

Materials Scarcity, Managed Austerity and the Elements of Hope

Wie sicher ist die Rohstoffversorgung für die Energietechnologien der Zukunft?
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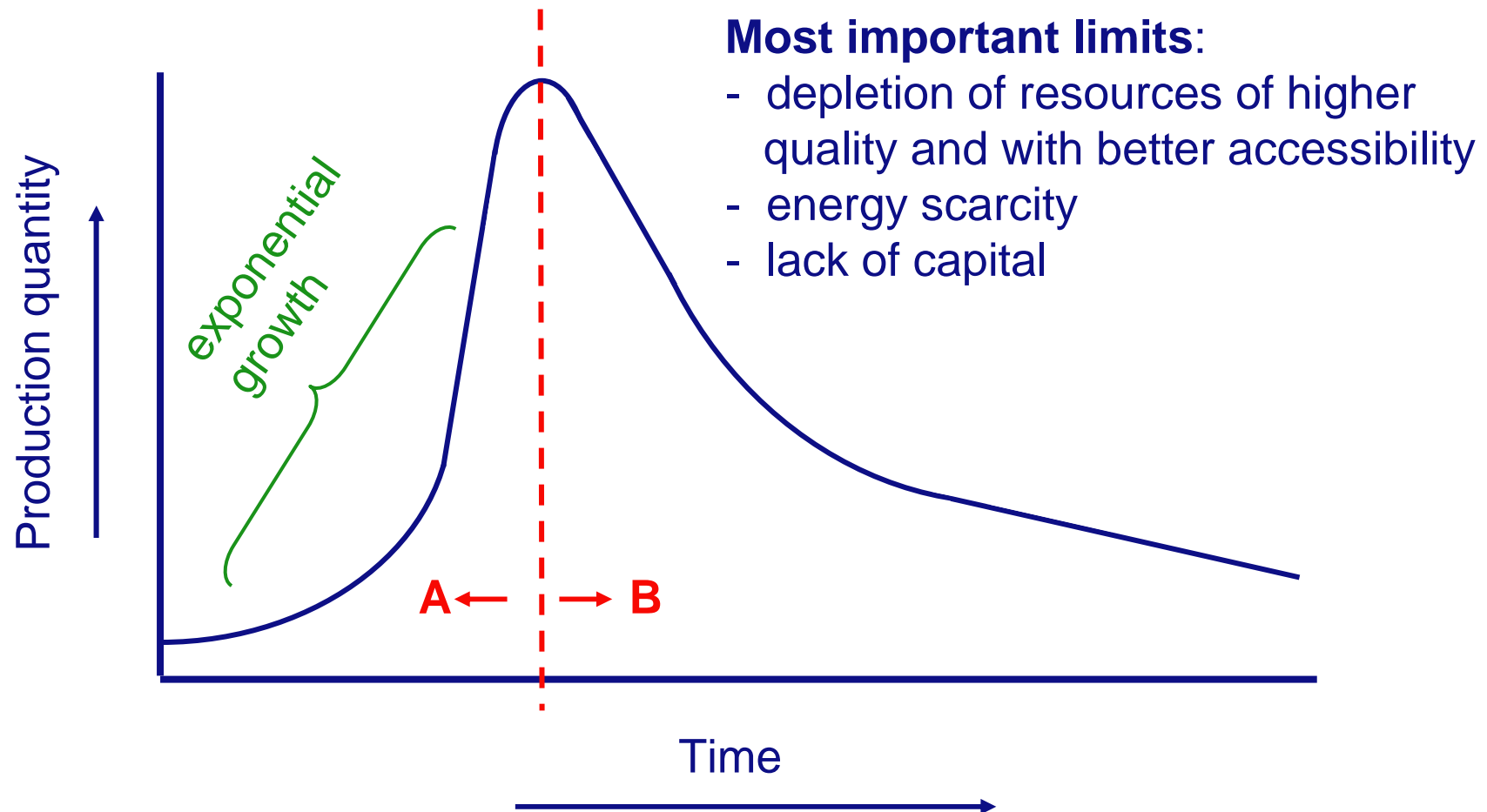
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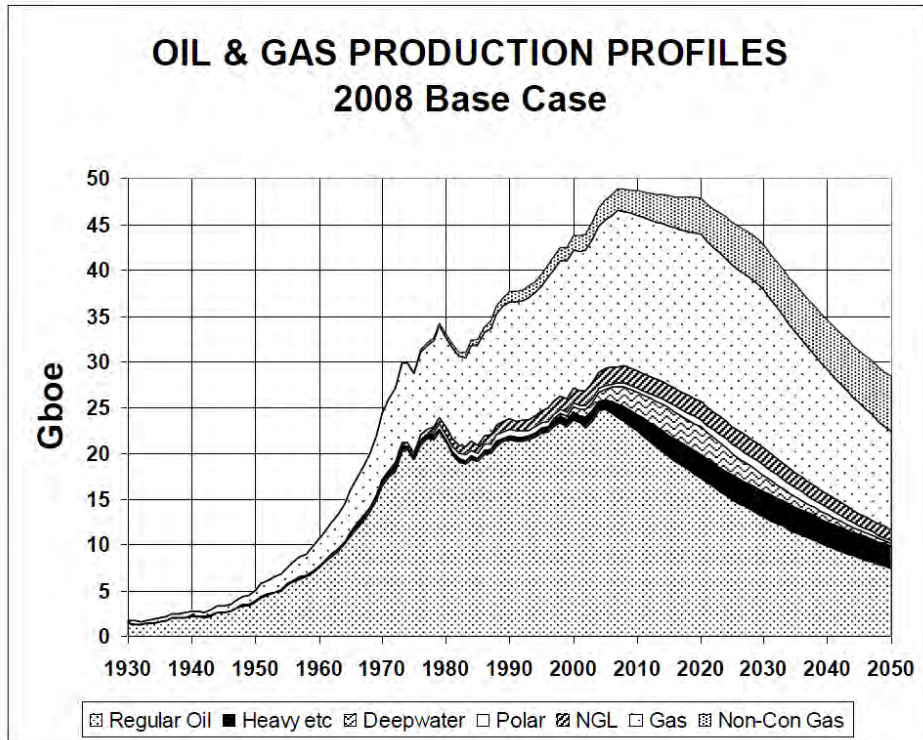
NL-2280 AA Rijswijk

TNO Defence, Security and Safety
Physical Protection & Survivability
Rijswijk, The Netherlands

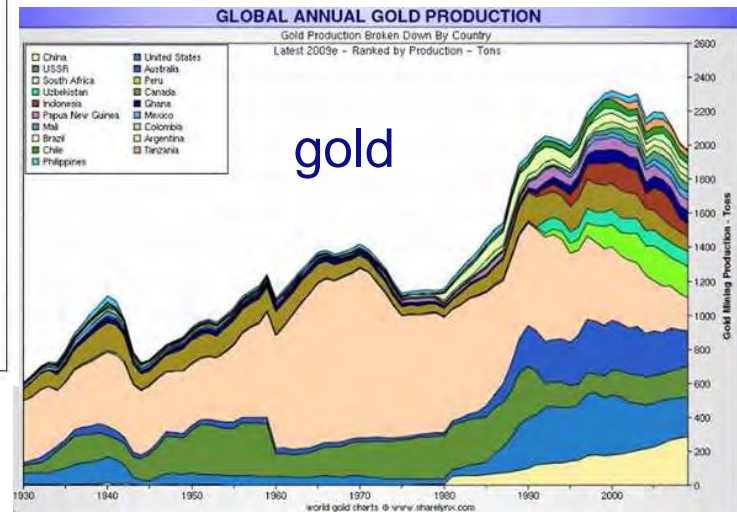
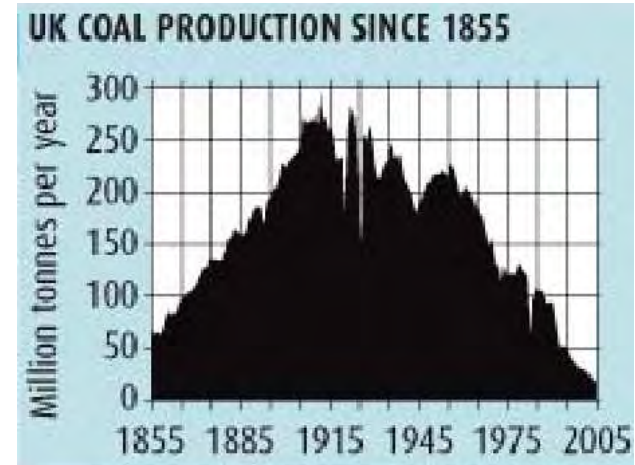
Materials scarcity: what matters is production *rate*



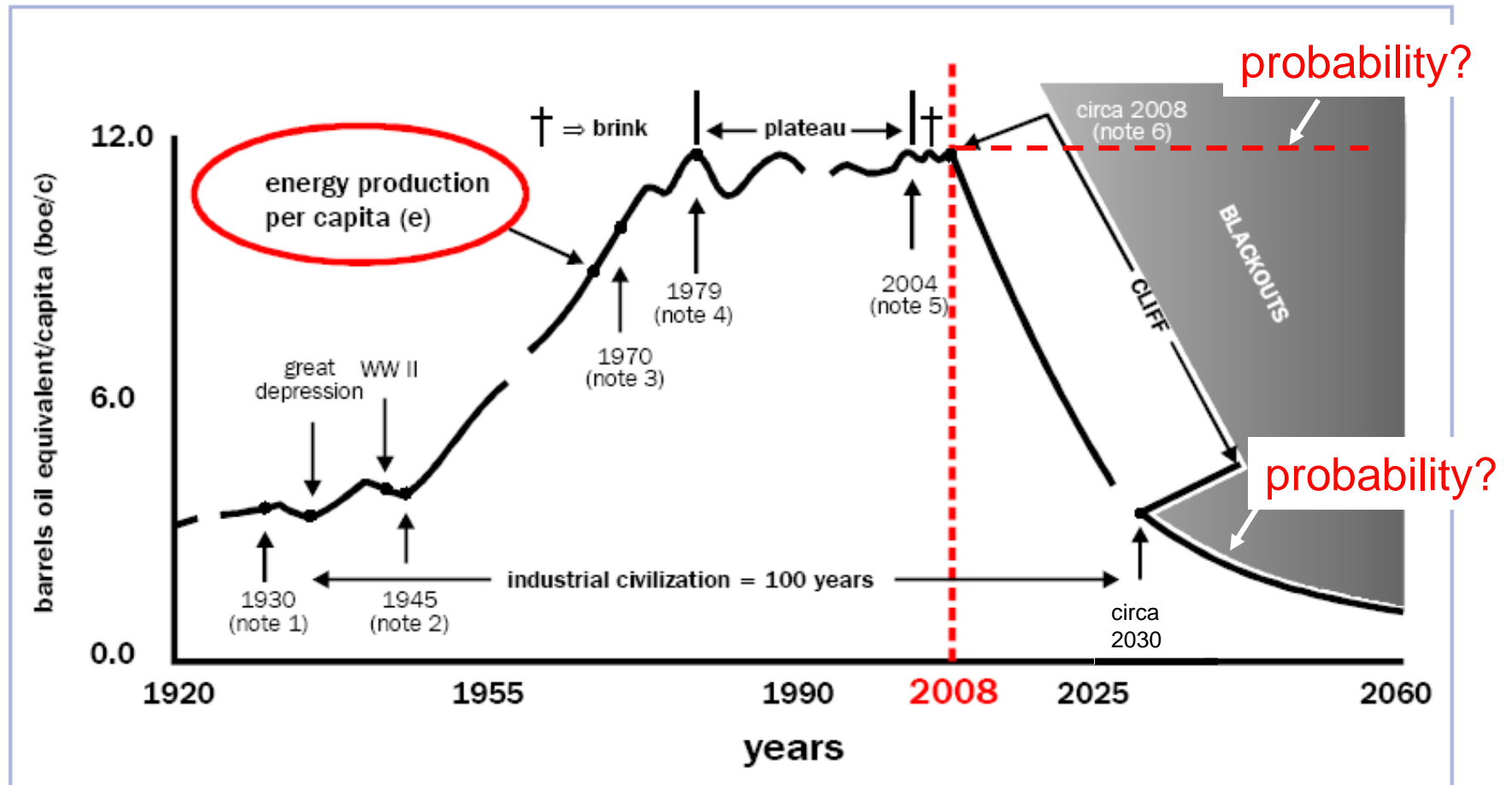
Examples (primary production per year)



↑
Source: ASPO

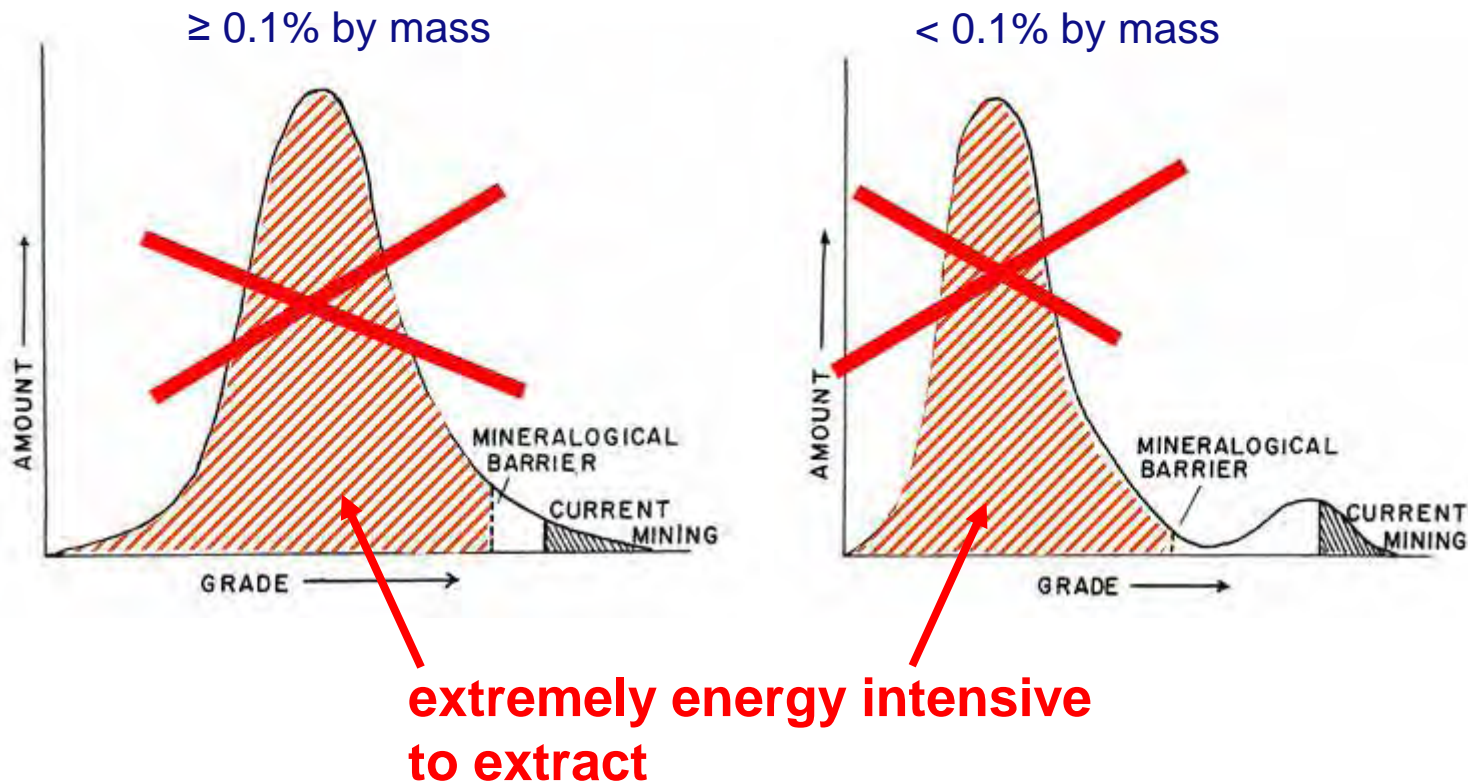


Energy scarcity



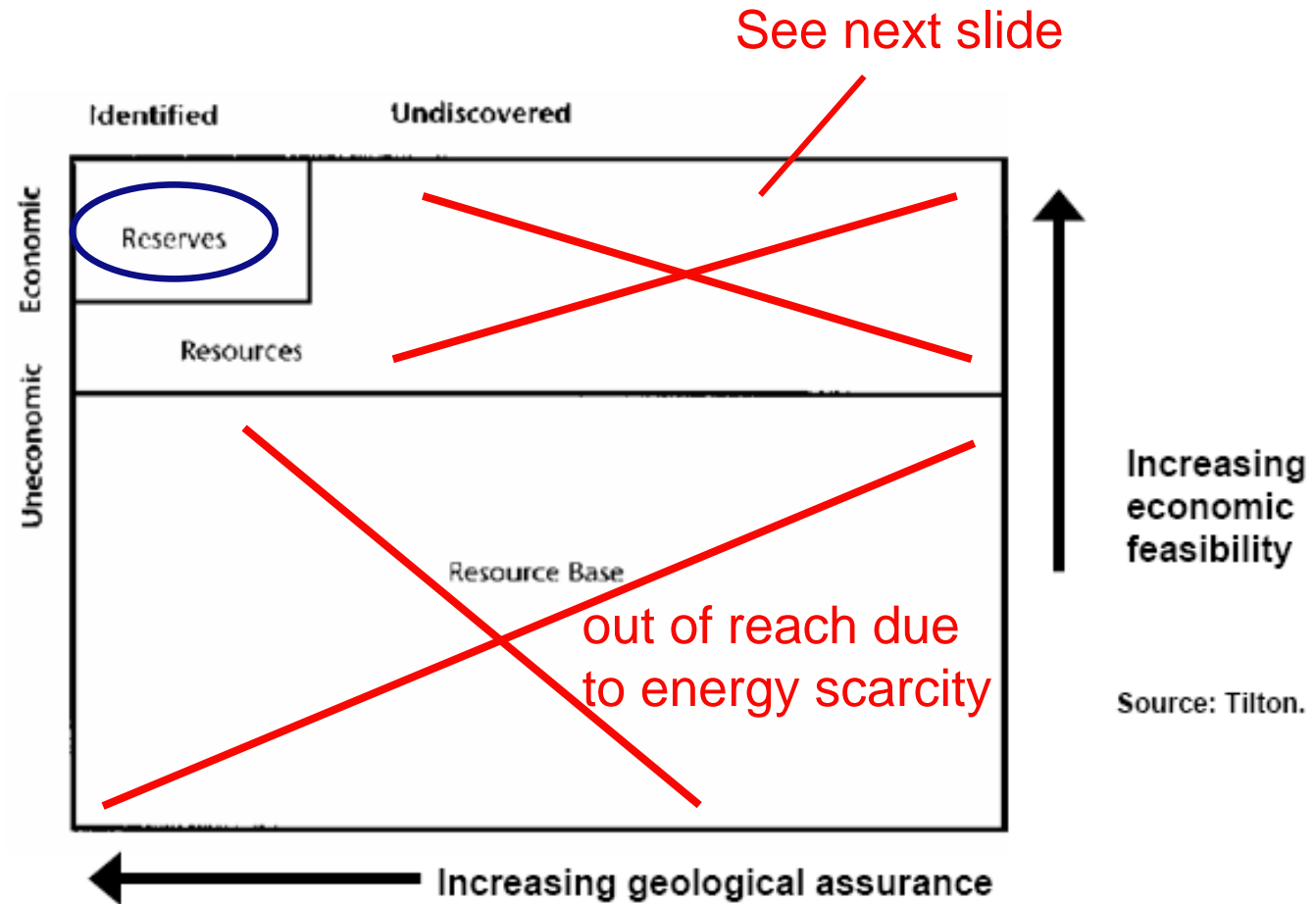
Source: The Olduvai Theory, Richard C. Duncan, 2005/2006

Elements of the Earth's crust: the bulk is out of reach

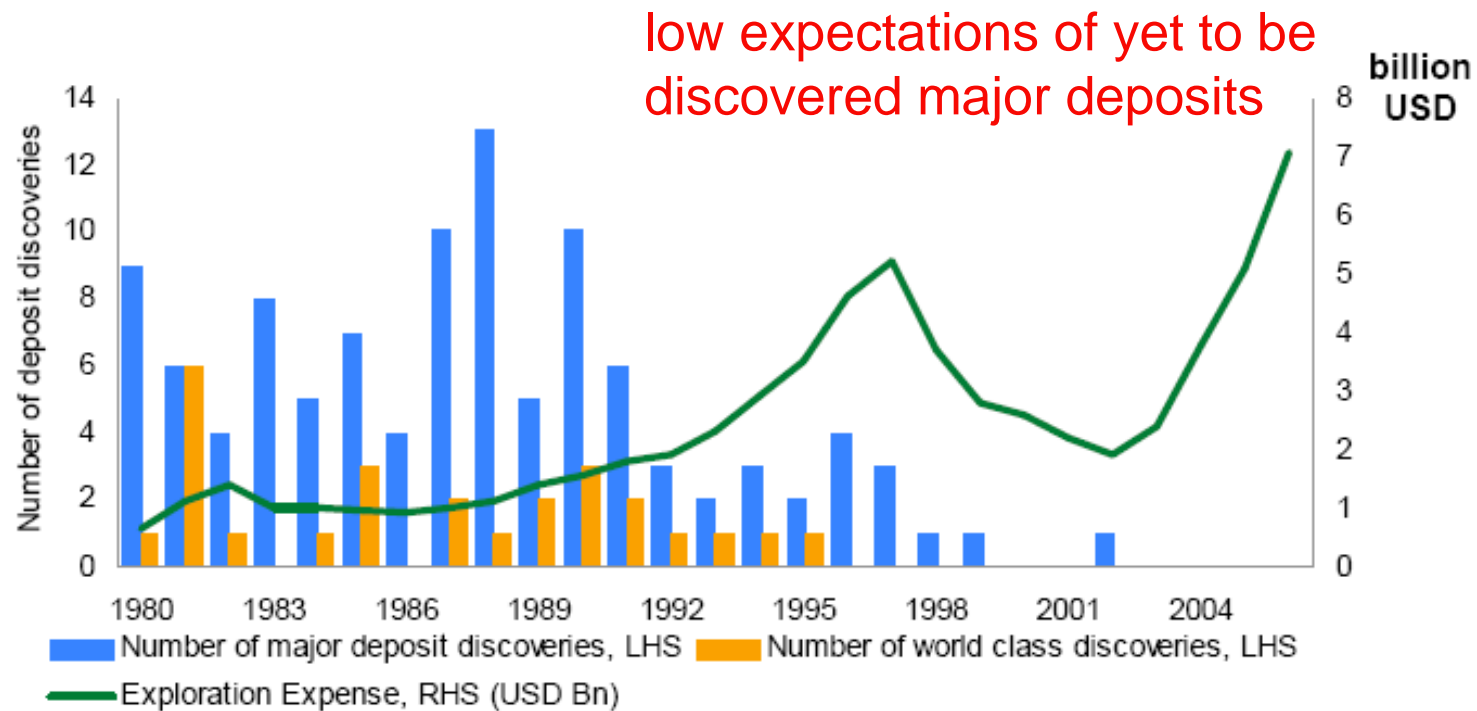


Source: "Exploring the resource base"
Brian J. Skinner, Yale University, 2001

“The Earth’s crust is so big” is true and at the same quite useless information



Exploration of major mineral deposits and the “Law of diminishing returns”



Sources: BHP Billiton, MEG, UBS WMR.

Graph: Raw Materials Group, Sweden

Metals scarcity

- Current / Short term demand > supply:

precious metals (Ag,Au,most platinum group metals), most rare earth metals (lanthanides), a number of minor metals (Ga,Ge,In,Te), “tungsten group” metals (W,Ta,Zr,Nb,Mo),

- Long term demand > supply:

all metals except Elements of Hope (include Fe,Al,Mg)

Metals scarcity interferes with energy transition



→ false sense of security!

Requires around 3 million tons of neodymium; current annual production rate: 18,000 tons

replace ALL fossil fuels by 2030 using:

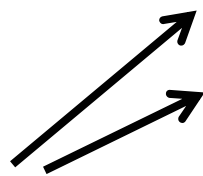
- 490,000 1MW tidal turbines +
- 5,350 100MW geothermal plants +
- 900 1,300MW hydroelectric plants +
- 3,800,000 5MW wind turbines +
- 720,000 0.75MW wave converters +
- 1,700,000,000 0.003MW rooftop photovoltaic systems +
- 49,000 300MW concentrated solar power plants +
- 40,000 300MW photovoltaic power plants

Metals scarcity interferes with energy transition



replace ALL fossil fuels by 2030 using:

- 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 +
- **40,000** 300MW photovoltaic power plants



Requires around 90,000 tons (net) of gallium and 500,000 tons (net) of indium (2µm CIGS panels)

or

around 800,000 tons (net) of tellurium (2µm CdTe panels)

or

around 17,000 tons (net) of ruthenium (dye-sensitized panels)

Current annual primary production rates (*estimates*):

gallium: around 100 tons

indium: around 600 tons

tellurium: around 450 tons

ruthenium: around 40 tons

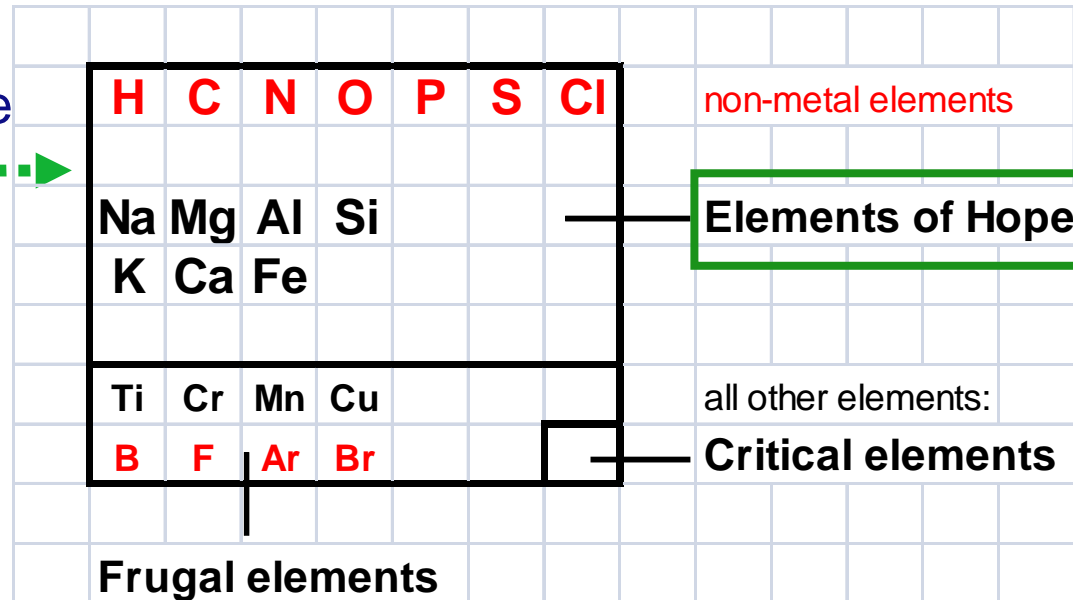
Technology softens the consequences, don't expect miracles



- Timeliness?
(think in decades, not years)
- Economic scalability?
- Technology has to abide with the laws of thermodynamics!
- 'Solutions' increase risks and efforts related to next level of problems
- Are we making the right choices?

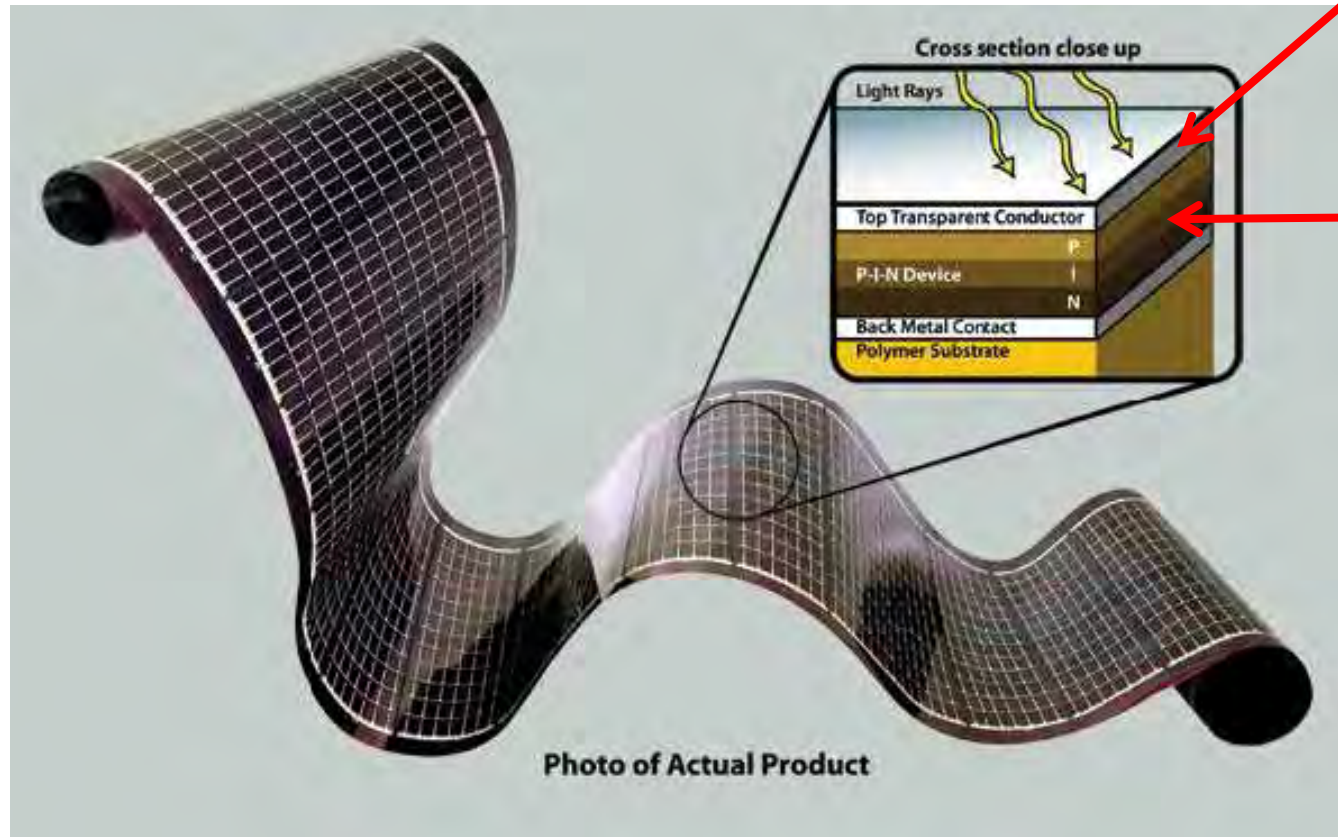
Adaptation framework with intrinsic benefits, applicable to energy as well as metals

1. Use less (*involves human behaviour and “**managed austerity**”*)
2. Longer life
3. Re-use and recycle
4. Substitute▶
5. Product and process (re)design
6. Buffers



Source: Global Resource Depletion, Managed Austerity and the Elements of Hope (2010), ISBN 9789059724259

Solar panels without exotic metals?

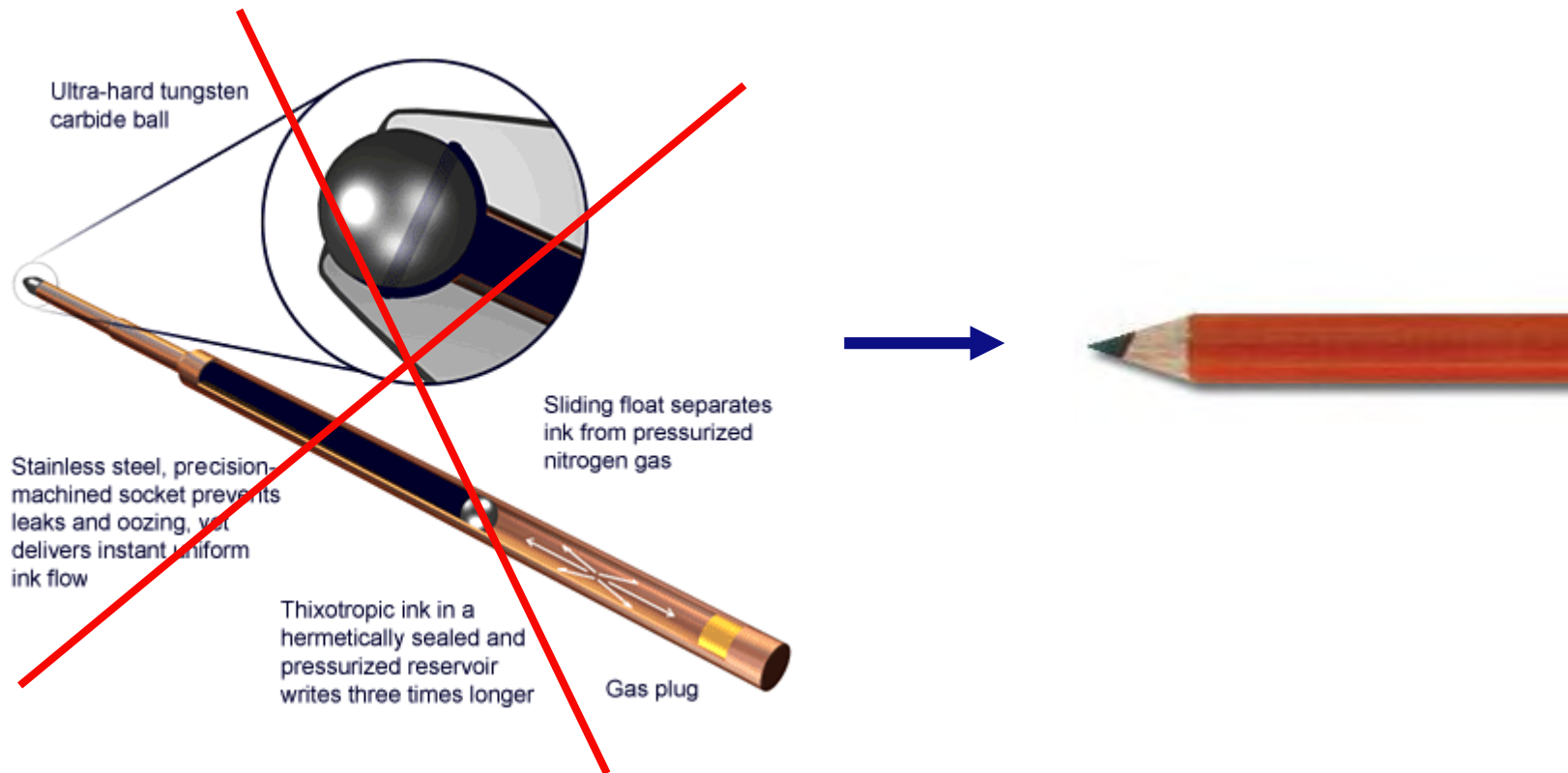


replace transparent conductor by aluminium grid

amorphous silicon without exotic doping

Picture: PowerFilm

Simplification and optimization instead of performance maximization yield huge leverage w.r.t. energy and materials input



Summary

- We are facing energy shortages (demand exceeding supply) on a *global scale*
- Energy scarcity means metals scarcity, which in turn aggravates energy scarcity
- This in turn *restricts* the materialization of a new infrastructure needed to harvest diluted energy sources like sunshine and wind due to issues w.r.t. affordability and availability
- A viable adaptation framework should include a focus on the most abundant elements or the **Elements of Hope** together with using less (also in an absolute sense) or **Managed Austerity**
- This means vast opportunities for using the leverage of a *selective* retreat from performance maximization

Thank you for your attention!

