Metals scarcity: A sobering perspective
Part II: Crisis management: technology & beyond

Delft University of Technology, Faculty Industrial Design Engineering,
The Netherlands, December 2, 2009
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Slide 1
Where Part I focuses on our predicament, Part II deals with ways of easing the consequences of scarcity and ways to change into the direction of sustainability.

Contents of Part II

- **Solution framework with intrinsic value**
  - Amongst others the **Elements of Hope**
  - Roadmap towards sustainability?
- **The huge pitfall of suboptimization**
  - Context dropping
  - Technology worship
  - Human behaviour
- **Let sound engineering knowledge and practice be your base guide**
  - You can't beat the laws of nature using technology
  - "All models are wrong, some are useful"
- **Creativity and inventivity are "without limit"**
  - Let nature inspire you
  - Out of the box thinking

Slide 2
As already mentioned in Part I of this presentation, discussion of our predicament is in no way meant to invite pessimism or defeatism. As I will show you in this Part II of the presentation, working on viable solution directions challenges people's ingenuity and creativity and offers meaning and purpose.

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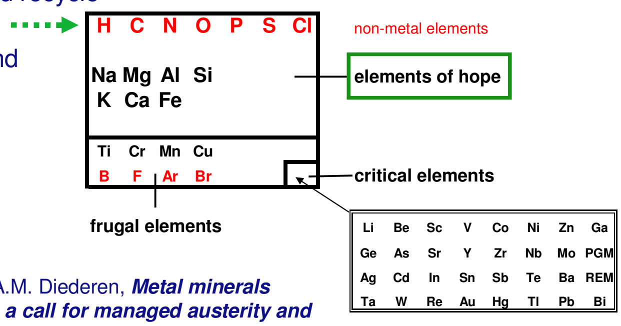
Slide 3
A particularly powerful solution direction is the substitution of scarce metal elements by the most abundant elements, the so-called Elements of Hope.
I'll propose a preliminary (and very incomplete) roadmap which gives specific measures of performance to be realized within a specific timeframe in order to stimulate discussion.

Solution framework with intrinsic benefits, applicable to energy as well as metals

1. Use less (most important solution but reluctant human behaviour leads to low priority)
2. Longer life
3. Re-use and recycle
4. Substitute
5. Product and process (re)design
6. Buffers



Source: A.M. Diederen, ***Metal minerals scarcity: a call for managed austerity and the elements of hope***, March 10, 2009

Slide 4

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

1. Use less or "managed austerity"

"Technical" solutions:

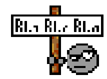
- Efficiency gains
  beware of Jevon's paradox!
- Useful products instead of disposables
  - basic necessities
    temperature (shelter), water, food, clean air, sanitation
  - human relations
    example: telecommunication
  - useful luxuries
    example: musical instruments
- Localisation and less complexity
  reduced distribution and transmission losses, more resilient and robust

Slide 5
Using less can also be combined with one or more of the other solution directions, leading to efficiency gains and "dematerialization". Dematerialization often boils down to replacing a large quantity of one material by a much smaller quantity of another material (in fact a combination of using less and substitution). An example is the replacement of film tapes by digital photography. Please keep in mind that "dematerialization" still involves materials: you still need physical substrates to store the digital information and people still like to make prints. In order to have benefit from efficiency gains and dematerialization solutions, care should be taken to avoid the pitfall of Jevon's paradox, e.g. more kilometers per year travelled in a more fuel efficient car or making more photo prints or using digital photo frames running on batteries instead of framing a print. Jevon's paradox is the proposition that technological progress that increases the efficiency with which a resource is used, tends to increase (rather than decrease) the rate of consumption of that resource. So, technological progress on its own (without 'control') will only accelerate the depletion of reserves.

More a behavioural change than a "technical" solution is to focus on essential goods and services, i.e. basic necessities as opposed to short-lived luxuries. People should (re)learn the difference between inconvenience or discomfort on the one hand and real (even life-threatening) problems on the other hand.

The third main bullet may be phrased "keep it smart and simple".

1. Use less or “managed austerity”



Policy solutions:

- Sound advice to decision makers
  Politicians are inclined to postpone decisions on disputed items
- Education of the population
- Living “here and now” and acting accordingly
  it’s easier to make noble plans for the future than taking real action now
- Frugality (using less) as opposed to greed
  nature doesn’t maximise but optimises within its very broad system boundaries
- How to “measure” wealth and prosperity?
  Include human arts and preserved nature as ways of providing well-being?

Slide 6
I think one of the few real options to avoid an unguided (gradual?) collapse of industrial civilization is to use less. This would require some form of “managed austerity”. As Nate Hagens pointed out earlier this year, chances of this going to work without taking into account human behaviour are close to zero (see http://www.theoildrum.com/node/5519).

2. Longer product lifetime

- **End planned and perceived obsolescence**
- Reduce complexity for improved quality

"transparent technology"

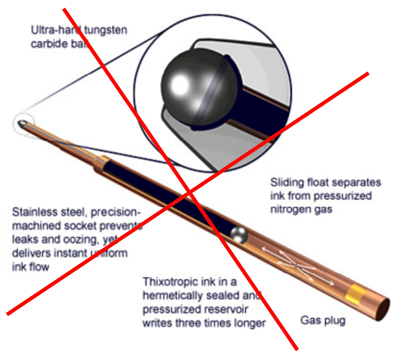
- Design for maintenance and repair

Slide 7
The first thing to abandon is planned and perceived obsolescence, especially applicable to various consumer products. Planned obsolescence is the strategy to make products with such a poor quality that the rate of consumption is maximized whilst the quality is marginally sufficient to prevent the products from remaining unsold. Perceived obsolescence is making people believe (using marketing) that they should buy new stuff to prevent them from being seen as morons or to be more successful etcetera.

Longer product lifetime is facilitated by reducing complexity (transparent technology is helpful here) and by design dedicated to easy maintenance and repair.
A slide-rule is a wonderful example of transparent technology: it's much easier to comprehend how calculations are being performed than using a calculator (do you know how the microchip works in detail?). Moreover, the calculator needs batteries and its lifetime is much less than a durable (non-plastic) slide-rule.
Cars used to have space left under the hood (sober designs), amongst others making it easy to change a light. Many modern cars (often luxury designs compared to the past) have to be taken to a workshop for a simple task such as changing a light.

3. Recycling and reuse of materials

- Design for reuse and intense recycling
- Reduce complexity to diminish waste

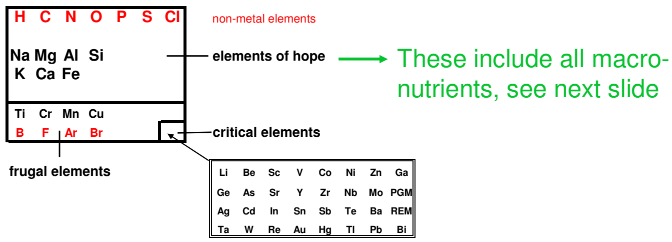


Slide 8

Recycling the current and constantly growing inventory of metal elements in use in various compounds and products is the obvious choice in order to buy time and avoid or diminish short- to medium-term supply gaps. Although recycling is nothing new, generally the intensity could be further enhanced. We should keep in mind though that recycling has inherent limits, because even 100% recycling (which is virtually impossible) does not account for annual demand growth. At the present course we need to continue to expand the amount of metal elements in use in order to satisfy demand from developing countries like China and India whose vast populations wish to acquire a material wealth comparable with the standard of living of the industrialized western world. Furthermore, recycling also costs lots of energy (progressively more with more intense recycling) and many compounds and products inherently dilute significant parts of their metal constituents back into the environment owing to their nature and use. So even with intense recycling, we will need a continued massive primary production to continue our present collective course.

4. Substitution of materials

- Substitute scarce metals using the “Elements of Hope”



- Design for use of Elements of Hope

- Dematerialisation (e.g. digital photography)
  beware of Jevon’s paradox!

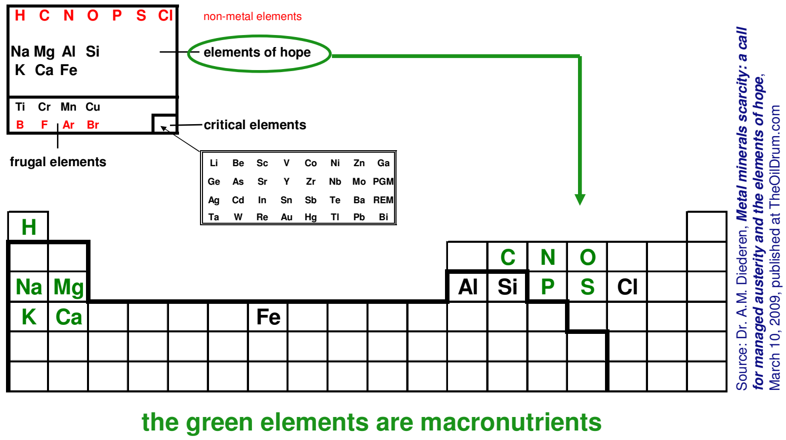
Slide 9
It is self-evident that - at our current level of technology - substitution of scarce metals by less scarce metals (or other materials) for major applications will lead to less effective processes and products, lower product performance, a loss in product characteristics, or will lead to less environmentally friendly or even toxic compounds. An important and very challenging task is therefore to realise the desired functionalities of such products with less scarce elements and to develop processes for production of these products at an economic scale. The best candidates for this sustainable substitution are a group of abundantly available elements, that I have baptised the ‘Elements of Hope’. These are the most abundant elements available to mankind and can be extracted from the earth’s crust, from the oceans and from the atmosphere. They constitute both metal and non-metal elements.

We can look at the remaining producible global reserves of metals as a toolbox for current and future generations.
The largest part of the toolbox is reserved for the elements of hope.
Another part of our toolbox is reserved for less abundant but still plentiful building blocks, the ‘frugal elements’. These elements should be used predominantly for those applications for which there is no substitute with current technology (example: chromium for stainless steel). In this way their remaining reserves will last longer (most notably copper and manganese). For the sake of completeness, also the non-metals belonging to this category are included.
Finally a small corner of the toolbox is reserved for all other metal elements combined, the ‘critical elements’, which should be saved for essential applications where substitution with less scarce elements is not possible.

Solution direction no. 4 (substitution) is also linked to product and process (re)design (solution direction no. 5, slide 11).

I already covered dematerialization in the text with slide 5 (“use less”).

Elements of Hope: can be inherently environmentally friendly



Slide 10

Not coincidentally, all macronutrients of nature (all flora and fauna including the human body) are found among the elements of hope: nature either uses these elements (metabolism, building blocks) or has shown to be tolerant to these elements (in their abundant natural forms). Substitution based on the elements of hope therefore can be inherently environmentally friendly, they lack any heavy metal.

Hydrocarbons for production of materials (including plastics) could be extracted progressively more from biomass, albeit at a much lower extraction rate than from concentrated (fossilized) biomass (oil, natural gas and coal). The feasible scale size of biomass materials production is limited by amongst others water availability, competition with food requirements, availability of usable land (with proper replenishment of soil nutrients) and available energy.

5. Develop adapted/new products and processes

- 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

- Make much more products fit for replacements or upgrades of components
  example: retrofit of ships and airplanes

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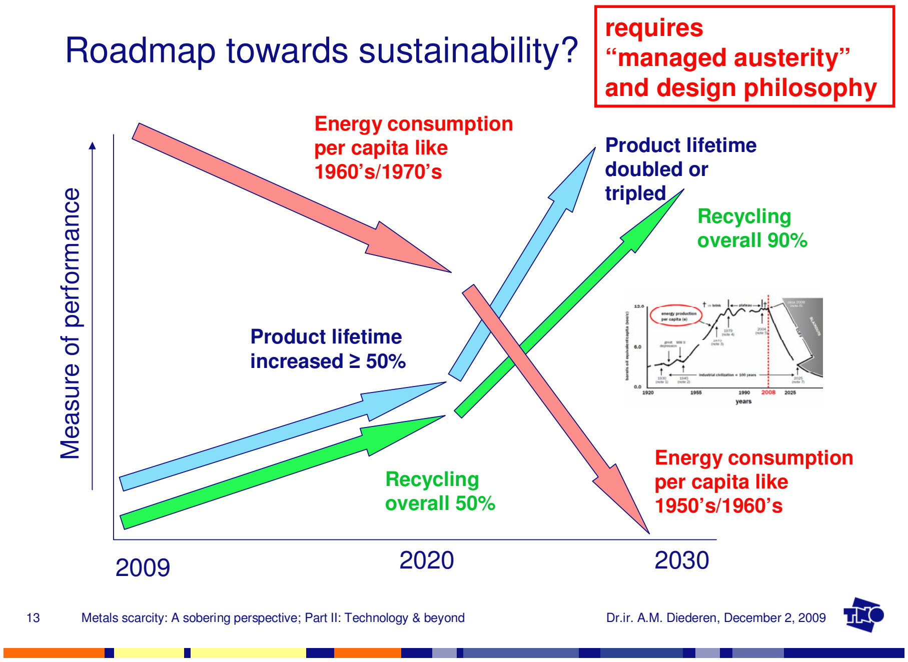
Slide 11
Not coincidentally, important material technology breakthroughs from a less energy-intensive and less material-intensive past may point towards material developments which are suitable for a less abundant future. An example is given by low alloy steels developed during the 1930s which are viable only recently for reliable and quality-consistent mass production owing to modern process technology.
The example of replacement of components or upgrades of components could be taken to extremes and thus include smaller items like household appliances and consumer products by making labour much less expensive relative to materials. It will (again) make more sense to repair things or replace subcomponents instead of discarding complete subassemblies or complete products.

6. Buffers / stockpiles

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

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

Slide 12
With the arrival of the age of scarcity industrialism (the term "scarcity industrialism" has been coined by John Michael Greer, see his extensive work at http://thearchdruidreport.blogspot.com/) a lot of common wisdom arisen in times of plenty might need some revision! One of them might be the "just in time" philosophy to minimize cost and maximize turn-around rates and profits. In times of scarcity with associated high price volatility it might be profitable again to have buffers to be able to cope with supply disruptions and to have the luxury to temporarily stop purchasing raw materials and products at unfavourable high cost during price peaks.
On a larger scale, national stockpiles of strategic metals, like the USA used to have during the Cold War, might be reinstated.



Slide 13

Because of the urgency and severity of the interrelated threats as discussed in Part I of this presentation, the goals in this roadmap are quite challenging; we should drastically reduce our energy use per capita. Maybe we should be lucky if we could maintain an energy per capita use (global mean value) by 2030 similar to the mid-1950s which is shortly after abandoning rationing in Europe after World War II. We have to drastically increase product lifetime and we have to recycle much more intensively. Of course, this roadmap is far from complete. Maybe some of you readers feel challenged to propose additions to this roadmap.

In order to realize the proposed roadmap, the six solution directions mentioned before and their combinations are useful. To recapitulate a few:

- Reduce complexity (if we're going to (gradually?) collapse, complexity will be reduced anyway) in order to improve quality, reduce waste and facilitate a design philosophy enabling longer product lifetime, more intense recycling and dedicated substitution with less scarce materials.
- Try to dematerialize as much as possible.
- Learn from Mother Nature, who has learned to optimize rather than maximize (see slides 28 and 29).

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Slide 14

One of the big pitfalls is to solve scarcity on a piece of paper or on a page in the blogosphere by notionally putting all of our attention, focus and means on solving a particular problem. For instance "an Apollo program to ramp up lithium production for electrification of all automobiles". Problem solved. The next problem is equally solved ("an Apollo program" to massively expand installed windpower or solar power generation and so on). Then, extremely put, these separate issues are summed up as if they were independent and all problems seem solved.

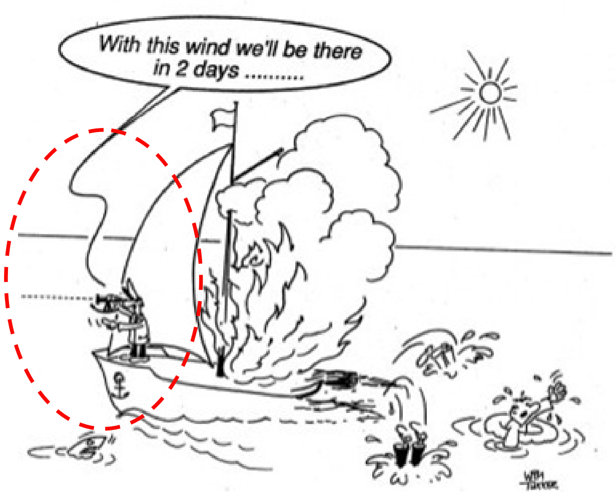
Of course we can only afford to spend a finite amount of effort and resources to the various problems in a given time.

The huge pitfall of suboptimization

"well intended actions can have unintended consequences"

Slide 15
This dark humour says it all. The situation with biofuels from corn comes to mind. Or farm fishing to "save" the wild fish, while these fish farms consume around one third of all wild fish harvested worldwide to feed the "tame" fish.

Context dropping



Slide 16
Of course we have to make abstractions from the complex reality in order to be able to make sense of it all, but the danger of abstraction is choosing the wrong boundaries, i.e. leaving essential parts out of the area of concern.

Context dropping


ENERGY

A PATH TO SUSTAINABLE ENERGY BY 2030

Wind, water and solar technologies can provide 100 percent of the world's energy, eliminating all fossil fuels. HERE'S HOW

By Mark Z. Jacobson and Mark A. Delucchi

KEY CONCEPTS

Scientific American, November 2009

Slide 17

Leaving out essential parts from the area of concern may cause pipe dreams like this sympathetic plan (Scientific American, November 2009) to replace ALL fossil fuels by 2030. The plan includes construction of 490,000 1MW tidal turbines, 5,350 100MW geothermal plants, 900 1,300MW hydroelectric plants, 3,800,000 5MW wind turbines, 720,000 0.75MW wave converters, 1,700,000,000 0.003MW rooftop photovoltaic systems, 49,000 300MW concentrated solar power plants and 40,000 300MW photovoltaic power plants. They don't explain where and how they are going to get the metals to construct all this (except put most of their hopes to recycling). They only mention a possible "materials hurdle" for a few already obviously constrained materials like neodymium, indium, tellurium and platinum.

Technology worship

Example: tickets for public transport

or

?

Technology worship

eyeball Mark I

or

?

Slides 18 and 19
Why do we apparently prefer sophisticated complex machines to take over normal-complexity jobs (no university degree required)? Not to mention the benefits of the human factor?
Why do we prefer sophisticated complex sensors to our own "eyeball Mark I"? Not to mention the fact that most people prefer live police officers in their neighbourhood?

Human behaviour

How to catch a monkey

Humans focus more on what they don't want to loose than on what they want to gain; see next slide!

Recommended reading:
Nate Hagens: ***The psychological and evolutionary roots of resource overconsumption revisited***, www.theoildrum.com, June 25, 2009

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Slide 20
Nate Hagens used a similar slide during the Oil Drum/ASPO Conference at Alcatraz, Italy in June 2009 to illustrate this aspect of human behaviour. No solution framework is complete if it doesn't address human behaviour.

People want "solutions" without making (perceived) sacrifices

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Slide 21
The terms "green" and "sustainable" are often abused to legitimize "business as usual", i.e. faking feeling passionate for good stewardship of our planet while being focussed on maximizing profit. That does not mean of course that sustainability and profitability would be mutually exclusive. But try to make a distinction between the black, the white and the various grey shades here. If you don't want to be fooled, then stop fooling yourself. People want to hear "solutions" without making any real sacrifices.

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Slide 22
To quote Warren Buffet in this context: "You're neither right nor wrong because other people agree with you. You're right because your facts are right and your reasoning is right – and that's the only thing that makes you right. And if your facts and reasoning are right, you don't have to worry about anybody".

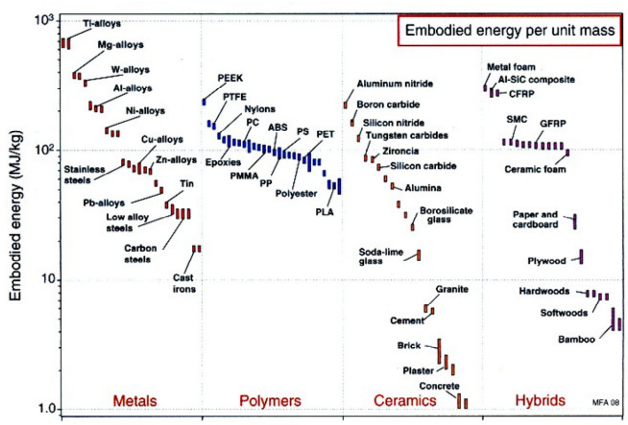
The 2nd law of thermodynamics

- Energy conversions are always accompanied with losses (not in quantity but in quality)
- It is much more easy to mix pure salt and pure pepper than to separate the mixture back into its separate ingredients
- Essence of the 2nd law of thermodynamics (within the context here): **it costs energy to concentrate energy**

Slide 23
Energy can neither be created nor destroyed, and left to itself, it always flows from higher concentrations to lower concentrations and this means that you can't concentrate energy without using energy to do it. A system that has energy flowing through it can develop eddies in the flow that concentrate energy in various ways. Living things like we humans (and the human body) are such eddies: we take energy from the flow of sunlight through the system of the earth in various ways (as food but also as stored sunlight in the form of fossil fuels), and

use it to maintain concentrations of energy above ambient levels. It takes energy to concentrate energy. If the rate and scale of our energy consumption keeps continuing well above ambient levels (with stored energy being rapidly depleted), we'll soon hit physical limits.

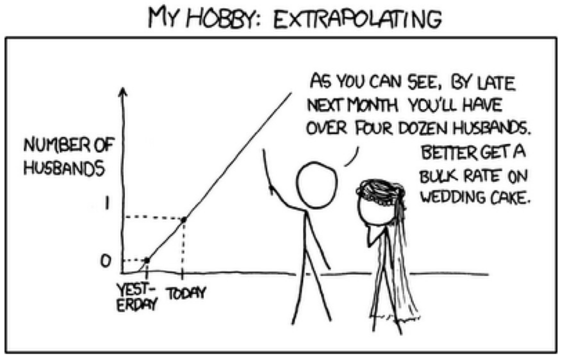
Embedded energy in materials



Source: Michael F. Ashby,
Materials and the environment – Eco-informed material choice, 2009

Slide 24
The graph taking from the book from Ashby (2009) gives an impression of the energy embedded in various materials. Please be aware of the fact that the values of embedded energy are NOT constant: a few decades ago the energy embedded in metals was often higher (see for instance "Tomorrow's Materials" from Ken Easterling), now it's on average lower thanks to efficiency gains / technology progress and a few decades from now the energy embedded in metals will probably again be higher on average (see part I of this presentation).

Your greatest assets: skills, experience, knowledge and sound judgements



Most models are descriptive, not predictive

Correlations can be wrong; correct correlations are applicable to the PAST but don't necessarily predict the future

Slide 25
People often confuse the descriptive quality of models with their perceived predictive power. Models are always abstractions of (real or perceived) reality and therefore should always be applied using common sense.

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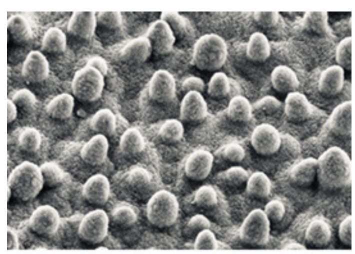
Slide 26
The resource-poor future pictured in this presentation strongly appeals to the ingenuity and creativity of engineers and scientists as well as many other people to cope with a limited choice and availability of resources. Fortunately, unlike fossil fuels and metal mineral resources, ingenuity and creativity are "unlimited".

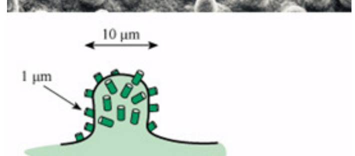
Nature

- Nature has several billion years of experience finding out how to optimize processes instead of maximize them. The question is not whether we can beat nature, but if we can match nature.
- By the way: we are part of nature!
- Nature’s way of assuring resilience of ecosystems is biodiversity; lesson to be learned here: strive for multiple proper solutions instead of “monocultures”

Slide 27
We are disconnected from nature. If you are driving in your car or are sitting on a boat, in a train or in an airplane, if you are working at your office (if that’s your job) or if you are at home, look around you. Besides bacteria and some other small stuff invisible to the naked eye, how many living things are around you? Most of the time, the only living things around you are other (disconnected) people. The rest is lots of dead stuff.

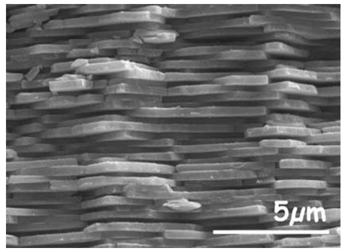
Nature



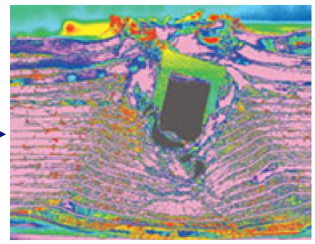


Water repellent surface of lotus leaf

Nature



Shell of the red abalone



Biomimicry using titanium and aluminium (stops high velocity fragment)

Source: University of California, San Diego

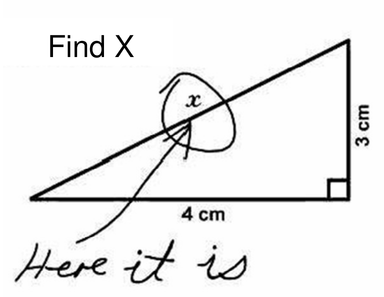
Slides 28 and 29

Nature has inspired humankind throughout history for its beauty and ingenuity. Where humans tend to maximize, nature has learned to optimize within its vast system boundaries. Some humans tend to measure and compare the efficiency of a leaf to that of a high-efficiency solar cell made from semiconducting materials. Those people miss the point that a leaf provides much more than just a way of converting solar radiation into another form of (partially stored) energy.

Humans have “nanotechnology” (often used for things on a microscale as well), whereas nature is capable of “engineering” on a molecular scale with far less energy and auxiliary materials then humans. The question is not whether we can beat nature, but if we can match nature.

The water repellent surface of the lotus flower is a well-known example. Another nice example is the shell of the red abalone which consists of a large number of small and hard but brittle lime platelets (97%), kept together by a kind of protein adhesive (3% of the shell). The University of San Diego has mimicked the shell of the red abalone by letting thin layers (approximately 1 mm) of aluminium and titanium react with each other. This results in hard layers of a titanium-aluminide intermetallic phase and ductile layers of titanium. The intermetallic phase of titanium aluminide is the complement of the abalone’s hard calcium carbonate phase, and the titanium alloy layer mimics the abalone shell’s compliant protein layers. This hybrid material is useful for impact resistant applications.

“If you don’t think out of the box, the box may become your coffin”



“Significant problems cannot be solved at the same level of thinking with which we created them” (Einstein)

Ocean/sea energy harvesting and simultaneous primary metal production? (Mg?, Li?)

Energy islands (by Robert and Rudolf Das, 1999)

Slides 30 and 31

Fine examples of “out of the box thinking” are provided by the Dutch Das brothers. In their beautiful and inspiring work “Visions of the Future – A New Golden Age for the Low Countries” (1999), among many things they envisage the construction of so-called energy islands in the North Sea. Combining their ideas with metals scarcity, it might be feasible on some scale in future to use excess electric power generation not for temporary storage in electric accumulators but instead use this for the primary production of metals from seawater. Magnesium has a relatively high concentration in seawater and possibly other valuable metals like lithium could be produced as well. Of course such primary production of metals from seawater would be (much) more expensive then current primary production on land, but nevertheless it might be interesting as an alternative (making by-products) to battery storage of excess electric power. A country like The Netherlands would then be able to have (to some extent) primary production of some useful metals using its own resources.

Our hope for the future includes **YOU**

Slide 32
I sincerely hope this second part of my presentation has motivated you to pursue proper and realistic solution directions and has inspired you to tap into your own unique resources of inventiveness and creativity.

Parts of this presentation have been presented earlier by me during the Oil Drum/ASPO Conference at Alcatraz, Italy on June 28, 2009 in a presentation titled "***Global Resource Depletion: A roadmap towards sustainability?***".

Part of the text used in this document has been published earlier this year in my March 10, 2009 paper "***Metal minerals scarcity: A call for managed austerity and the elements of hope***", published (with 198 comments) at the website TheOilDrum.com on May 4, 2009 (http://europe.theoildrum.com/node/5239) and available as pdf at http://www.materialscarcity.nl/Downloads.aspx.