



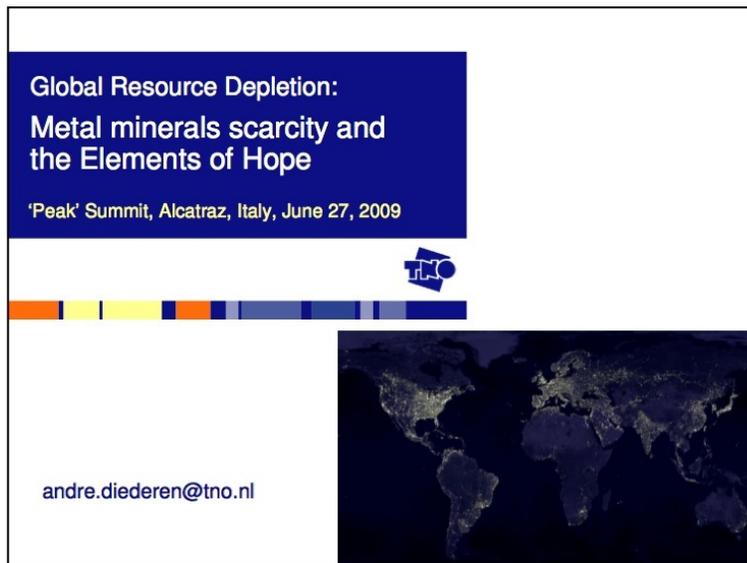
Metal Minerals Scarcity and the Elements of Hope

Posted by [Rembrandt](#) on July 9, 2009 - 10:53am in [The Oil Drum: Europe](#)

Topic: [Environment/Sustainability](#)

Tags: [a.m. dideren](#), [alcatraz conference](#), [mineral scarcity](#) [[list all tags](#)]

This is a presentation by Dr. A. M. Diederer, given at the Oil Drum/ASPO Conference at Alcatraz, Italy in June 2009. It can be downloaded here: [Global Resource Depletion: Metal minerals scarcity and the Elements of Hope](#), PDF 24 slides, 0.5 MB



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Slide 1

If policy does not change, the ongoing growth in global consumption of metals will cause shortages, aggravate energy scarcity and obstruct the transition towards a sustainable economy.

For my analysis the collective work presented by ASPO-members and at TheOilDrum has proven to be an invaluable source of information. I would like to especially mention the work of Prof. Ugo Bardi, because he has inspired me to look further into the issue of metal minerals depletion.

This presentation elaborates on my paper “Metal minerals scarcity: A call for managed austerity and the elements of hope”, published at the website [TheOilDrum.com](http://europe.theoil Drum.com/node/5239) on May 4, 2009 (<http://europe.theoil Drum.com/node/5239>) and at the TNO website on June 24, 2009 (<http://www.tno.nl/>).

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Slide 2

Metals scarcity is becoming one of the most urgent global problems, comparable with energy scarcity which is its root cause.

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

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Slide 3

The underlying problem is exponential growth of the world’s population and associated consumption of natural resources. Earlier this year, the IMF (within the context of the current

The Oil Drum: Europe | Metal Minerals Scarcity and the Elements of Hope <http://europe.theoil Drum.com/node/5559> global crisis) stated that a “healthy” world economy grows each year with 3% or more. Sustained growth of 3% per year means a doubling time every 24 years. Compare this with the average growth of China’s economy during the last 15 years and associated growth in metals consumption: 10% or more per year, meaning a doubling time of 7 years (or shorter). This is of course nothing less than a Ponzi Scheme.

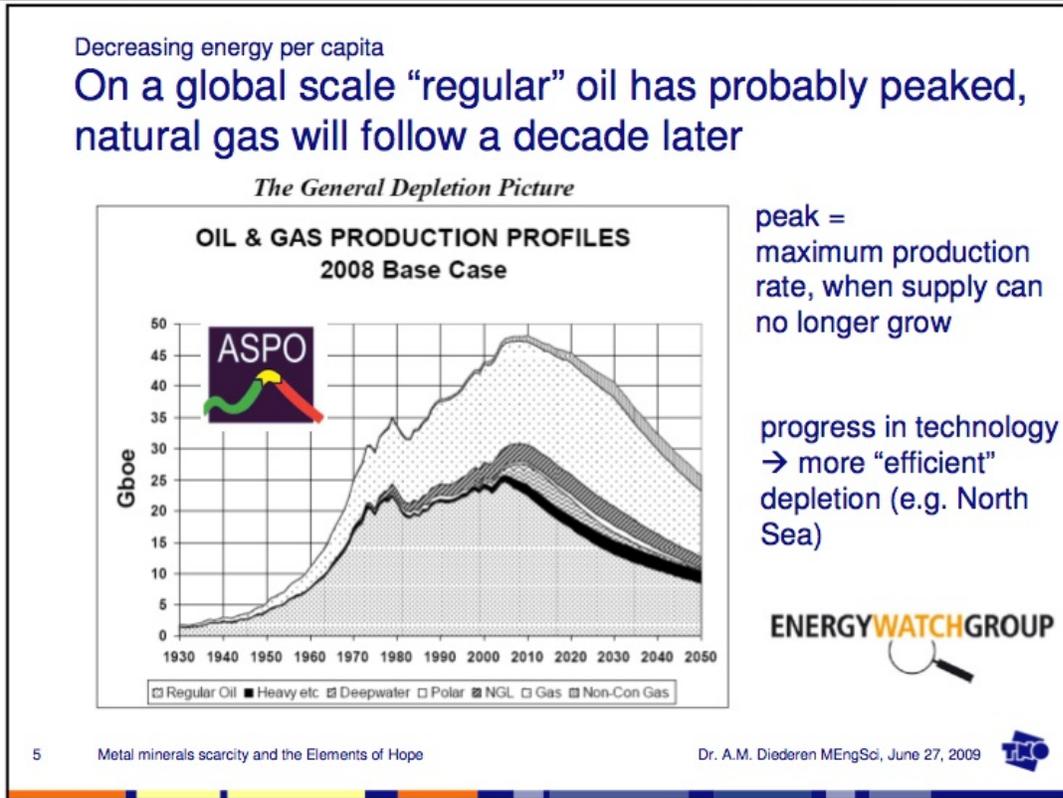
“Harvesting speed” versus “ultimate quantity”

- 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”

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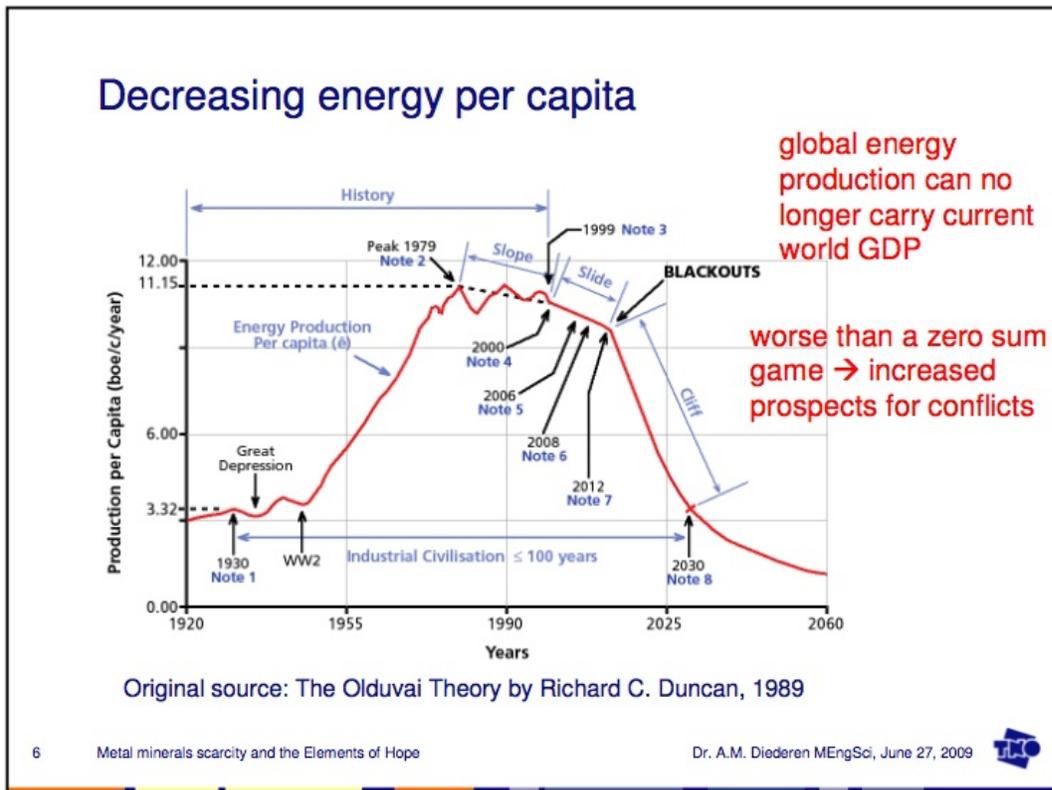
Slide 4

I would like to lend a phrase from the peak oil community and apply it to mineral resources as well: it’s not the size of the well that matters but the size of the tap. About a quarter of the earth’s crust consists of silicon, yet we are already short (for years) on pure enough silicon to make high efficiency solar cells. Of course we can purify the less favourable sources of silicon, but this takes (lots of) energy.



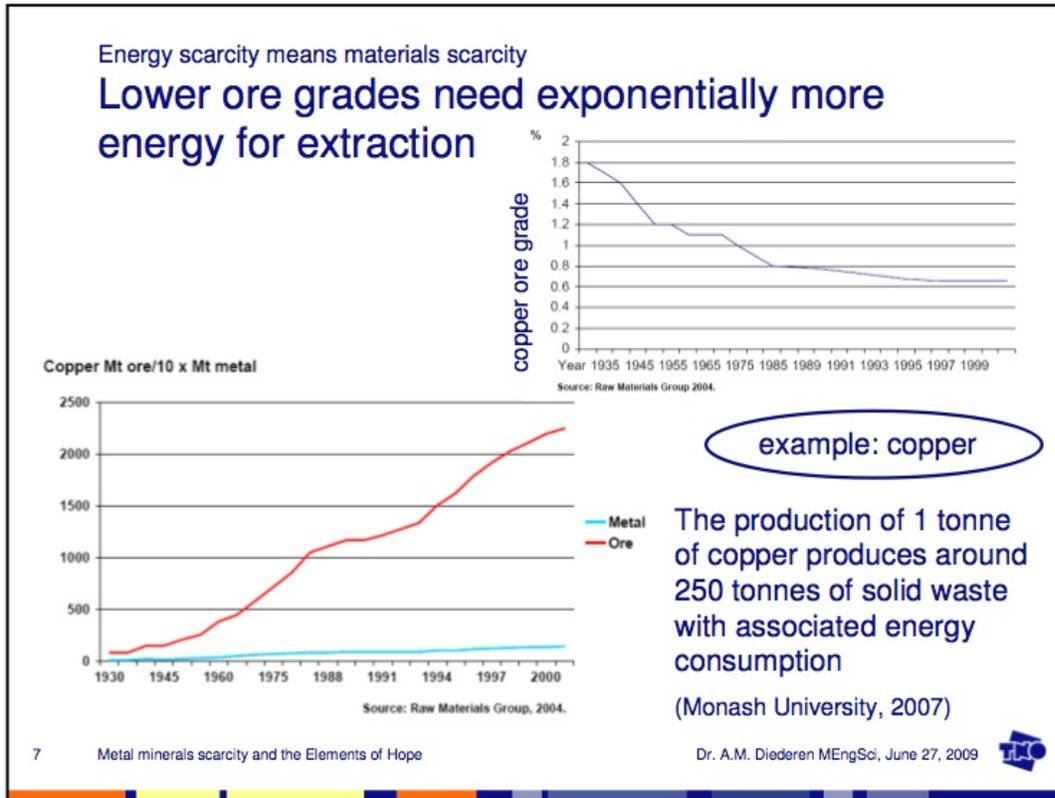
Slide 5

As with energy, also for metals one should not be misinterpreted as saying that we are running out (of metals). We are running out of “easy” metals, i.e. high ore grades at favourable locations.



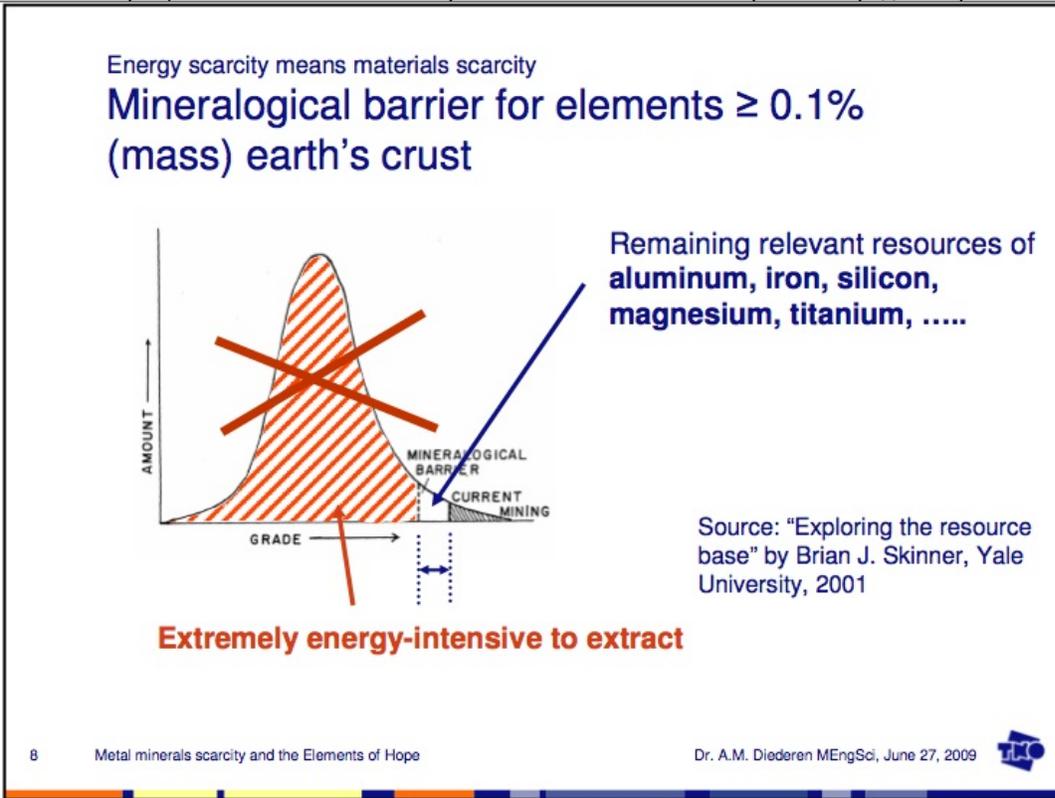
Slide 6

This graph is the scariest graph I’ve seen in years if you think about its implications. It’s even worse than a zero sum game: even zero growth at one part of the globe will inevitable cause



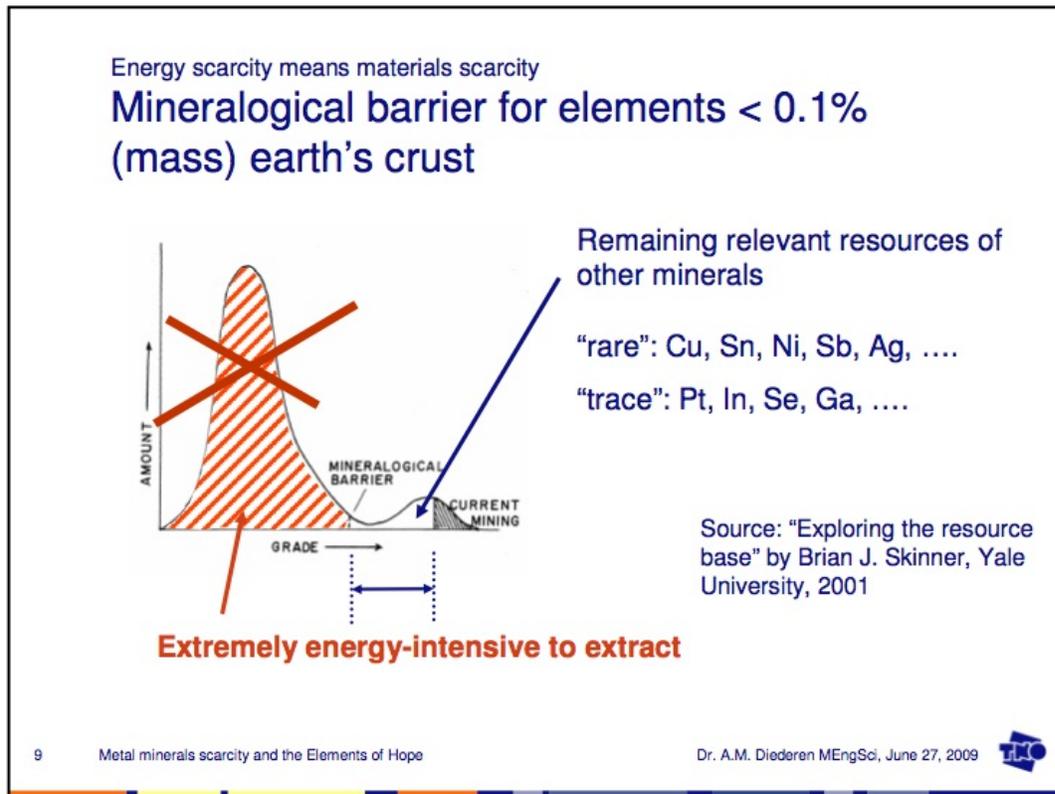
Slide 7

A typical critique on stating that we are running into metals scarcity is the notion that you will find 300 times more ore as you lower the ore grade with a factor of 10. This misses the point that you need much more energy to keep extracting the same amount of metal. Even when the ore grade is more or less stable (example: copper over the last few decades), you still need increasingly more energy to extract the same amount of copper because you have to dig deeper and handle ever more quantities of solids to get to the ores. Of course lower ore grades aggravate the situation and increase energy expenditures much more because of the amounts of solids which have to be processed to keep up the production rate of concentrated metal.



Slide 8

Below the so-called mineralogical barrier (a certain low ore grade), essentially you should pull the source material (e.g. a piece of rock) chemically apart to extract the individual metals. Combined with the enormous amounts of low grade source materials required to maintain a certain production rate of metal, in an energy constrained world the vast majority of resources is out of our reach.



Slide 9

This graph could be valid for all non-abundant metal minerals and it shows that at lower ore grades the amounts of source materials first may tend to go down, not up. This may aggravate metal minerals scarcity.

Energy scarcity means materials scarcity
Materials scarcity: parallels with “peak oil”

source: Bardi en Pagani, 2007

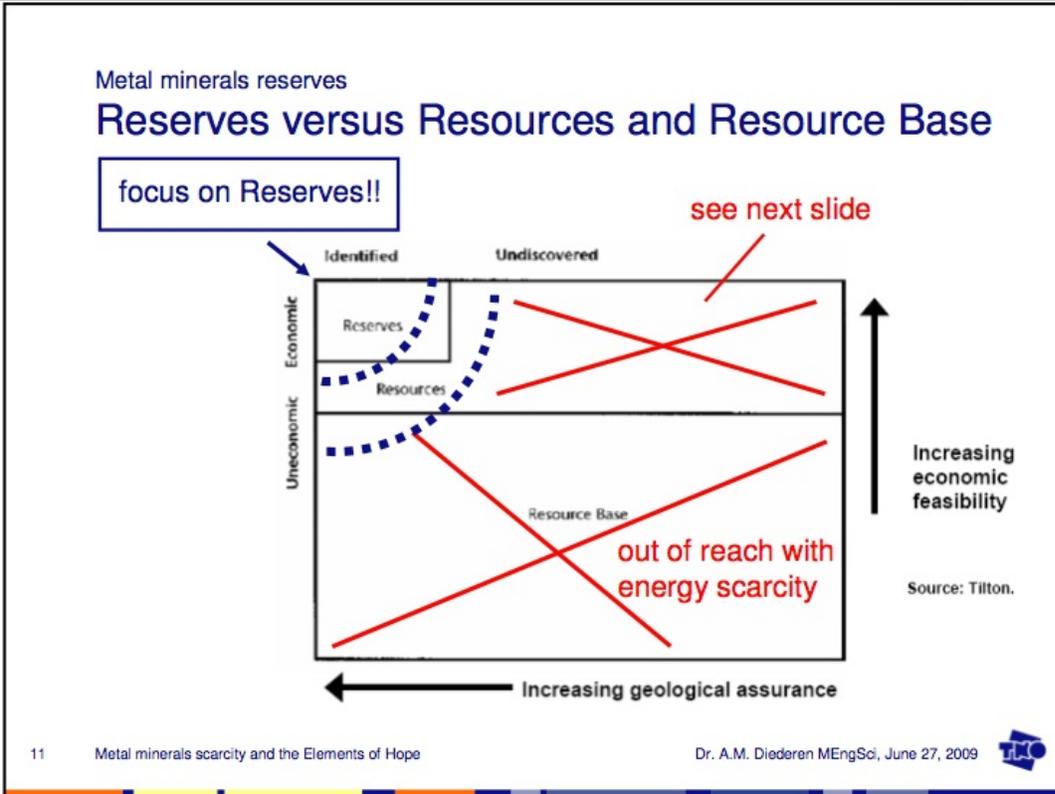
The first graph, titled 'Zirconium mineral concentrates world production - USGS data', plots 'Zirconium mineral concentrate production, millions' on the y-axis (0 to 1) against 'year' on the x-axis (1940 to 2010). It shows a bell-shaped curve with a peak around 2000 and a correlation coefficient of R=0.971. The second graph, titled 'OIL & GAS PRODUCTION PROFILES 2008 Base Case', plots 'Gt/yr' on the y-axis (0 to 50) against 'Year' on the x-axis (1930 to 2050). It shows a bell-shaped curve for oil production peaking around 2005 and a similar but lower curve for gas production peaking around 2015.

- 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

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Slide 10

The work of Bardi and Pagani in recent years showed the striking similarities between peak oil and peak minerals.



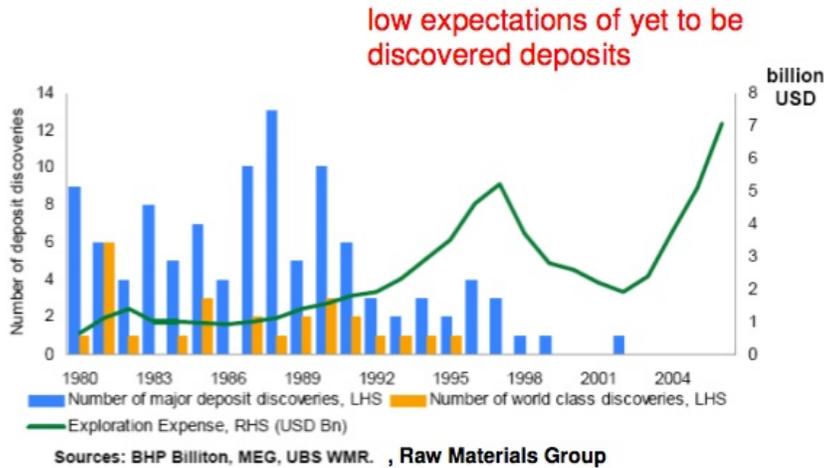
Slide 11

A typical critique on stating that we are running into metals scarcity is the notion that the free market (the laws of demand and supply) will upgrade parts of the resources or the resource base into reserves once reserves start to get tight. This has seemed to be true for decades when there was cheap and abundant energy available. However with energy scarcity, the big lower part of the graph in figure 11 is out of reach (red crossed lines). We should also let go of the notion that vast amounts of rich ore deposits lie waiting somewhere to be discovered (red crossed lines), see slide 12.

In short: it looks quite rational to focus on reserves instead of the huge amounts of resources and the vast resource base. Of course there are many cases to be made to argue that the boundaries of the reserves may be stretched in favour of larger quantities; however there are as many cases to be made to argue that with an energy crisis not even the currently stated reserves remain within our reach to be exploited (blue dotted lines).

Metal minerals reserves

Discovery rate of major mineral deposits



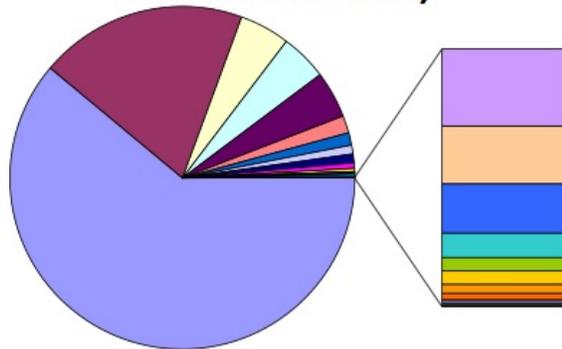
Slide 12

In analogy with oil scarcity: it's highly unlikely that we will find another "Saudi-Arabia" or another "North Sea" of rich mineral deposits.

Timing of metals scarcity

Absolute and relative quantities: global reserves

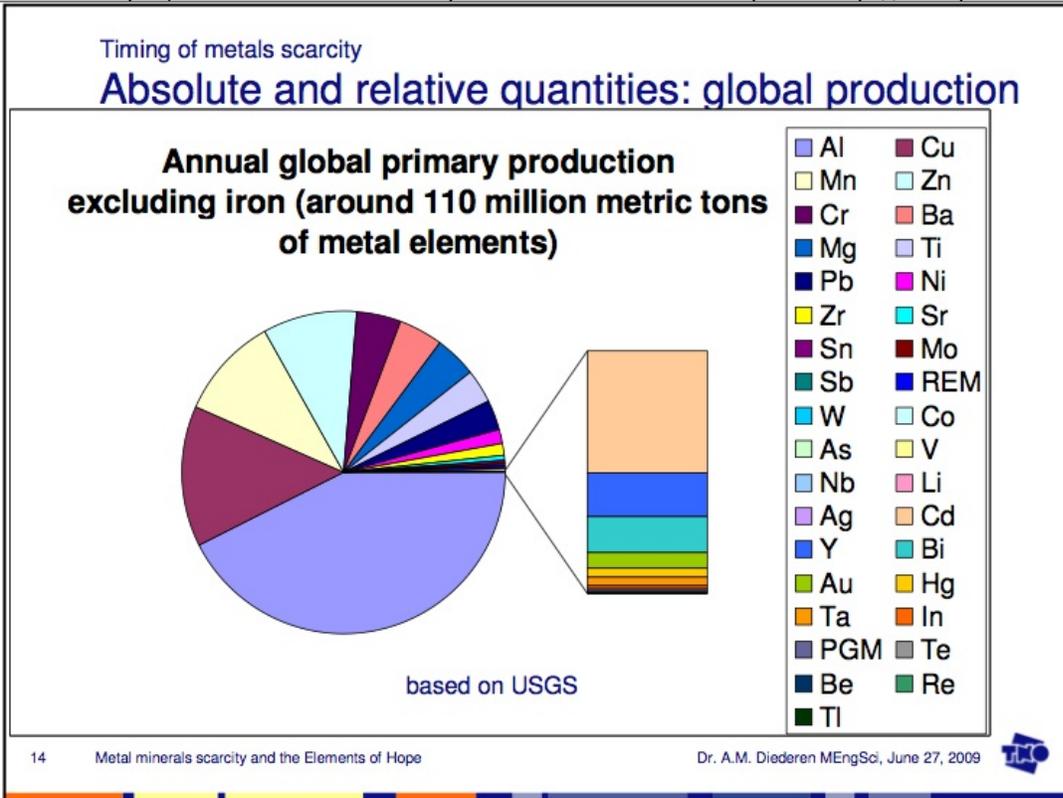
Global reserves excluding magnesium and iron (around 10 billion metric tons of metal elements)



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

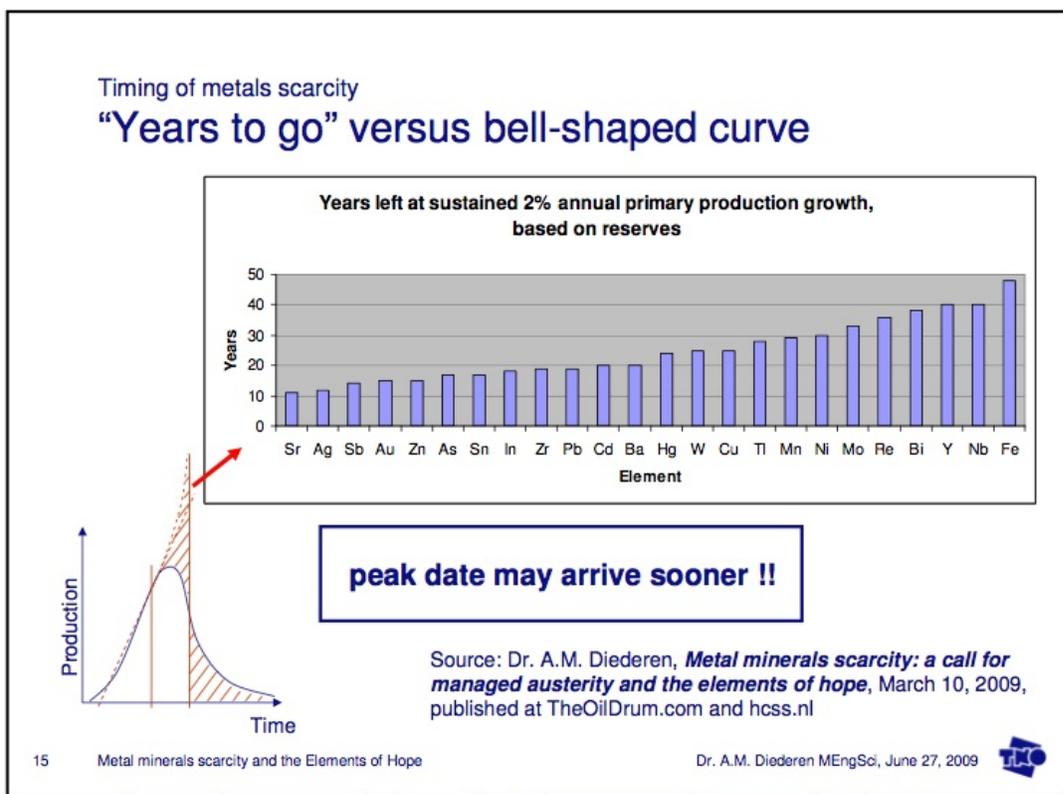
based on USGS





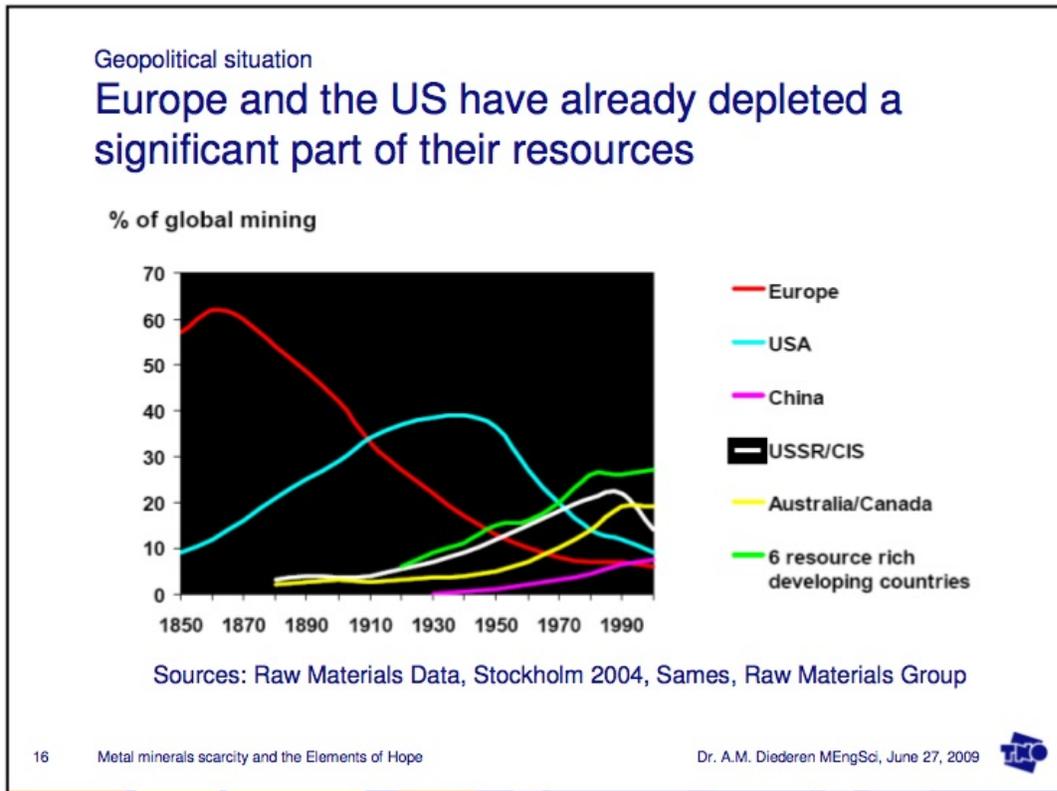
Slides 13+14

Using the only consistent global database (from USGS) on metal mineral reserves and global production rates, one can paint a picture what it actually means if we focus on reserves. All data from USGS are converted (where necessary) into metal element content for consistency, see the paper "Metal minerals scarcity: A call for managed austerity and the elements of hope", published at the website TheOilDrum.com on May 4, 2009 (<http://europe.theoil Drum.com/node/5239>) and at the TNO website on June 24, 2009 (<http://www.tno.nl/>).



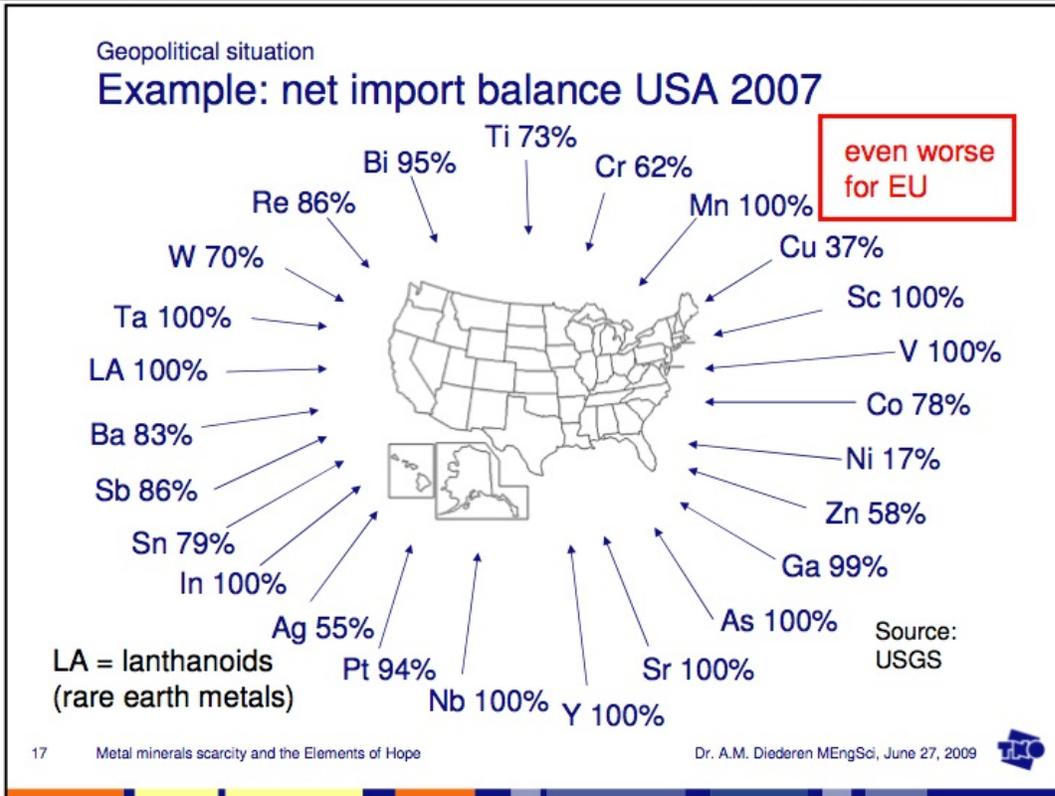
Slide 15

Using a simple calculation, including sustained annual growth of only 2% (the IMF states 3% growth or more is needed for a healthy world economy), the bar chart in slide 15 can be drawn to give a feel for the urgency of metals scarcity. Of course in reality we do not experience a sustained global production growth until year “n” and a subsequent drop to zero production in year “n+1”. This is depicted in the graph in the lower left corner of slide 15: a production peak is reached years before the “lifetime” of the bar chart has been reached. Bardi and Pagani recently have published data on several metals which indeed already peaked.



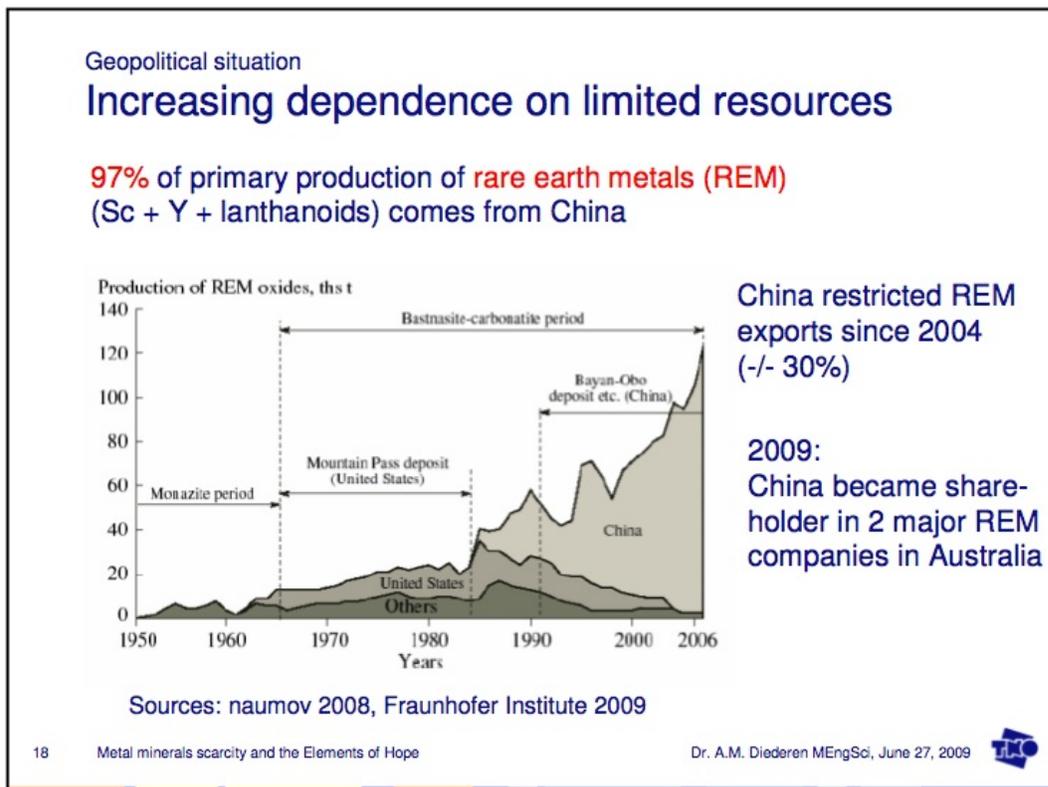
Slide 16

To make things even worse, as with oil and gas, global (or average) metals scarcity will be preceded by spot shortages due to the non-linear distribution and depletion of metal mineral resources across the globe. The industrial revolution started in Europe and later the US became an industrial giant, so it comes as no big surprise that both Europe and the US have depleted a large part of their mineral resources.



Slide 17

The United States, although still an important primary producer of metals, is strongly dependent on imports of various strategic metals, often 100%. The situation for the European Union is even worse than the picture of slide 17.



Slide 18

Many important metals are produced for a large part in only one or a few countries. A striking

example are the so-called rare earth metals (REM) for which China dominates world production. REM are required for various kinds of high-efficiency applications in technologies which are needed to make a transition towards a more sustainable economy, away from our dependence on fossil fuels. An example is neodymium, required for high-efficiency permanent-magnets needed for generators (wind mills) or motors (electric vehicles).

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 !!

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Slide 19

The consequences of metals scarcity will be serious. Not only various established sectors like machining and the chemical industries will be affected. Especially the promising “new” sectors will be hit hard. For example there are no satisfactory substitutes available yet for essential and already scarce metals for efficient and mass-produced solar cells, permanent-magnet drives/generators (wind mills, hybrid cars, electric cars), catalysts, fuel cells, batteries and various electronic devices (telecommunication, displays/ touch screens/ plasma screens, micro-electronics).

Without a shift from scarce to less scarce metals, a large-scale transition towards a more sustainable economy doesn't stand a chance. Moreover metals scarcity aggravates energy scarcity because the energy sector is one of the largest metals consumers. This applies to the whole chain from exploration, production, storage and distribution up to conversion into the desired forms of energy.

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

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Slide 20

There are six solution frameworks to diminish our dependence on scarce metals: using less, longer product lifetime, more intensive recycling, substitution with less scarce metals, a new product design philosophy and adapted inventory management.

Realization of these solution frameworks challenges people’s ingenuity and creativity and offers meaning and purpose. “Using less” requires nothing less than some form of managed austerity. Also technology can play an important role by enabling dematerialization (like film rolls which have been replaced by digital photos). A number of solution frameworks are facilitated by reducing complexity in order to enhance quality and diminish waste.

Solution frameworks
What can be done about metals scarcity?

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H C N O P S Cl	non-metal elements
Na Mg Al Si K Ca Fe	elements of hope
Ti Cr Mn Cu B F Ar Br	critical elements
frugal elements	

Li	Be	Sc	V	Co	Ni	Zn	Ga
Ge	As	Sr	Y	Zr	Nb	Mo	PGM
Ag	Cd	In	Sn	Sb	Te	Ba	REM
Ta	W	Re	Au	Hg	Tl	Pb	Bi

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

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Metal minerals scarcity and the Elements of Hope

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Slide 21

A particularly powerful solution framework is the substitution of scarce metal elements by the most abundant elements, the so-called Elements of Hope. This requires engineering sciences as well as disciplines like agriculture and biosciences. The scarcest metal elements are called the critical elements and these should be saved for essential applications where substitution with less scarce elements is not possible. The frugal elements are much less scarce, albeit scarcer than the Elements of Hope, and should be used predominantly for those applications for which there is not yet a substitute with current technology (example: chromium for stainless steel).

Solution frameworks

The Elements of Hope → substitution

non-metal elements: H C N O P S Cl

elements of hope: Na Mg Al Si, K Ca Fe

critical elements: Ti Cr Mn Cu, B F Ar Br

frugal elements: Li Be Sc V Co Ni Zn Ga, Ge As Sr Y Zr Nb Mo PGM, Ag Cd In Sn Sb Te Ba REM, Ta W Re Au Hg Tl Pb Bi

the green elements are macronutrients

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

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Slide 22

The Elements of Hope are potentially inherently environmentally friendly and sustainable as they contain all macronutrients of life and lack any heavy metal.

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"**

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Slide 23

If policy does not change, the ongoing growth in global consumption of metals will cause shortages, aggravate energy scarcity and obstruct the transition towards a sustainable economy.

Technology alone is not going to save us. A holistic approach to the vast underlying problem of exponential growth and overconsumption requires involvement of various disciplines. “Using less” requires nothing less than some form of managed austerity and involves disciplines like psychology, philosophy, law, finance, economics, system dynamics and politics. Nate Hagens has explained during the discussion after this presentation that we need to understand and implement all that we know about human behaviour for any solution to stand a chance of becoming viable (see the recent excellent work by Nate Hagens).

Discussion

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

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The slide features a yellow thinking emoji with its hand on its chin, positioned to the right of the text. At the bottom left, there is a small logo with the text 'SOME RIGHTS RESERVED'. At the bottom right, there is a small blue logo with the letters 'TLO'.

Slide 24

The free market alone cannot solve these problems. Some form of government intervention for the sake of collective interest is required. How does a country like China approach these problems? Can we learn something from them?



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