Global Resource Depletion: Metal minerals scarcity and the Elements of Hope

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andre.diederen@tno.nl

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Bottomline
Exponential growth
root cause of global resource depletion

<table>
<thead>
<tr>
<th>growth rate (% per year)</th>
<th>doubling time (years)</th>
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<tbody>
<tr>
<td>2</td>
<td>36</td>
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<td>3</td>
<td>24</td>
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<td>7</td>
<td>10</td>
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<td>10</td>
<td>7</td>
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</table>

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)

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

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

The production of 1 tonne of copper produces around 250 tonnes of solid waste with associated energy consumption (Monash University, 2007)

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, ….

Extremely energy-intensive to extract

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

Energy scarcity means materials scarcity

Materials scarcity: parallels with “peak oil”

• 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

source: Bardi en Pagani, 2007
Metal minerals reserves

Reserves versus Resources and Resource Base

focus on Reserves!!

Reserves

Unreserves

Identified

Undiscovered

Economic

Uneconomic

Increasing economic feasibility

out of reach with energy scarcity

Increasing geological assurance

Source: Tilson.

Metal minerals reserves

Discovery rate of major mineral deposits

low expectations of yet to be discovered deposits

Number of deposit discoveries

Exploration Expense (USD Bln)

Sources: BHP Billiton, MEO, UBS WMR, , Raw Materials Group

billion USD


0 2 4 6 8 10 12 14

Number of deposit discoveries, LHS

Number of world class discoveries, LHS
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
- Cu
- Mn
- Ti
- Cr
- 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

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

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Import Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn</td>
<td>100%</td>
</tr>
<tr>
<td>Co</td>
<td>78%</td>
</tr>
<tr>
<td>Ni</td>
<td>17%</td>
</tr>
<tr>
<td>Zn</td>
<td>58%</td>
</tr>
<tr>
<td>Ga</td>
<td>99%</td>
</tr>
<tr>
<td>As</td>
<td>100%</td>
</tr>
<tr>
<td>Sr</td>
<td>100%</td>
</tr>
</tbody>
</table>

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 shareholder 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
What can be done about metals scarcity?

1. Use less or “managed austerity”
   most important solution but reluctant human behaviour leads to low priority

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5. Develop adapted new products

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The Elements of Hope → substitution

- Non-metal elements
- Elements of hope
- Critical elements
- Frugal elements

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
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?
..........?
..........?
..........?