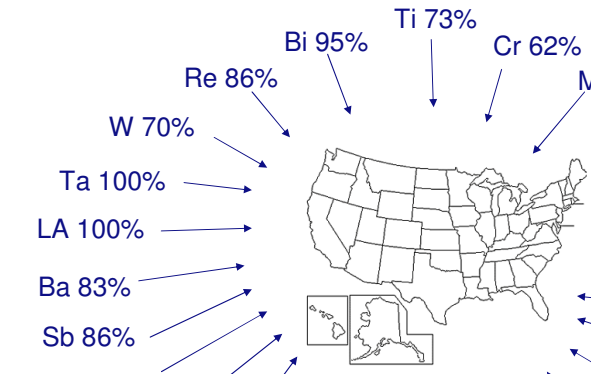
Europe and the US have already depleted a significant part of their resources



Sources: Raw Materials Data, Stockholm 2004, Sames, Raw Materials Group

Geopolitical situation

Example: net import balance USA 2007



Ti 73%
Bi 95%
Cr 62%
Re 86%
Mn 100%
W 70%
Cu 37%
Ta 100%
Sc 100%
LA 100%
V 100%
Ba 83%
Co 78%
Sb 86%
Ni 17%
Sn 79%
Zn 58%
In 100%
Ga 99%
Ag 55%
As 100%
Pt 94%
Nb 100%
Y 100%
Sr 100%

even worse for EU

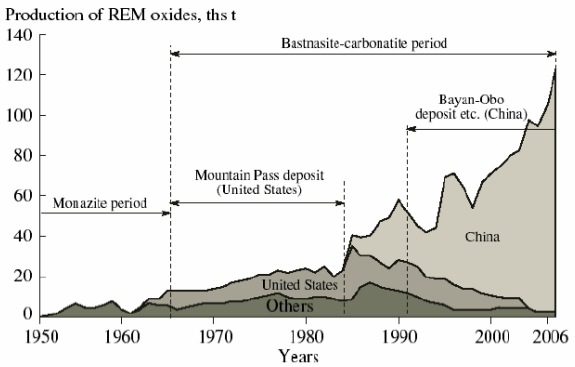
LA = lanthanoids (rare earth metals)

Source: USGS

Geopolitical situation

Increasing dependence on limited resources

97% of primary production of rare earth metals (REM) (Sc + Y + lanthanoids) comes from China



China restricted REM exports since 2004 (-/- 30%)

2009:
China became share-holder in 2 major REM companies in Australia

Sources: naumov 2008, Fraunhofer Institute 2009

Consequences of metals scarcity

- Less affordable mass-produced electronic products
  mobile phones, flatscreen TV's, PC's, …
- Forget large-scale conversion towards alternative energy sources
- Forget large-scale electrification of land-based transport
- Chemical compounds will become more expensive
- Construction and machining will become more expensive
- Metals scarcity will aggravate energy scarcity !!

Solution frameworks

What can be done about metals scarcity?

1. Use less or "managed austerity"
   most important solution but reluctant human behaviour leads to low priority
2. Longer product lifetime
3. Recycling and reuse of materials
4. Substitution of materials
5. Develop adapted new products
6. Stockpiles

Solution frameworks

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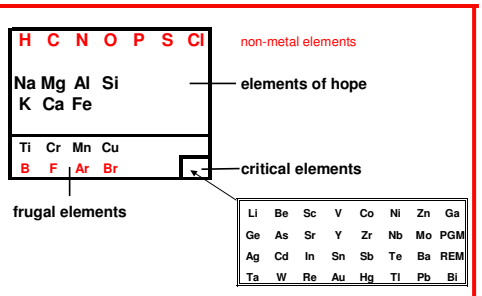

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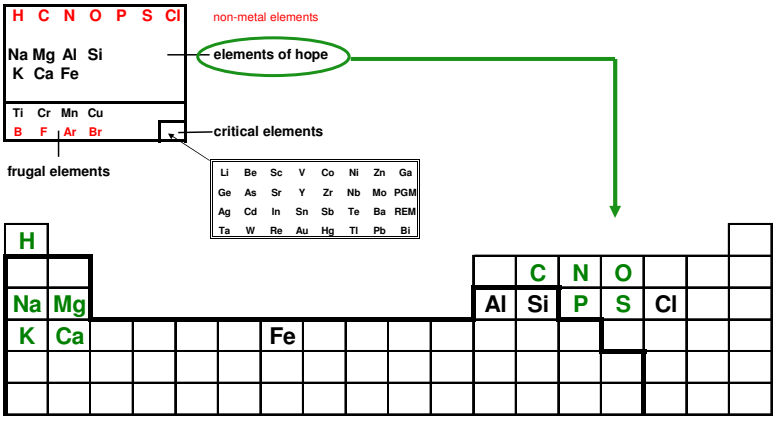
Solution frameworks

The Elements of Hope → substitution



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the green elements are macronutrients

Bottomline

- One of the grave consequences of energy scarcity is metals scarcity
  and metals scarcity will aggravate energy scarcity !!
- Metals scarcity directly undermines our ability to sustain our current level of material prosperity
- Logical conclusion: use less !!
- Technology alone won't solve our problems, we need to co-ordinate our efforts towards a collective goal of sustainability

  → **"managed austerity"**

Discussion

free market economy?
China's solution?
……?
……?
……?