Metal minerals scarcity and the Elements of Hope

Trends and needs for advanced materials for Defence & Security
NIDV, The Hague, June 23, 2009

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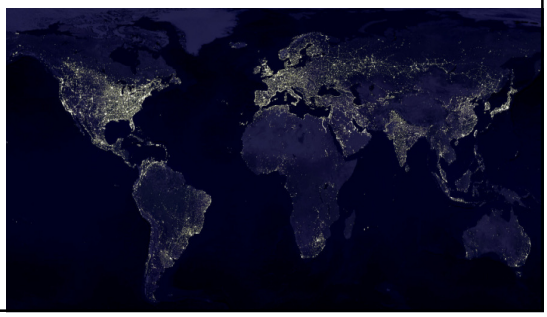

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- Learning from history
- The Elements of Hope

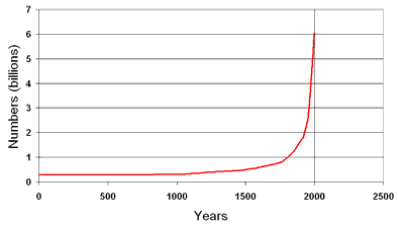
Exponential growth

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



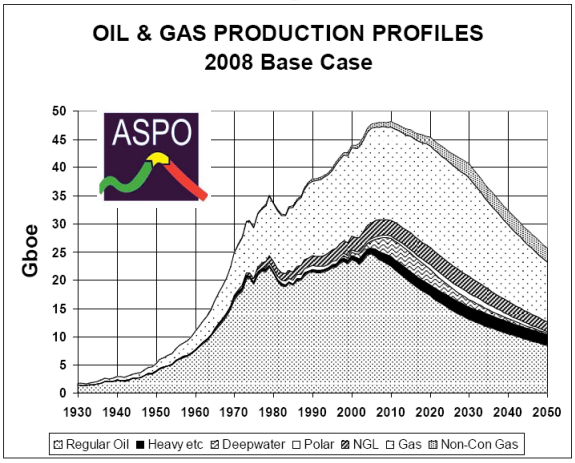
"Harvesting speed" versus "ultimate quantity"

- 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

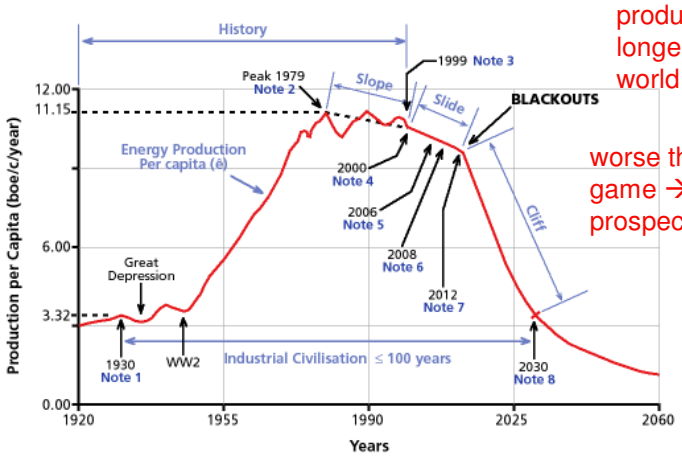


peak = maximum production rate, when supply can no longer grow

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

ENERGYWATCHGROUP

Decreasing energy per capita



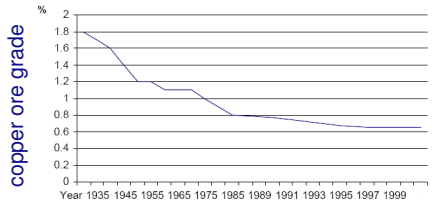
global energy production can no longer carry current world GDP

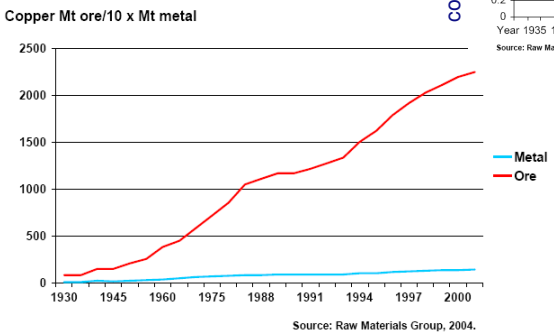
worse than a zero sum game → increased prospects for conflicts

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

Energy scarcity means materials scarcity

Lower ore grades, more remote / deeper mining means exponentially more energy for extraction





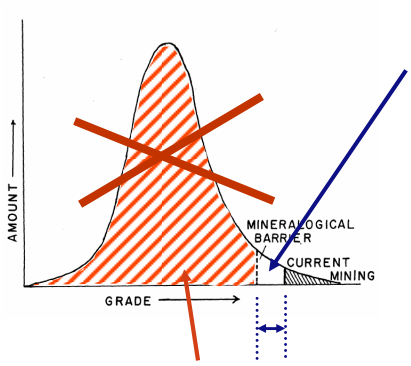
example: copper

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



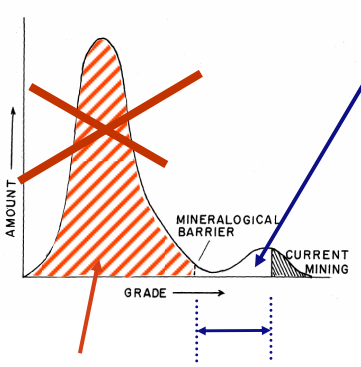
Remaining relevant resources of **aluminum, iron, silicon, magnesium, titanium, …..**

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, ….

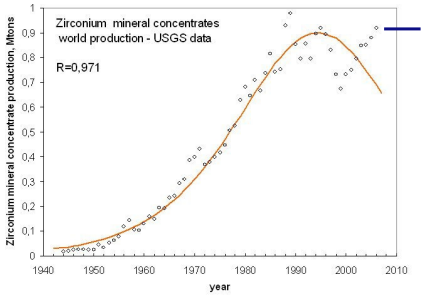
"trace": Pt, In, Se, Ga, ….

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

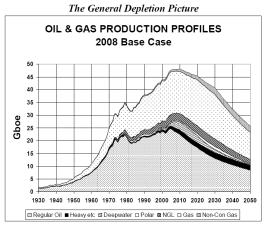
Extremely energy-intensive to extract

Energy scarcity means materials scarcity

Materials scarcity: parallels with "peak oil"



source: Bardi en Pagani, 2007



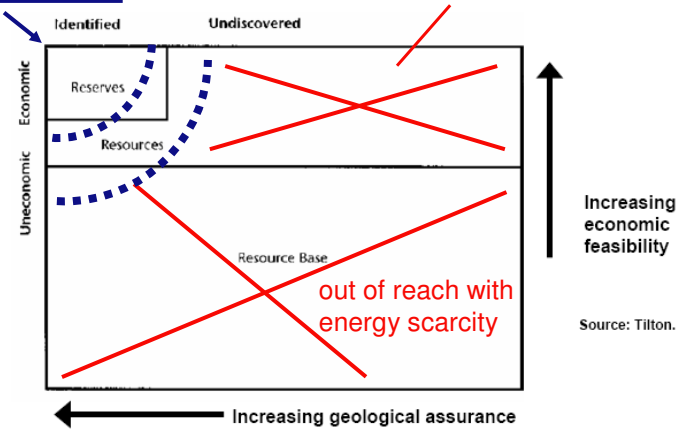
- The time-production profile of large individual mines and of the summation hereof resembles a bell-shaped curve comparable with oil
- The right part of the bell-shaped curve is more difficult to realize because the "low-hanging fruit" has already been harvested
- It takes increasingly more energy to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

Metal minerals reserves

Reserves versus Resources and Resource Base

focus on Reserves!!

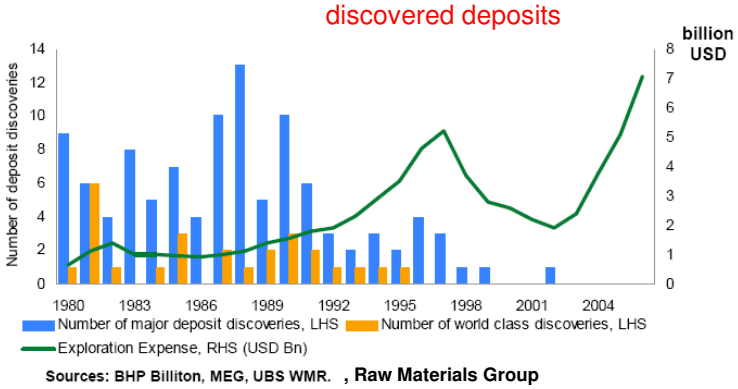
see next slide



Metal minerals reserves

Discovery rate of major mineral deposits

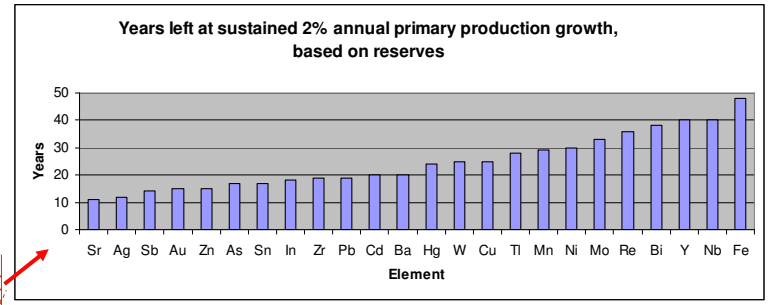
low expectations of yet to be discovered deposits

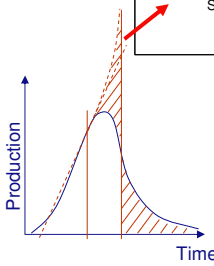


Sources: BHP Billiton, MEG, UBS WMR. , Raw Materials Group

Timing of metals scarcity

"Years to go" versus bell-shaped curve



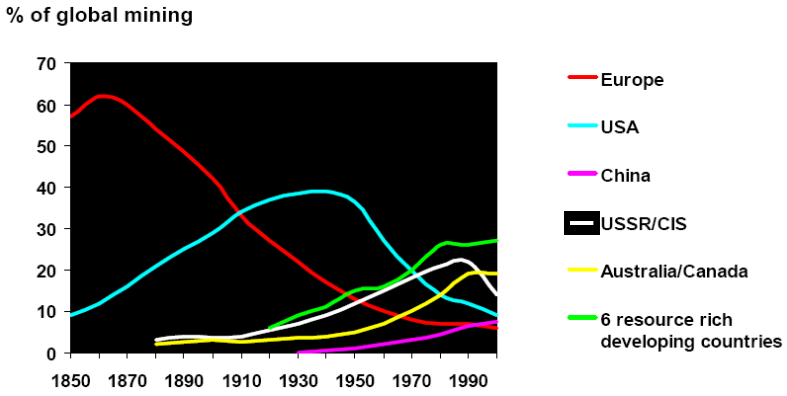


peak date may arrive sooner !!

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

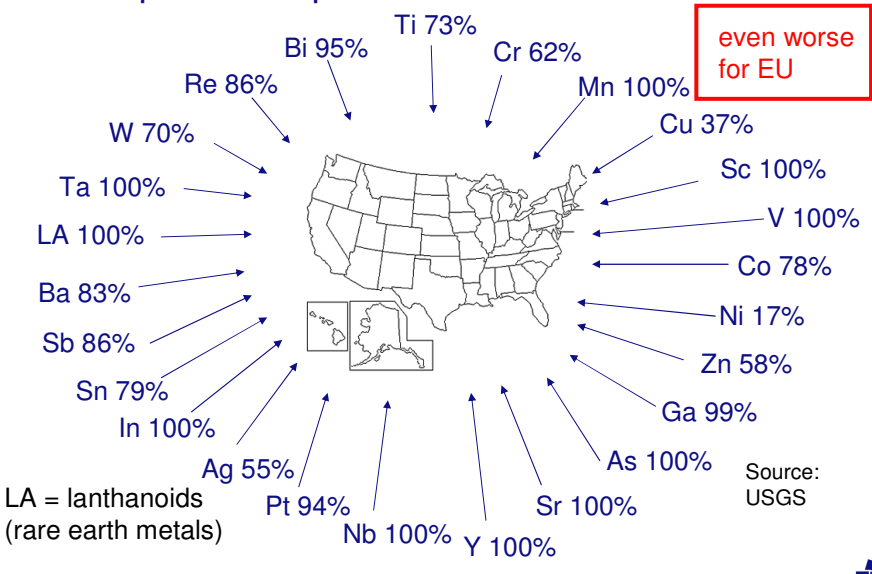
Europe and USA have already depleted a significant part of their resources



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

Geopolitical situation

Example: net import balance USA 2007



even worse for EU

LA = lanthanoids (rare earth metals)

Source: USGS

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

Stockpiles

- Keep buffers to cope with supply disruptions and to enable peak shaving

Simplest and easiest to realize solution, however not sustainable in itself

Solution frameworks

Develop adapted new products using past knowledge and experience

Learn from the past when society was much less energy intensive, when we were much less affluent in a material sense

examples: developments from WW-II and early Cold War

German Jagdtiger (WW-II), armour steel >94% iron

1950s/1960s: aluminum 5083 (± 4.5% magnesium)

Solution frameworks

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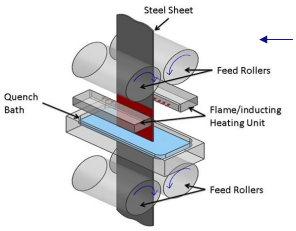
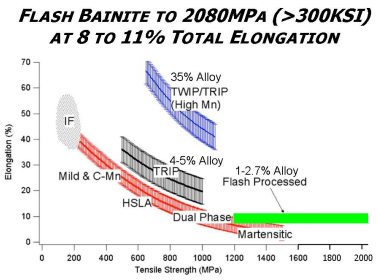
Learn from the past when society was much less energy intensive, when we were much less affluent in a material sense

example: low alloy steels from 1930s



2009

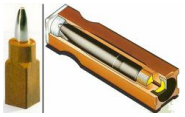


Solution frameworks

Implications for munitions

- Closest “cheap” alternative for high-density projectile materials is steel (around 8 instead of around 19 kg/dm^3)
- Comparable kinetic energy by increased impact velocity?

- Reuse existing technologies?



Heckler & Koch G11 with caseless ammunition (1970s-1980s)

- “Dematerialization”: Directed Energy Weapons?
  Beware of problem shifting!

Solution frameworks

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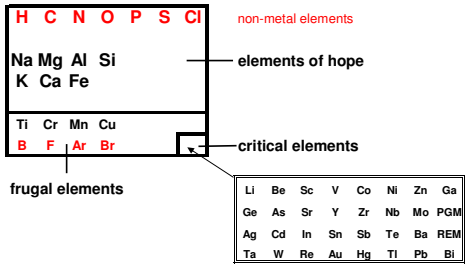

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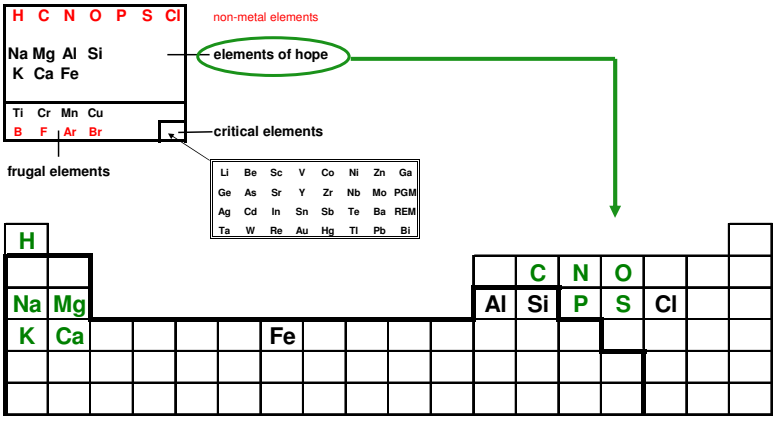
Solution frameworks

The Elements of Hope → substitution



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the green elements are macronutrients

Questions?