The need of mineral resources for a low-carbon society

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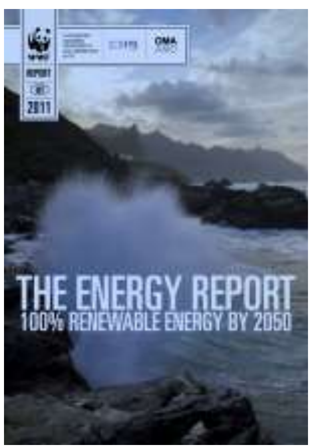
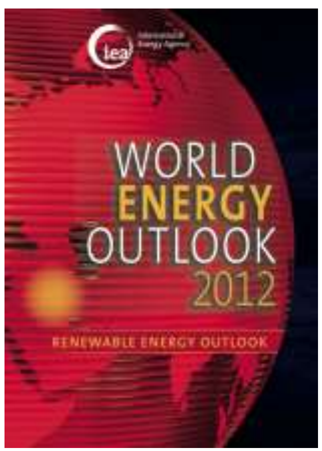
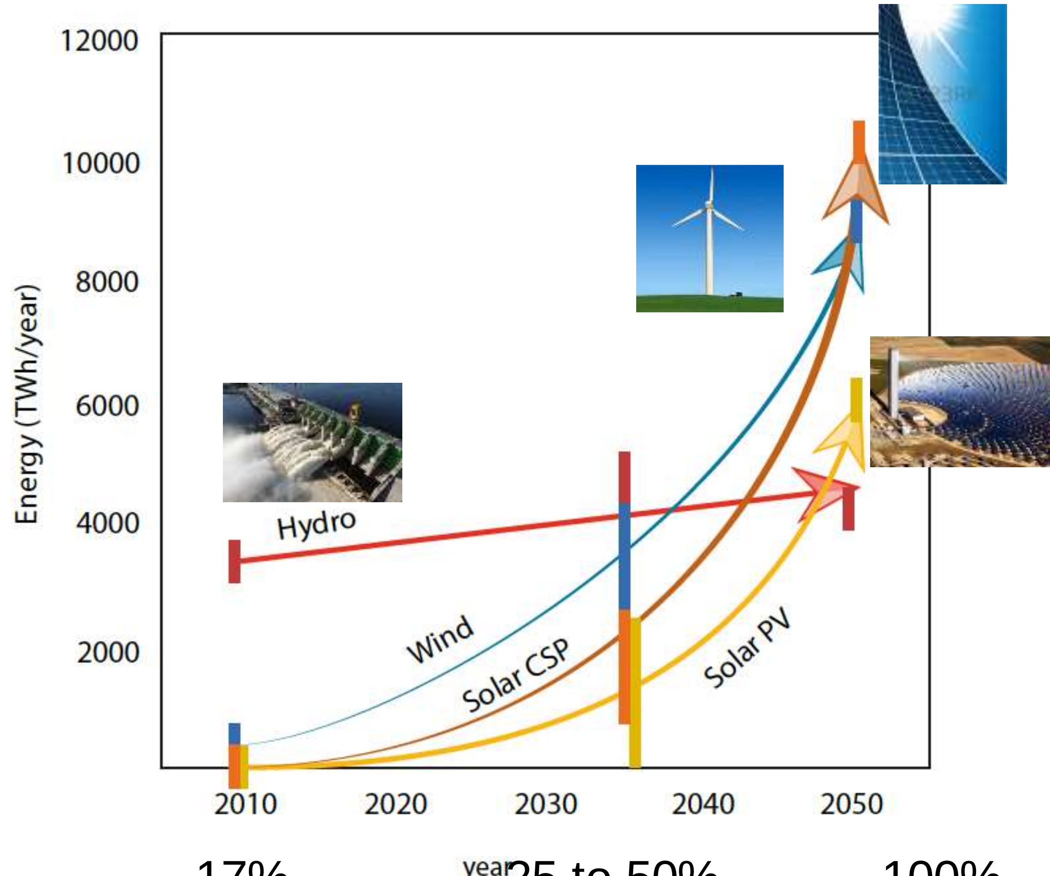
Evolution of hydro, solar and wind energy production for the next 40 years

The scenarios of the IEA and Ecofys (WWF) rely on a strong increase in the share of solar and wind energy







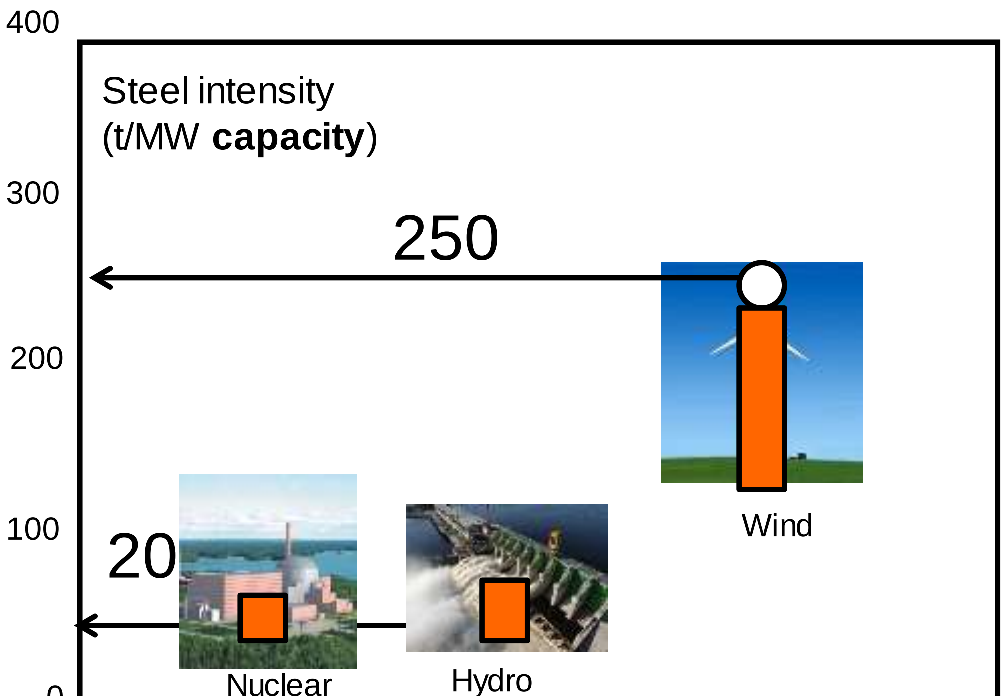
17% 25 to 50% 100%

of global electricity generation

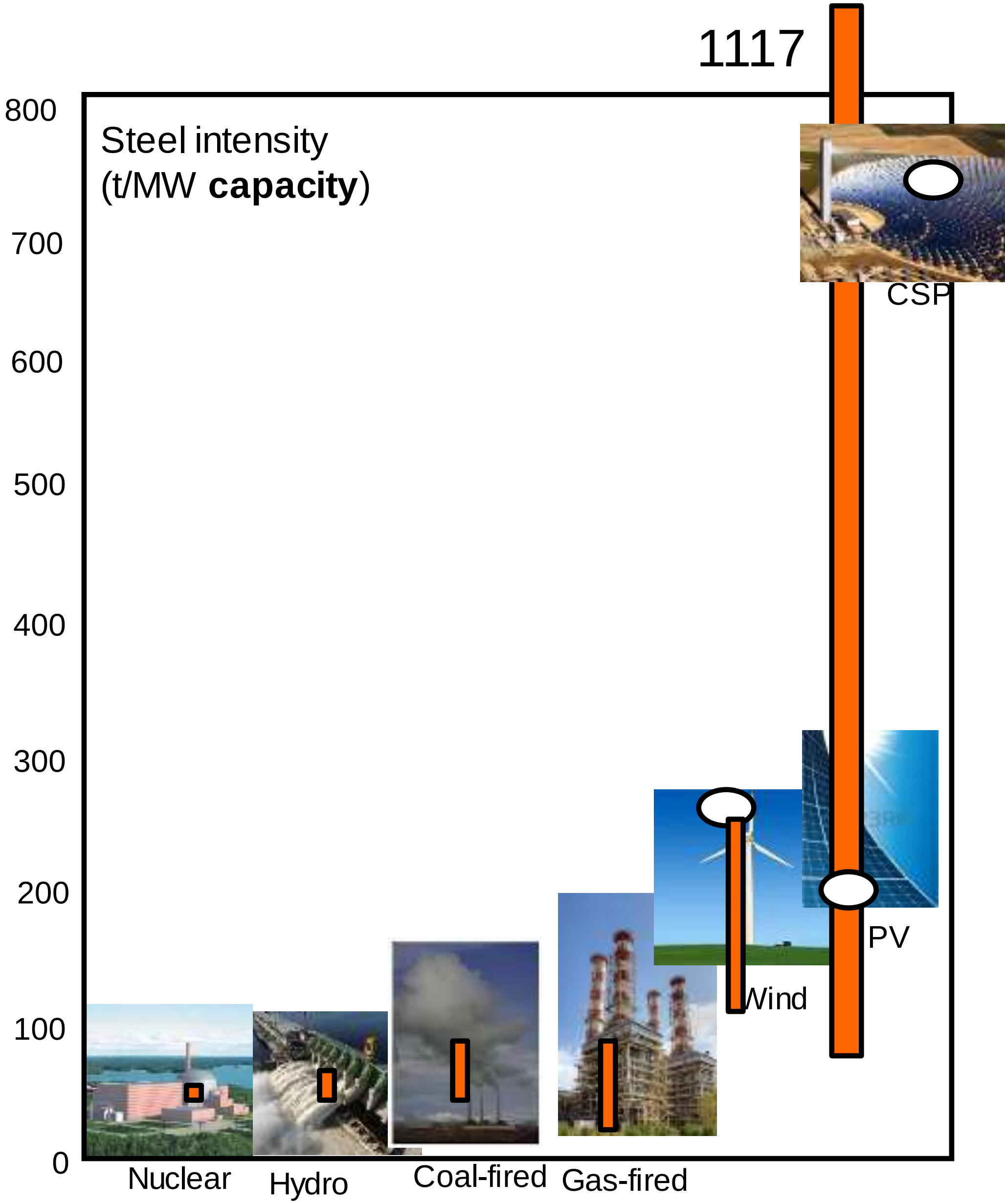
(about 40% of global E demand)

Solar and wind sources are diluted and require large facilities

Latest wind turbine generation:
6 Mw, basement at 60 m depth, rotor > 150 m, *>1500 t of steel*
Permanent magnet with ≈1 t REE (Nd, Dy, *Sm, Gd, or Pr)*



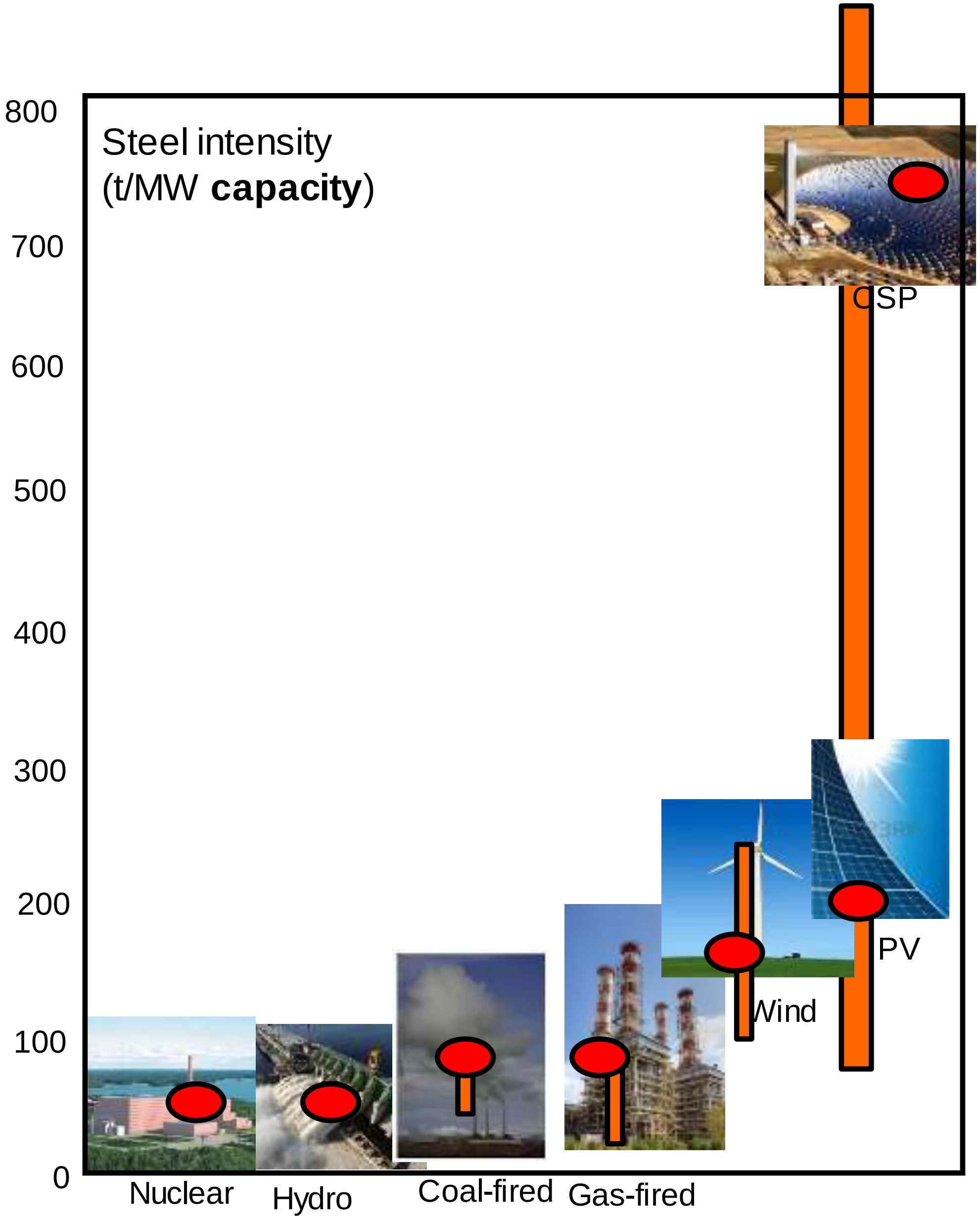
870 wind turbines to produce the same energy (Wh) as a 1300 MW nuclear plan -> 1.4 10^6 t of steel



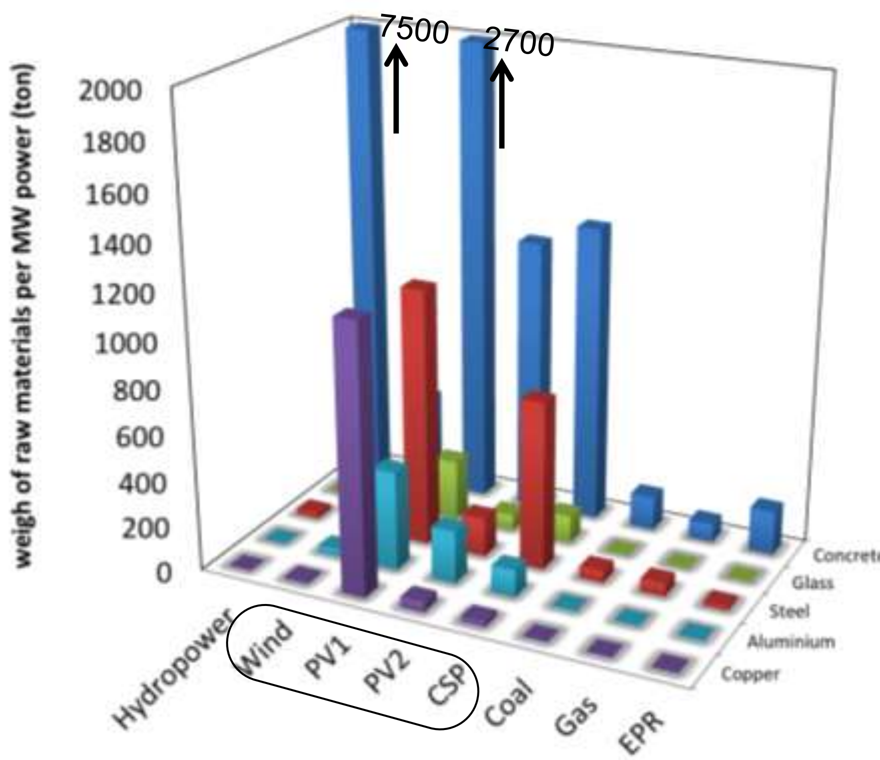
Vidal et al., 2013

PV: 8000m^2 for 1 MWe
25 kg steel/ m^2 => 200 t/MWe

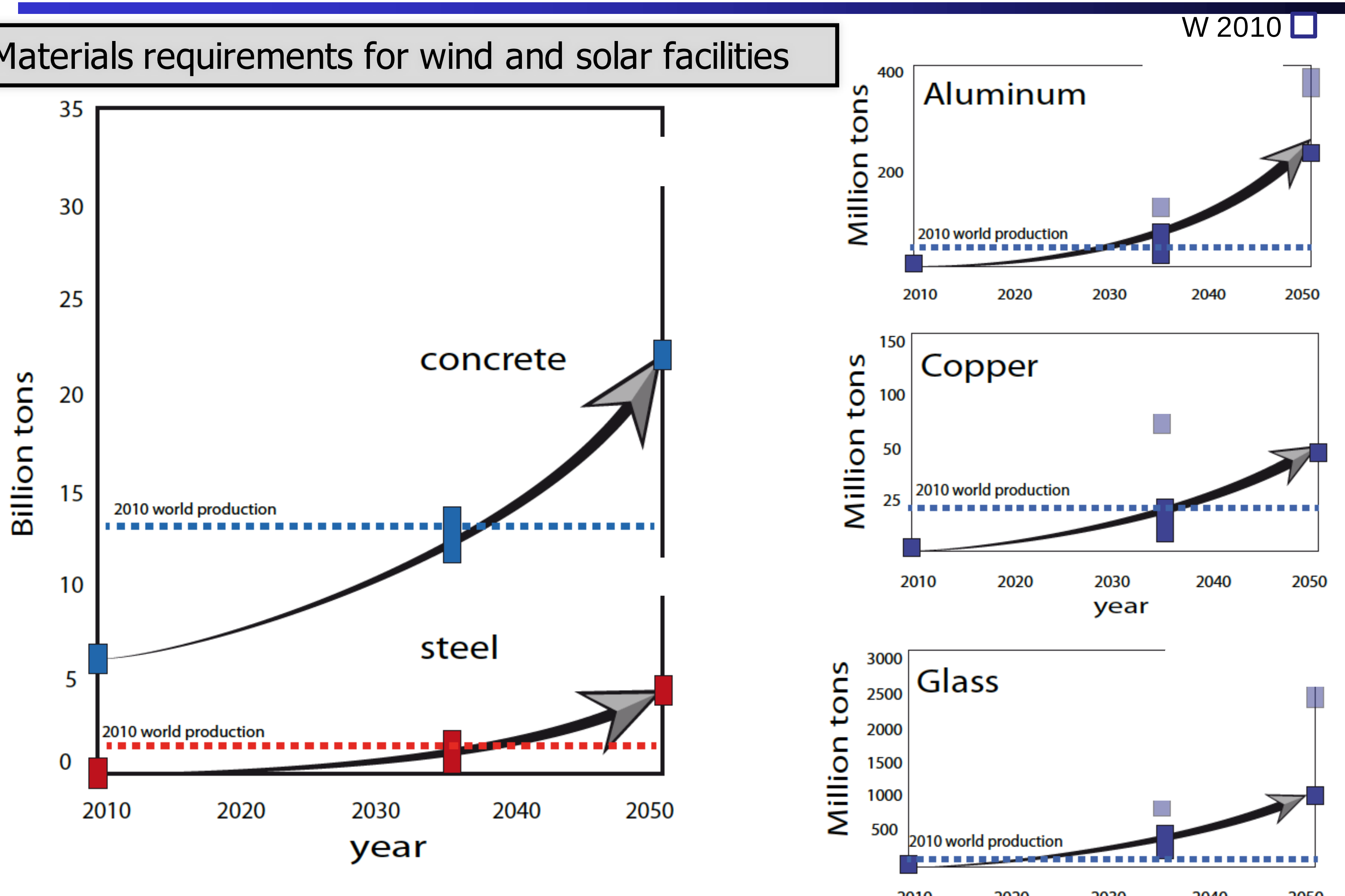
CSP: 730 t/MW



Vidal et al., 2013



Materials requirements for wind and solar facilities

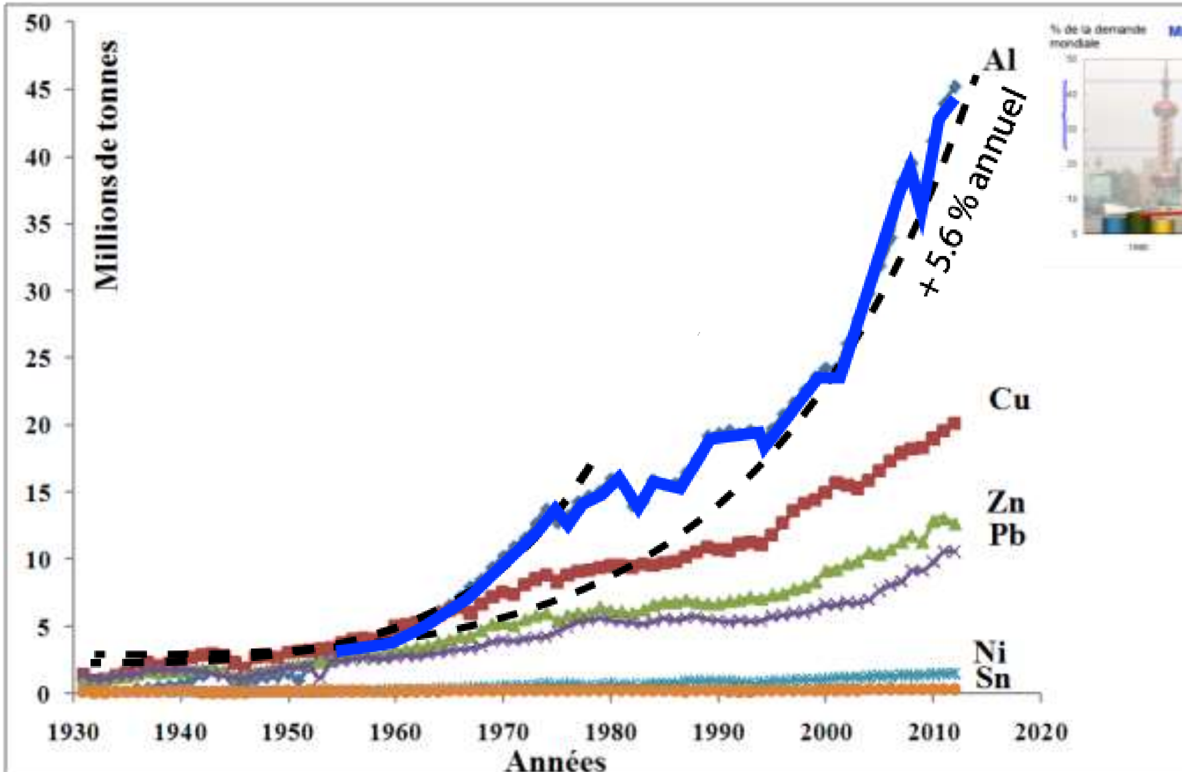


In 2050, the cumulative amount of concrete, steel, Al, Cu and glass sequestered in wind and solar facilities will be 2 to 8 times the 2010 world production

Materials requirements for wind and solar facilities: The base metals production will have to be boosted to 0.15 - 2% each of the next 40 years

Should we worry ?

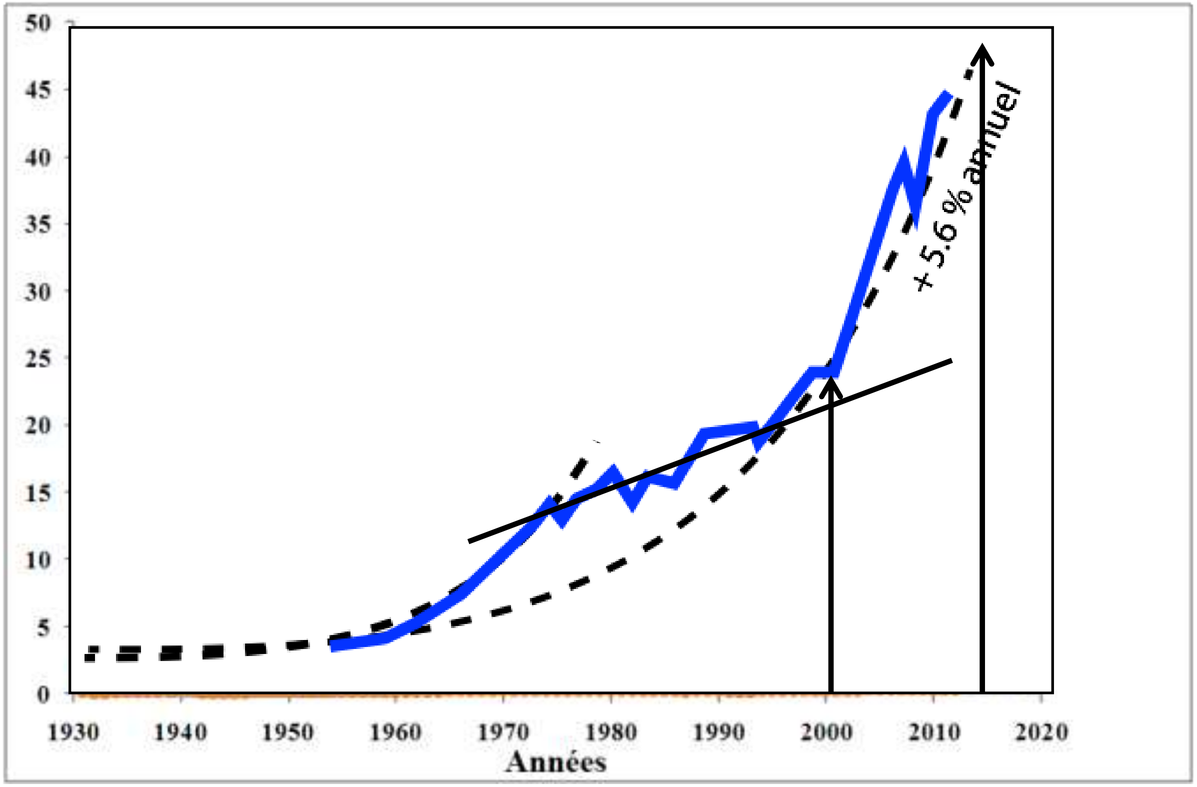
0.15 - 2%/year is lower than the present growth rates (about 5%)



The base metals consomption will be boosted to 0.15 - 1% each of the next 40 years...

Should we worry ?

0.15 - 2%/year is much lower than the present growth rates (about 5%)...

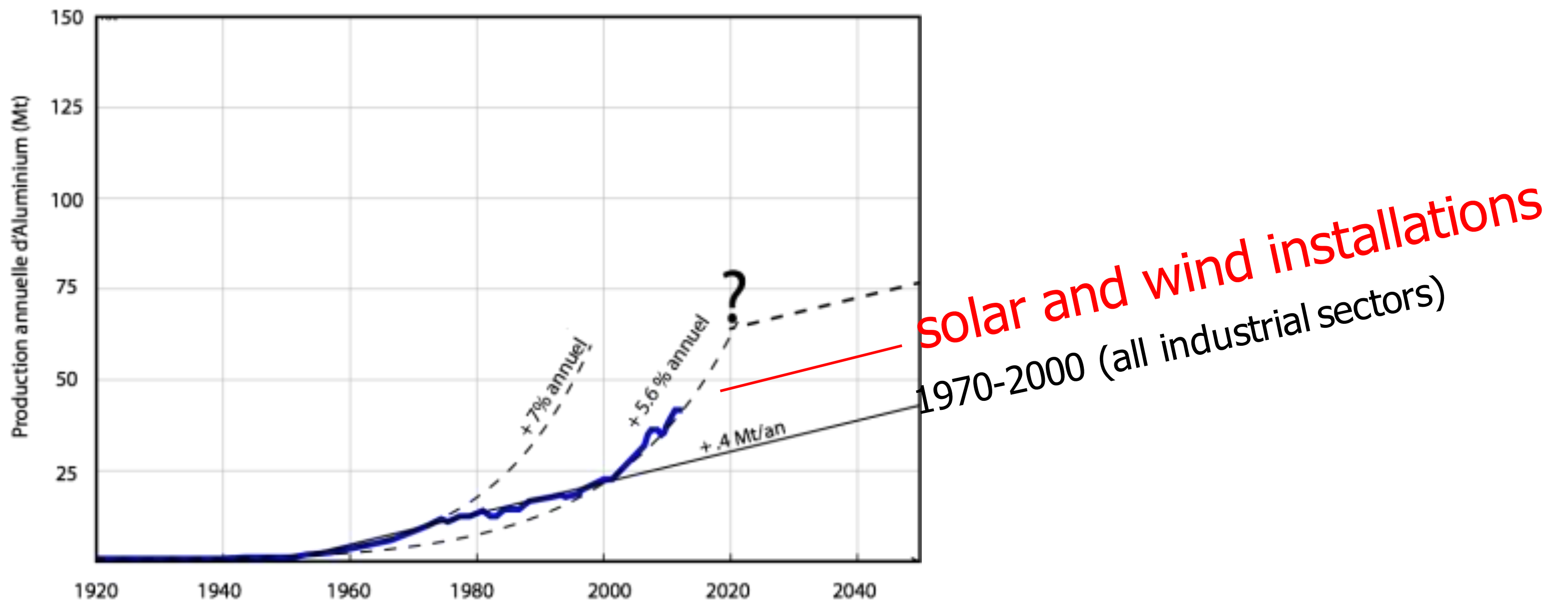


... but 5%/year growth rate means doubling the production every 15 years - hardly sustainable over 40 years.

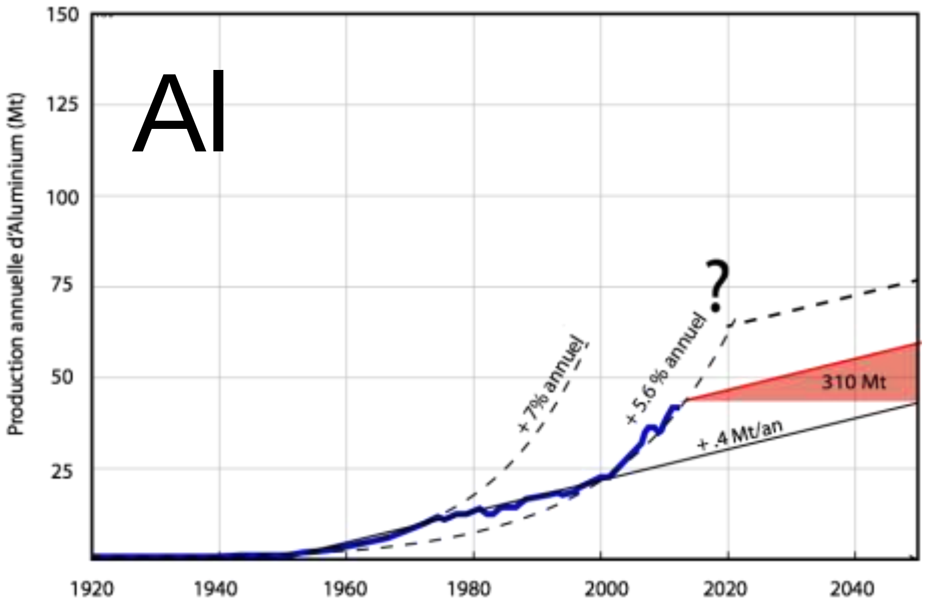
The base metals consomption will be boosted to 0.15 - 1% each of the next 40 years...

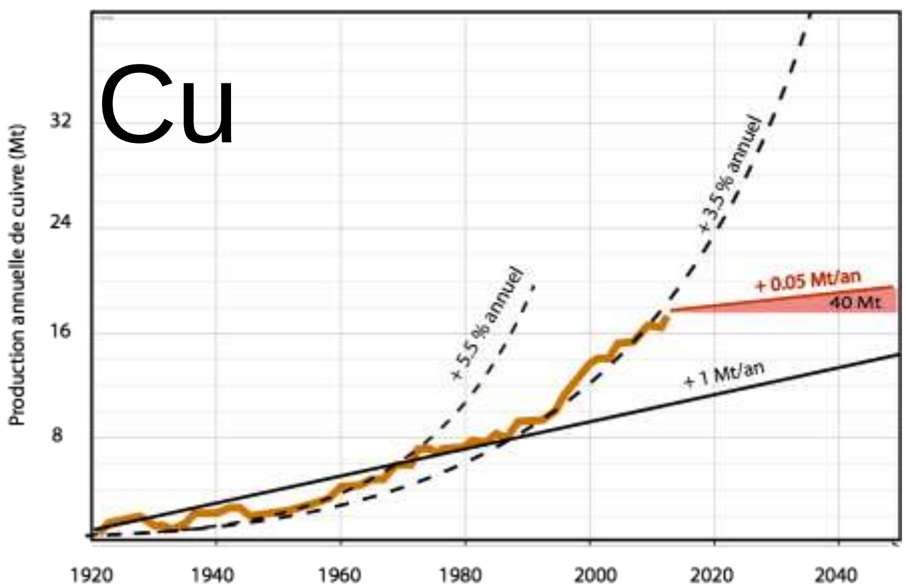
Should we worry ?

0.15 - 2% is much lower than the present growth rates (about 5%)… but

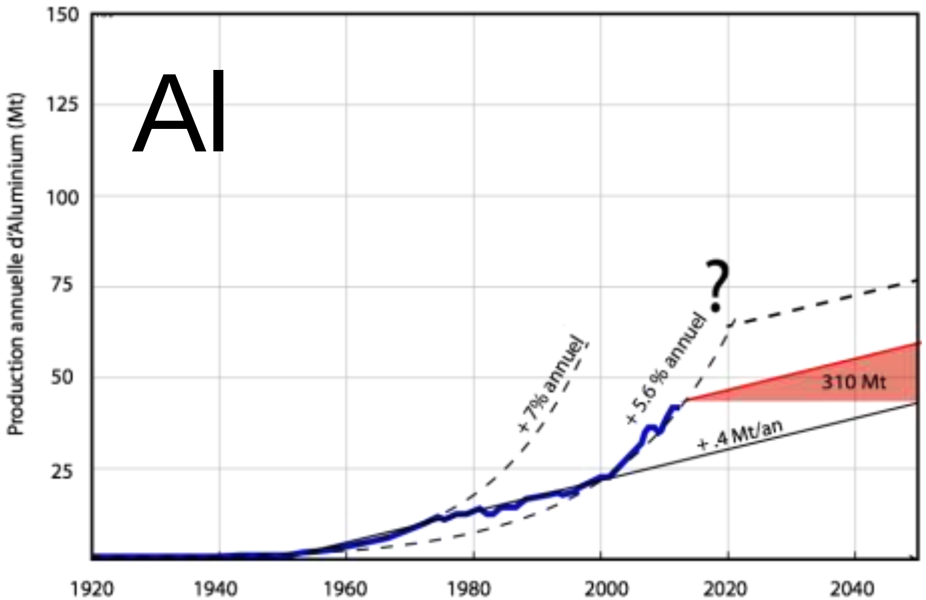


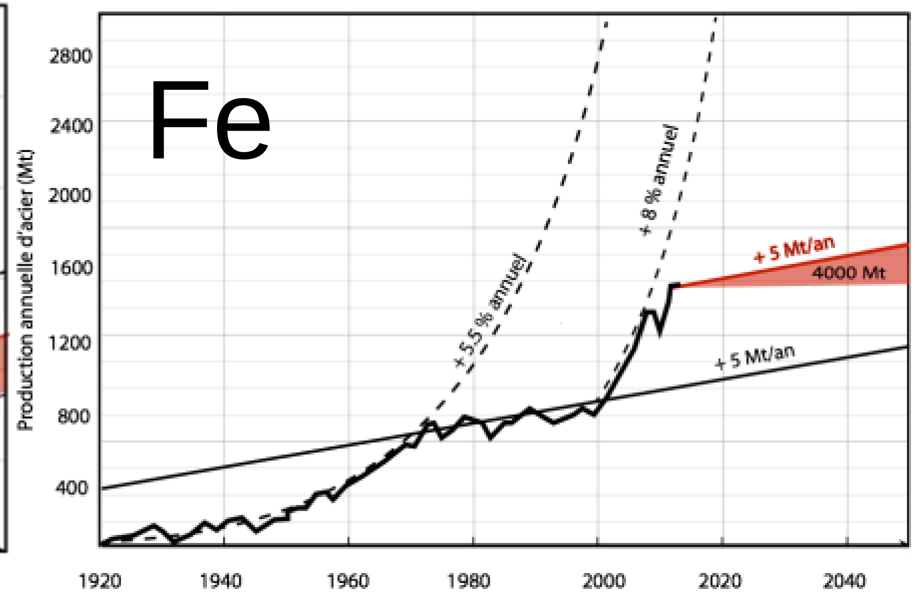
Until 2050, the increase in Al production needed to the construction of ***solar and wind*** facilities (<40% of global energy demand) will be the same as that driven by ***all industrial sectors*** between 1970 and 2000

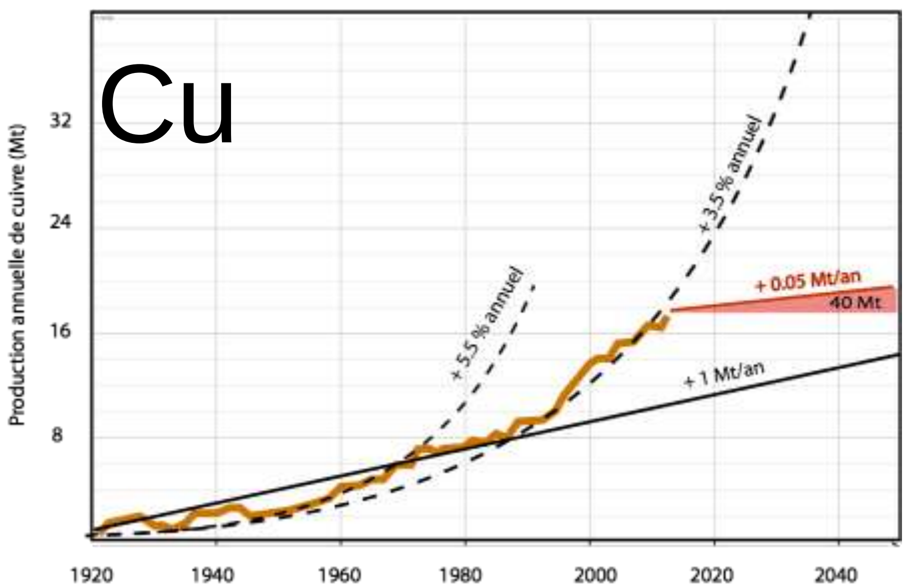




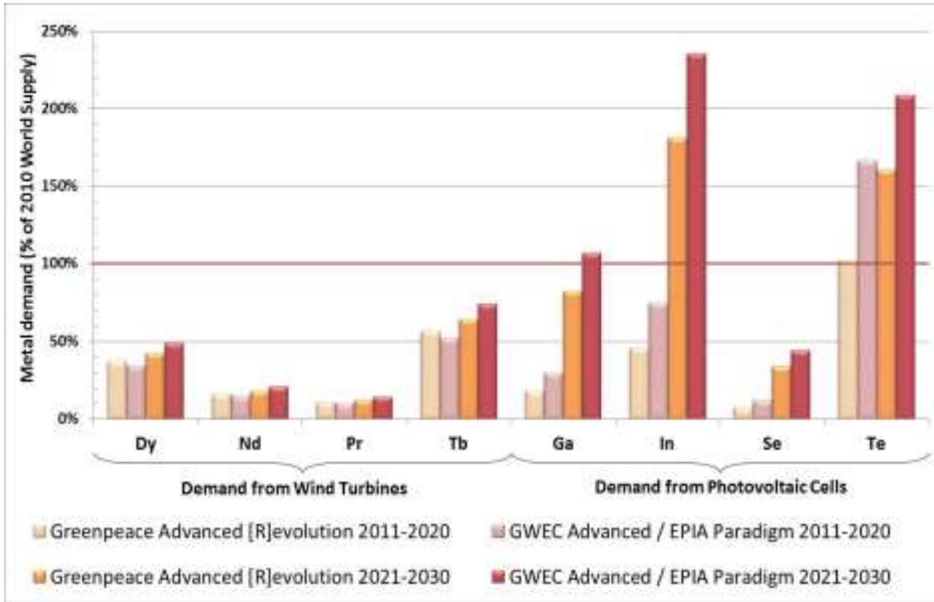
Werner (2010):
if CSP with 34.5% of Al frames and PV with12% Al (current guesstimate from an industry source), 460.10^{6}t Al should be produced by 2050… and less steel







Until 2050, the increase in Al, Cu, Fe production needed to the construction of ***solar and wind*** facilities will be similar to that driven by ***all industrial sectors*** between 1970 and 2000



Yearly global metal demand from photovoltaic cells and permanent-magnet wind turbines 2011-2030 under the most optimistic deployment scenarios

Until 2050,

- the increase in Al, Cu, Fe consumption needed to the construction of ***solar and wind*** facilities will be similar to that driven by ***all industrial sectors*** between 1970 and 2000
- The global production of concrete and glass will have to be boosted to 200% and 800% of the 2010 production, respectively.

Until 2030,
the yearly global demand in Ga, In, Se, Te, Dy, Nd, Pr and Tb will be boosted to 10 to 230% of the 2010 world supply

Can we make it ?

The optimist : No problem – in any 30-year period, mankind has consumed as much metal as during all previous history, and improvements in technology or the discovery of new deep seated on-shore and off-shore resources will allow the trend to continue.

However, it is important not to overstate the risks of raw materials bottlenecks for key decarbonisation technologies. This is because there are still many years before the large uptake of some technologies and there are numerous options available to mitigate the risks identified.

Critical Metals in the Path towards the Decarbonisation of the EU Energy Sector

Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies

JRC SCIENTIFIC AND POLICY REPORTS

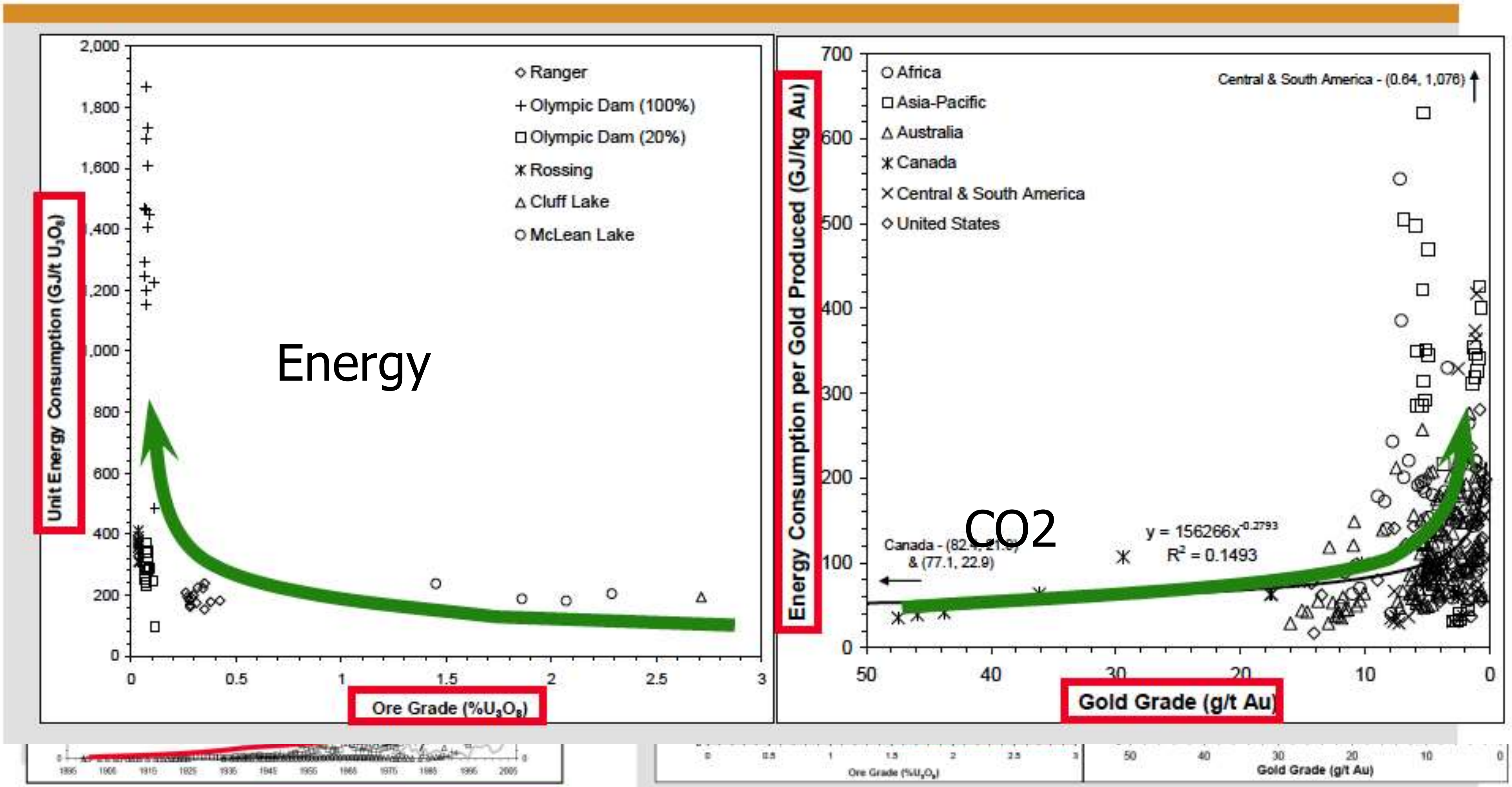
European Commission

Can we make it ?

The optimist : No problem – in any 30-year period, mankind has consumed as much metal as during all previous history, and improvements in technology or the discovery of new deep seated on-shore and off-shore resources will allow the trend to continue.

The pessimist: Doubling the metal production every 20-30 years has been possible in the past, but as mines become more remote and metal grades decline, and above all increasing energy demands, will put a limit to further expansion and the transition to a carbon-free society.

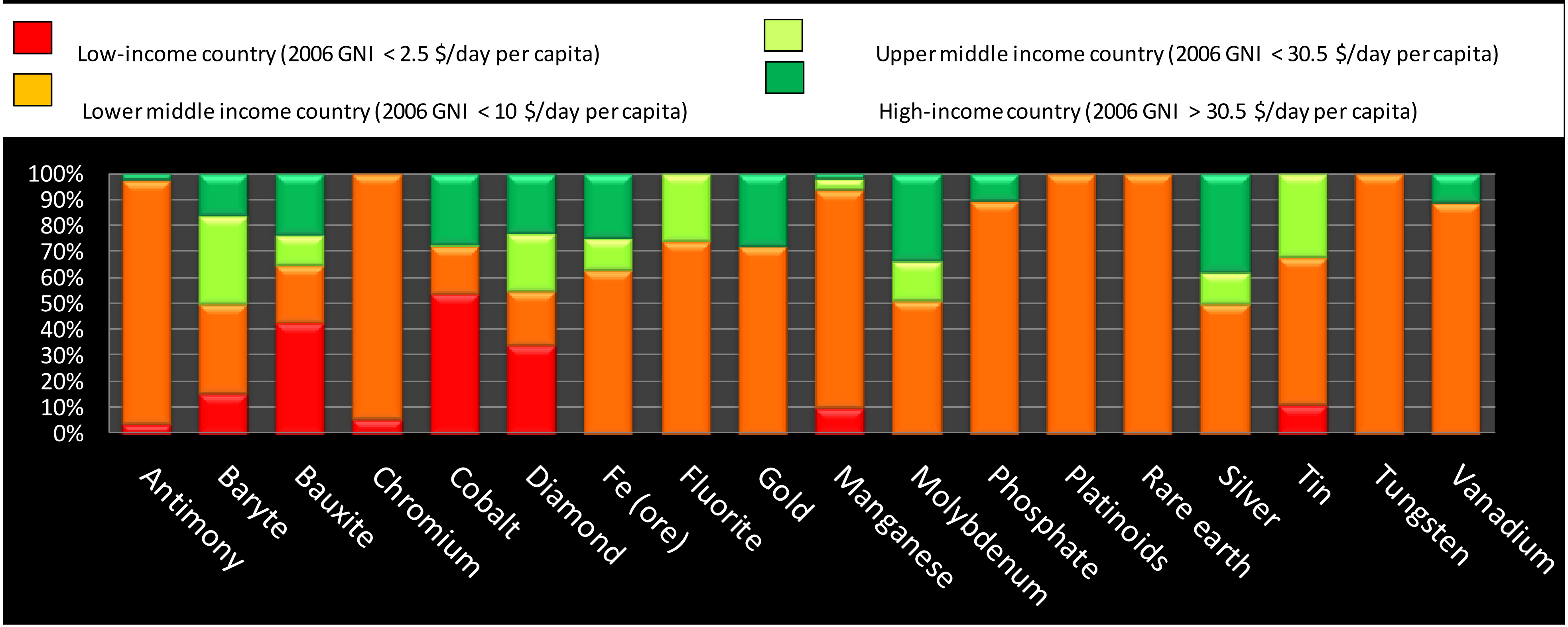
Doubling the metal production every 20-30 years has been possible in the past, but as mines become more remote and metal grades decline, the increasing cost of mining and increasing energy demands increase as well.



Minerals Council of Australia – Sustainable Dev't Conference, Cairns, October 2007
G M Mudd – Quantifying Sustainable Mining : Production, Reporting and Beyond 10

Localisation of the RESERVES of some main mineral commodities, per gross national income per day and capita of the hosting countries

Data sources: USGS (Reserves) and World Bank (GNI)



Countries with structural difficulties and limited possibilities to impose good social and environmental conditions of extraction.

Can we make it ?

The optimist : No problem – in any 30-year period, mankind has consumed as much metal as during all previous history, and improvements in technology or the discovery of new deep seated on-shore and off-shore resources will allow the trend to continue.

The pessimist: What has been possible in the past might become difficult in the future: As mines become more remote and metal grades decline, the increasing cost of mining, and above all increasing energy demands, will put a limit to further expansion and the transition to a carbon-free society.

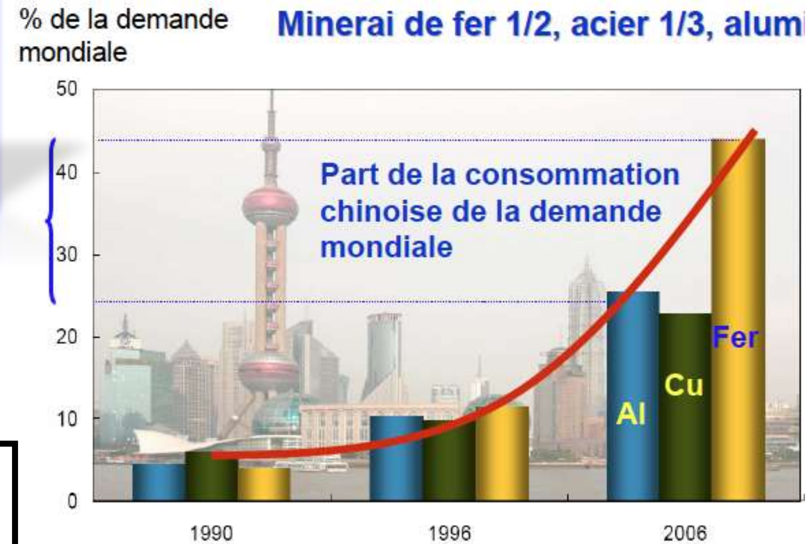
The realist: we must ensure that the availability of raw materials (fossil resource) does not become an obstacle to the energy transition…

Two different issues

1) **Base metal, glass and construction minerals**

1) **“High-tech” or “rare” or “critical” mineral commodities**

The reserves of base metals are large… but their consumption exploded in the last 15 years…



Prises de participations chinoises dans l'industrie minérale mondiale

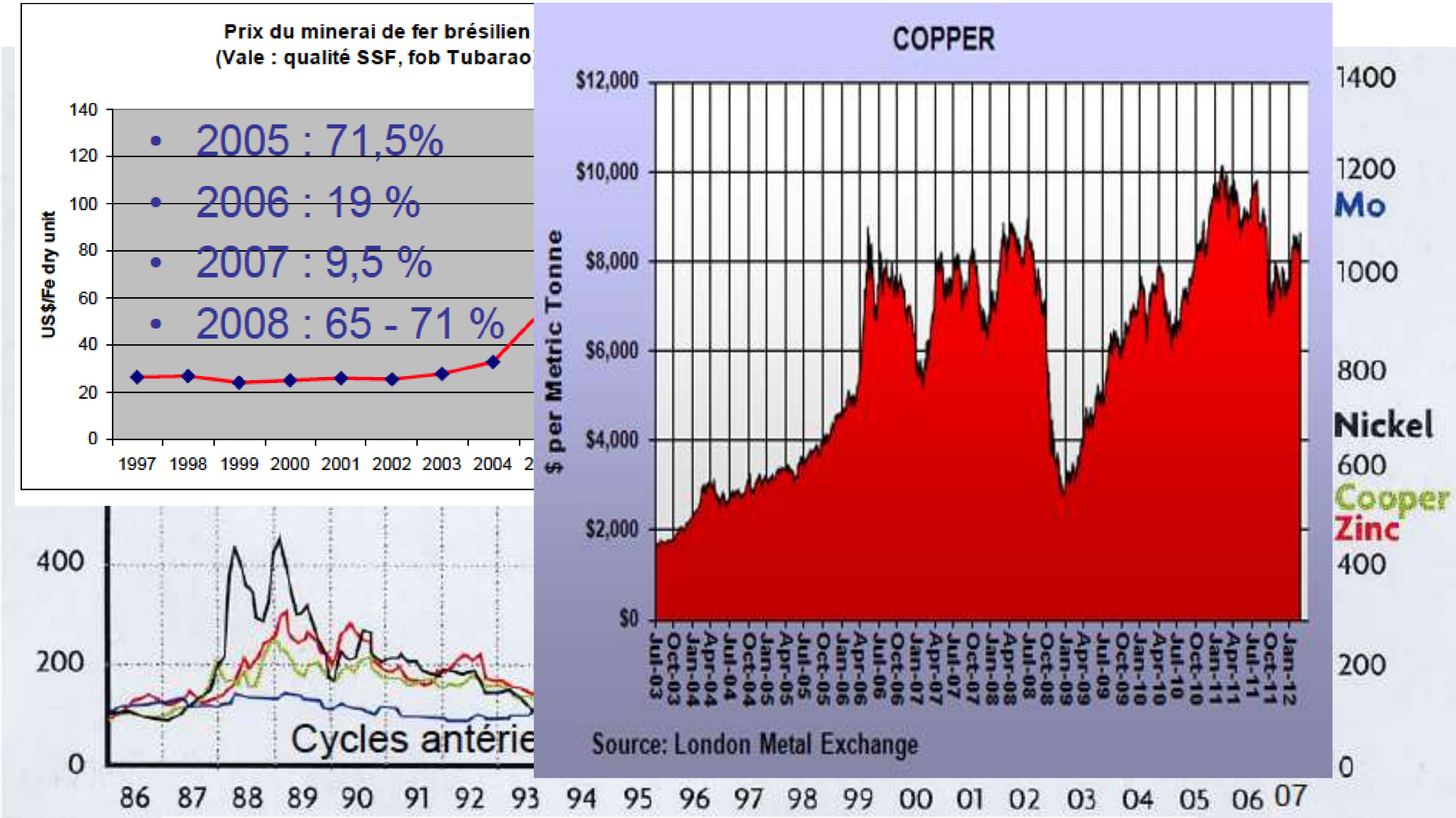
(D'après Van der Wath, Bateman Beijing Axis, « China and Africa: A Global Natural Resources Alliance?

Situation en 2004

Situation en début 2009

Situation en début 2010

Price volatility -> uncertainty of economic scenarios and for the mining industry (risk)



Serious consequences on the consumed fossil energy and GHG emissions

In 2011: 24 % of the global energy consumed by the industry was used for the production of base metals and concrete

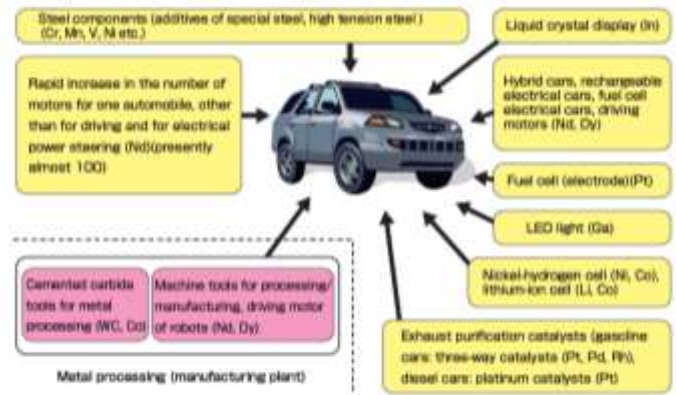
In addition to base metals, the high-tech sector uses a large variety of «scarce metals» in increasing quantities

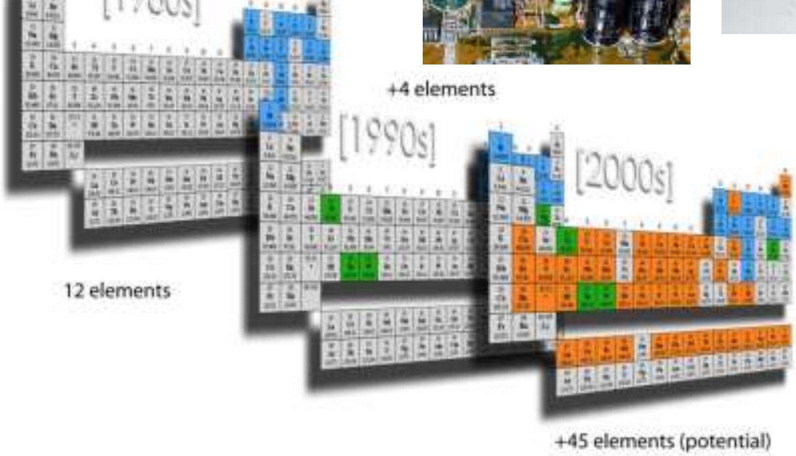
Öhrlund, I. (2011): Between 2010 and 2030, the yearly global demand in Ga, In, Se, Te, Dy, Nd, Pr et Tb for solar and wind facilities could be boosted to 10 to 230% of the 2010 world supply

B, Nd, Dy

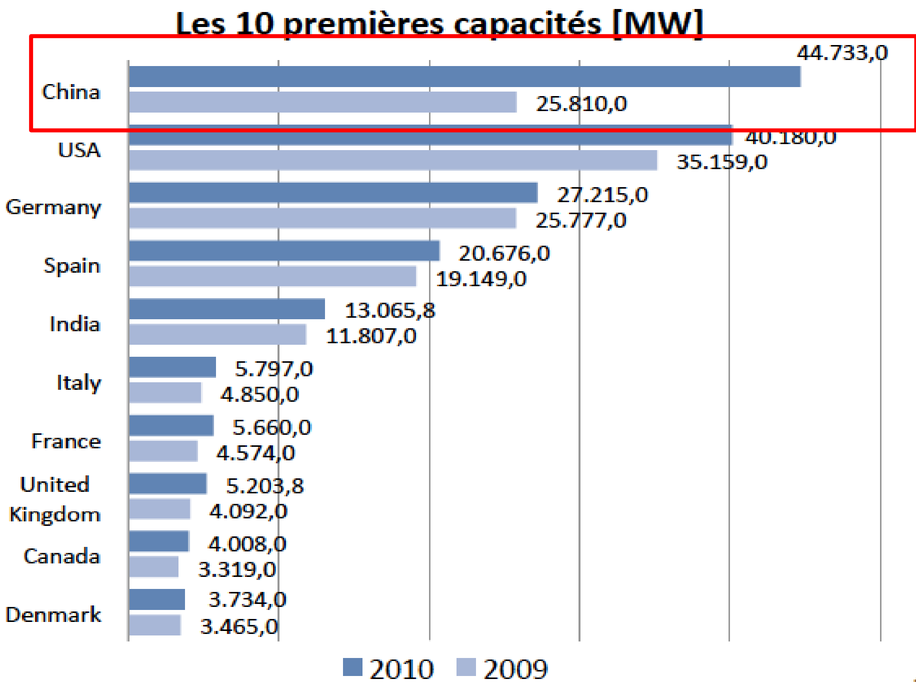
Ga, In, Se

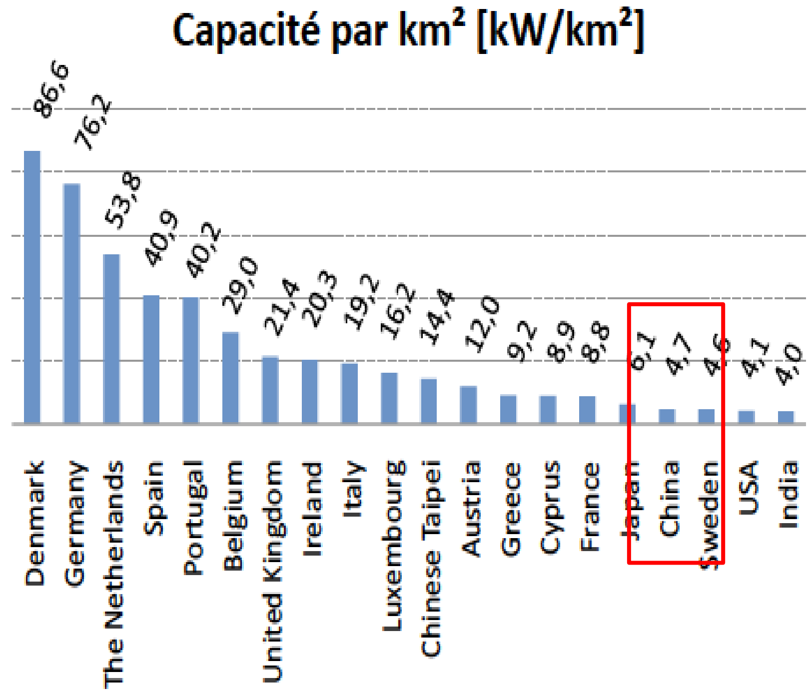
Ga





Co, Ga,
In, Nb,
Ta,W,
PGE, REE,
Cu, Ni, Pb, Bi, Li, Ag, Au





Wind power in China in 2008: 12GW, and in 2011: 63GW

8 kt/y used by China

One solution to open new mines… at the condition we find the good ores

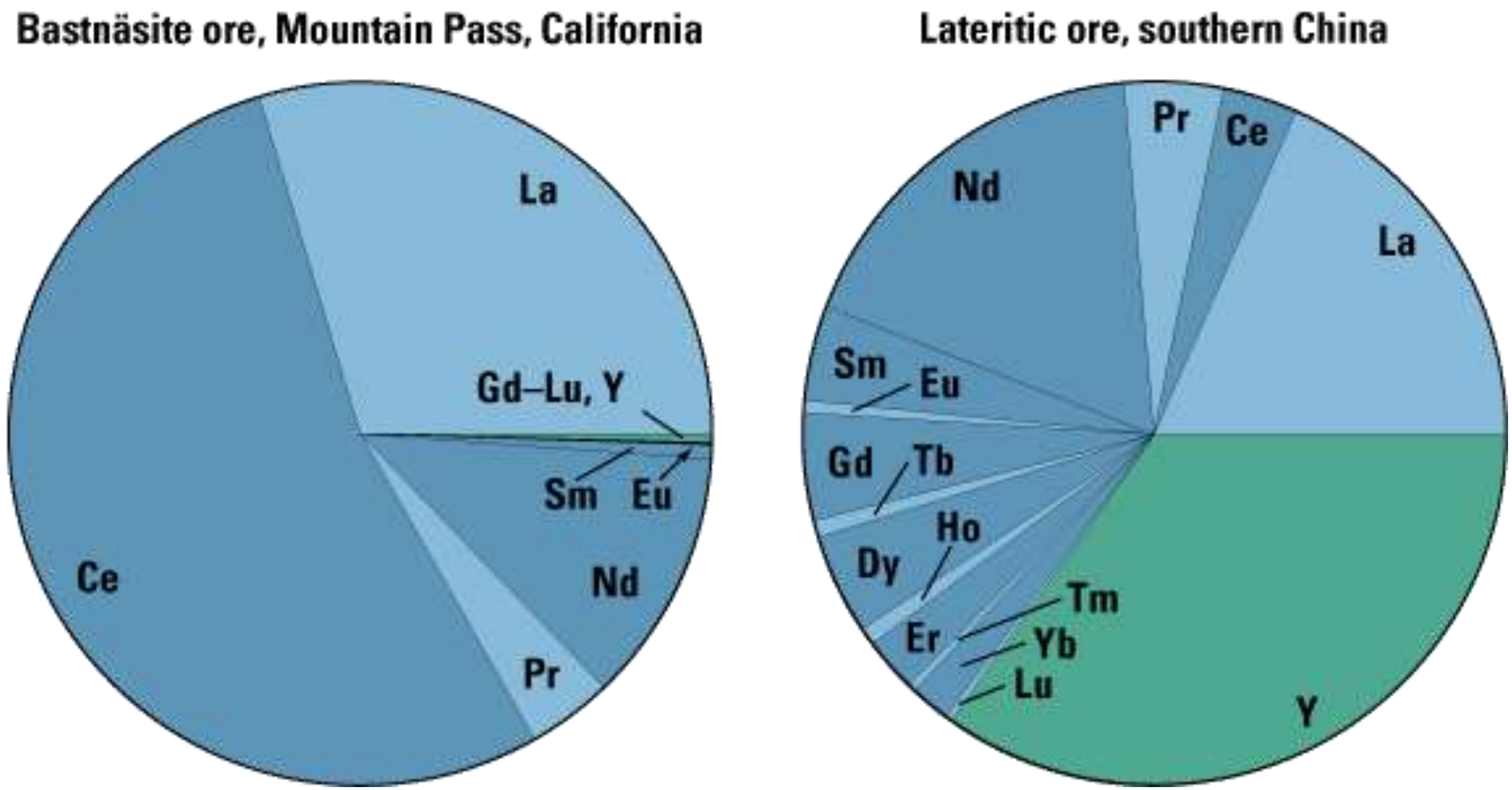
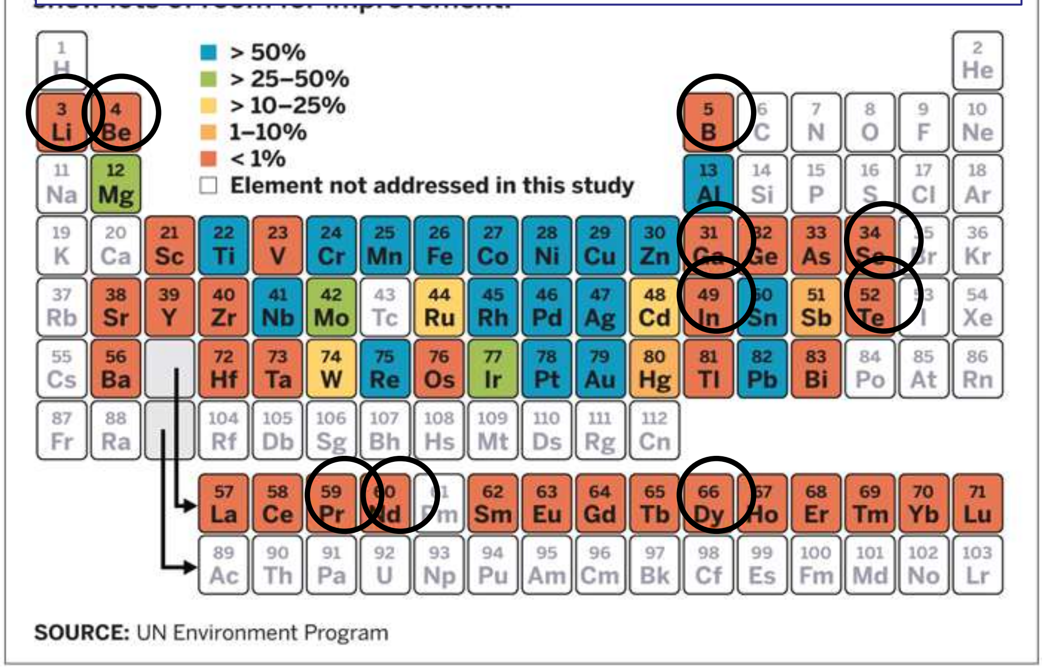


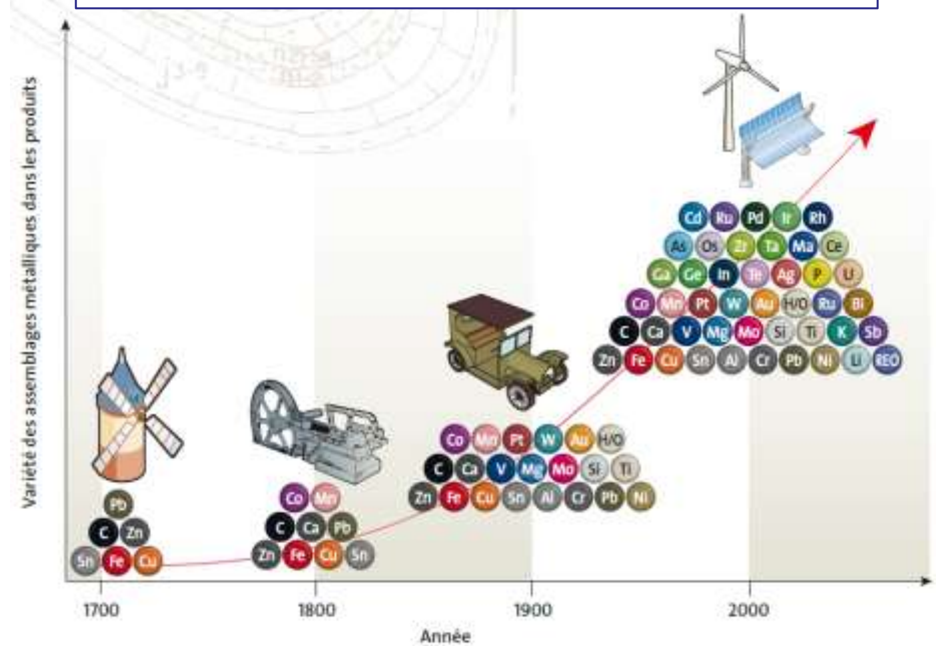
Figure 6. Proportions of individual REE in two representative ores: bastnäsite, dominated by La, Ce, and Nd, with Eu through Lu plus Y totaling only 0.4%; and lateritic ion-adsorption ore, Y-dominated. Dark blue and light blue sectors represent lanthanides of even and odd atomic number, respectively (see figs. 2, 3). Yttrium is indicated by green.

Additional issue: « rare » metals used in the high tech sector)(including clean energy) are not recycled yet

Reuse stats: Global postconsumer recycling rates
(UN Environment Program 2011)

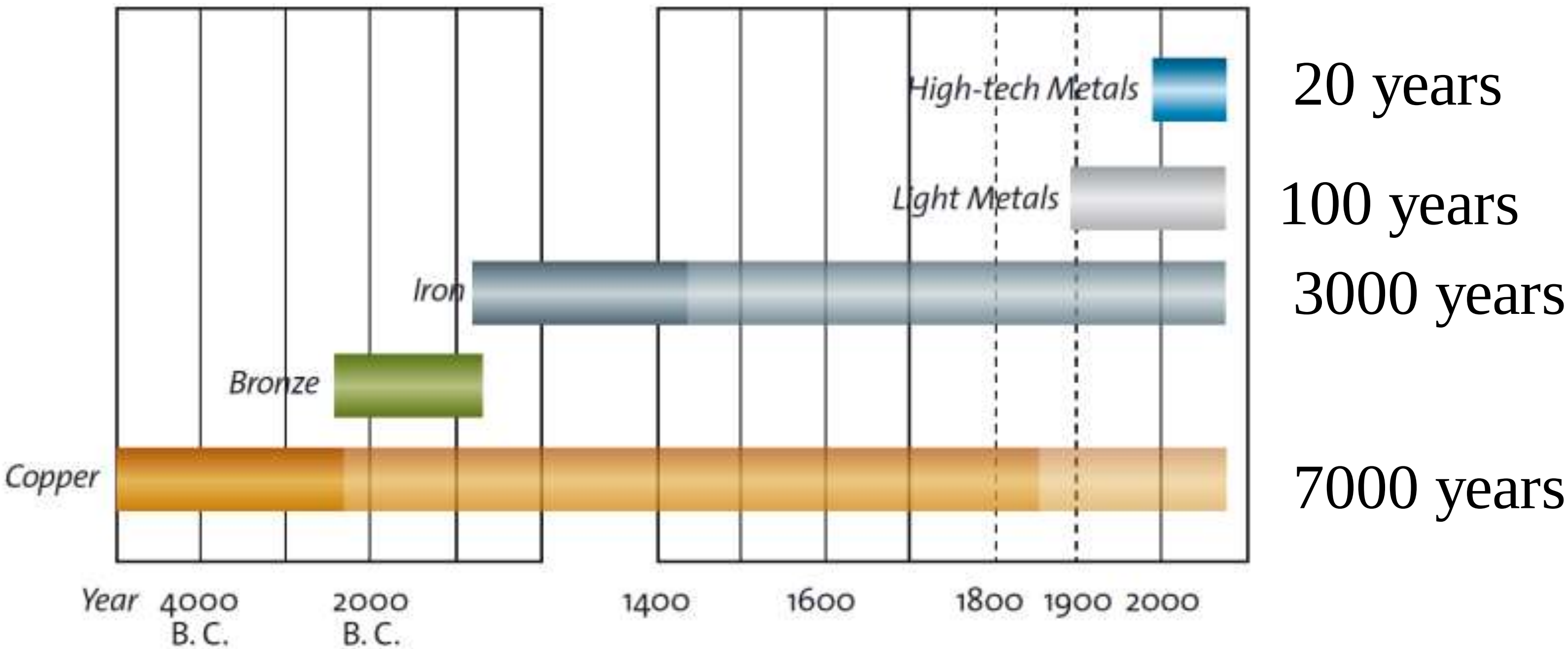


The increase in the complexity of metal assemblages in generic products *(Van Schalk and Reuter, 2012; adapted from Achzel and Reller)*



Our knowledge of the resources/reserves of mineral commodities used in the High-tech sectot is limited and their rate of recycling is very low.

The environnemental cost associated with their production is poorly known, and is never included in the life cycle analyses of infrastructures for renewable energy



Timeline depicting the use of metals from prehistoric to modern times in Central Europe. From Wellmer and Steinbach, 2011.

The classical view

1) **Base metals, glass and concrete**

Large volumes to be produced, but reserves and resources are "large"

High recycling potential

1) **High-tech metals**

Limited potential of recycling yet

Poor knowledge of resources/reserves

Production limited to few countries

The classical view

1) **Base metals, glass and concrete.**
   Large volumes to be produced, but “large” reserves and resources
   High recycling potential

1) **High-tech metals**
   Limited possibilities of recycling yet
   Poor knowledge of resources/reserves
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Risk assessment: the concept of criticality

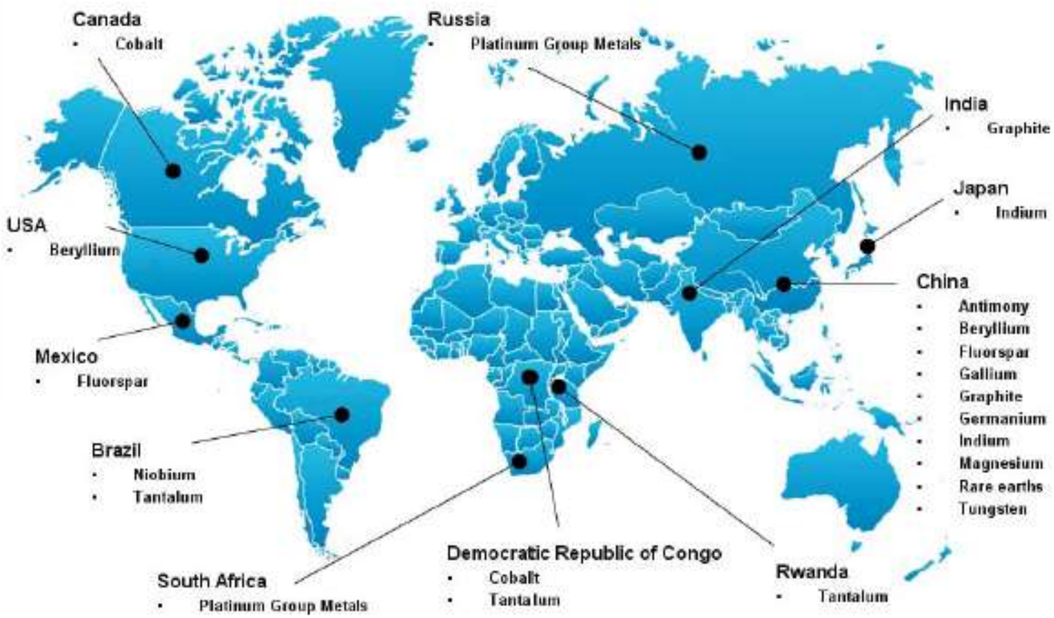
List of critical raw materials for the European Union

the EU is dependent on the importation of most metals, as its domestic production is limited to about 3% of world production.

- Antimony
- Beryllium
- Cobalt
- Fluorspar
- Gallium
- Germanium
- Graphite
- Indium
- Magnesium
- Niobium
- PGMs (Platinum Group Metals)
- Rare earths
- Tantalum
- Tungsten

+Borates
+Chromium
+Coaking coal
+Fluorspar
+Lithium
+Phosphate Rock
+Silicon Metal
(2014)

Production concentration of critical raw mineral materials



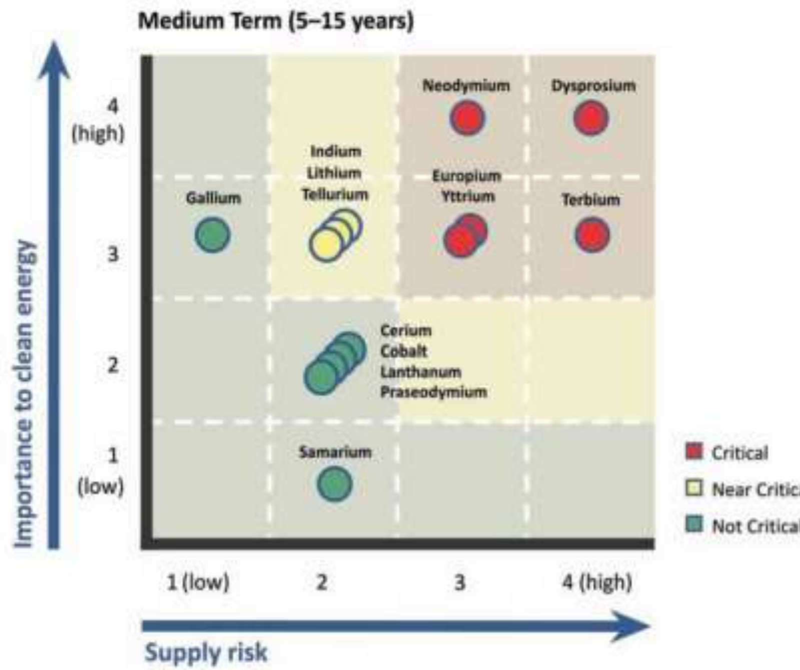
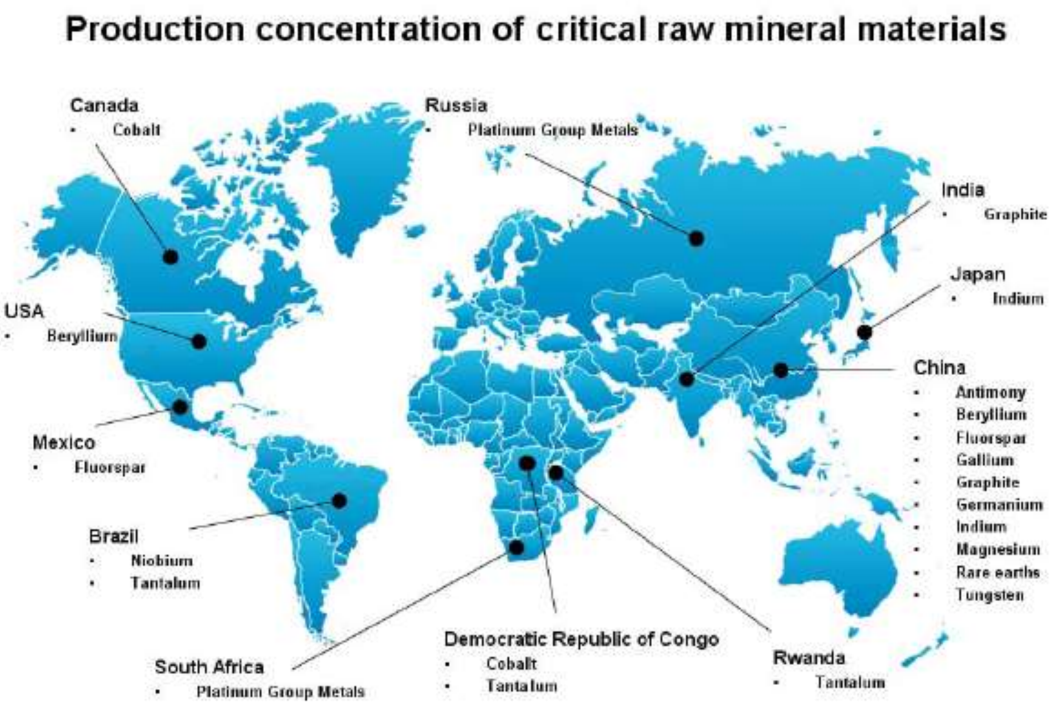


Figure ES-2. Medium-term criticality matrix the EU is dependent on the importation of most metals, as its domestic production is limited to about 3% of world production.

UE dependency to importation. In red: mineral commodities for which China is the main producer. Sources (2009): USGS, BRGM, PGI, WMD



Critical raw material	% Supply	Critical raw material	% Supply
Antimony	93%	Magnesite	86%
Beryllium	99%	Magnesium	96%
Borates	88%	Natural Graphite	93%
Chromium	88%	Niobium	99%
Cobalt	82%	PGMs	93%
Coking Coal	94%	Phosphate Rock	66%
Fluorspar	84%	REE (Heavy)	100%
Gallium	90%	REE (Light)	100%
Germanium	94%	Silicon Metal	79%
Indium	81%	Tungsten	91%
Lithium	83%	**Total**	**90%**

The classical view

1) **Base metals, glass and concrete.**

Large volumes to be produced, but “large” reserves and resources

High recycling potential

Not critical

1) **High-tech metals**

Limited possibilities of recycling yet

Poor knowledge of resources/reserves

Production limited to few countries

Critical

Short to middle terme vision (industry)

However,

1) **Base metals, glass and concrete.**

“Large” reserves and resources **but the concentrated and easily accessible ores are declining**

High recycling potential **(after 2050)**

No possible substitution

Not ? Critical

1) **High-tech metals**

Limited possibilities of recycling yet

Poor knowledge of resources/reserves

Production limited to few countries

Technology-dependant

Critical

Not only a matter of feasibility, but also of **energy intensity, environmental and social impact of production**

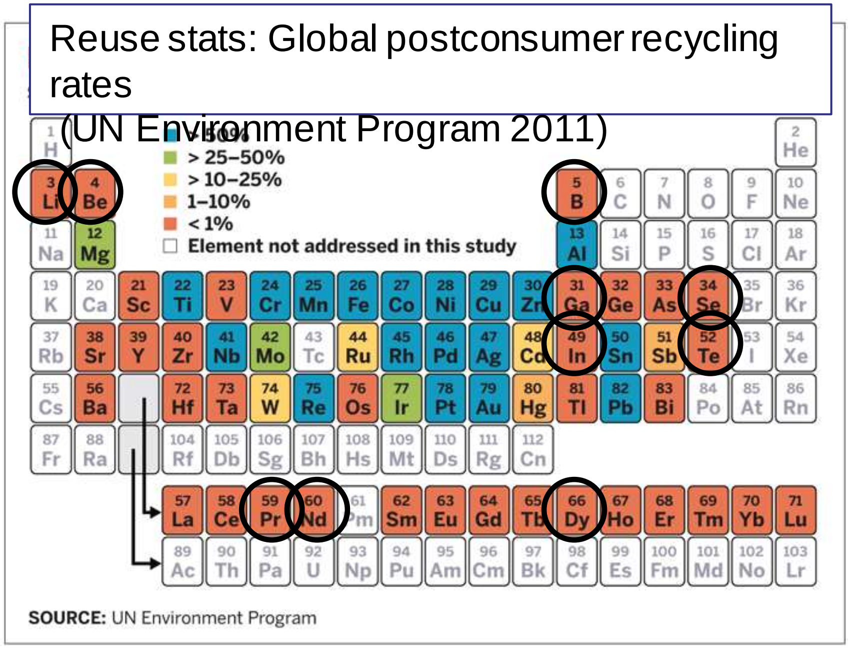
The transition toward a low-carbon society requires

- The availability of a variety of metals and other mineral resources
- Fossil energy to produce these raw materials

We are replacing one fossil resource (hydrocarbons) by another (metals), and increasing the consumption of energy and GHG emission

This is acceptable if there is a significant decrease of CO_2 production after a reasonable period of time, **and if metals are recycled**

Reuse stats: Global postconsumer recycling rates
(UN Environment Program 2011)



Improving recycling (rate, energy consomption) is mandatory

The transition toward a low-carbon society requires

- The primary production of a variety of metals and other mineral resources
- Fossil energy to produce these raw materials

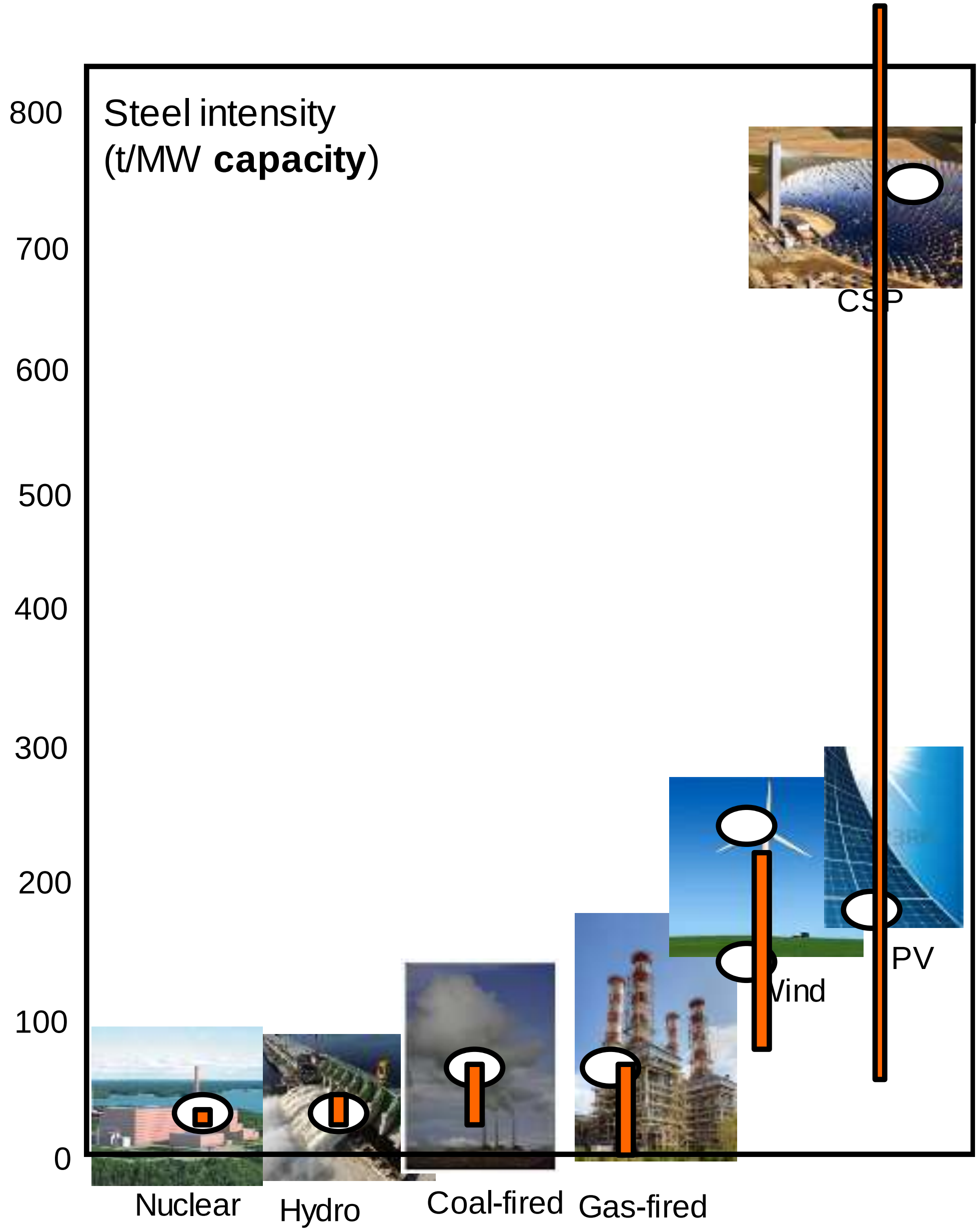
We are replacing one fossil resource (hydrocarbons) by another (metals), and increasing the consumption of energy and GHG emission

This is acceptable if there is a **significant decrease of CO_2 production and fossil energy consumption after a reasonable period of time**, and if metals are recycled

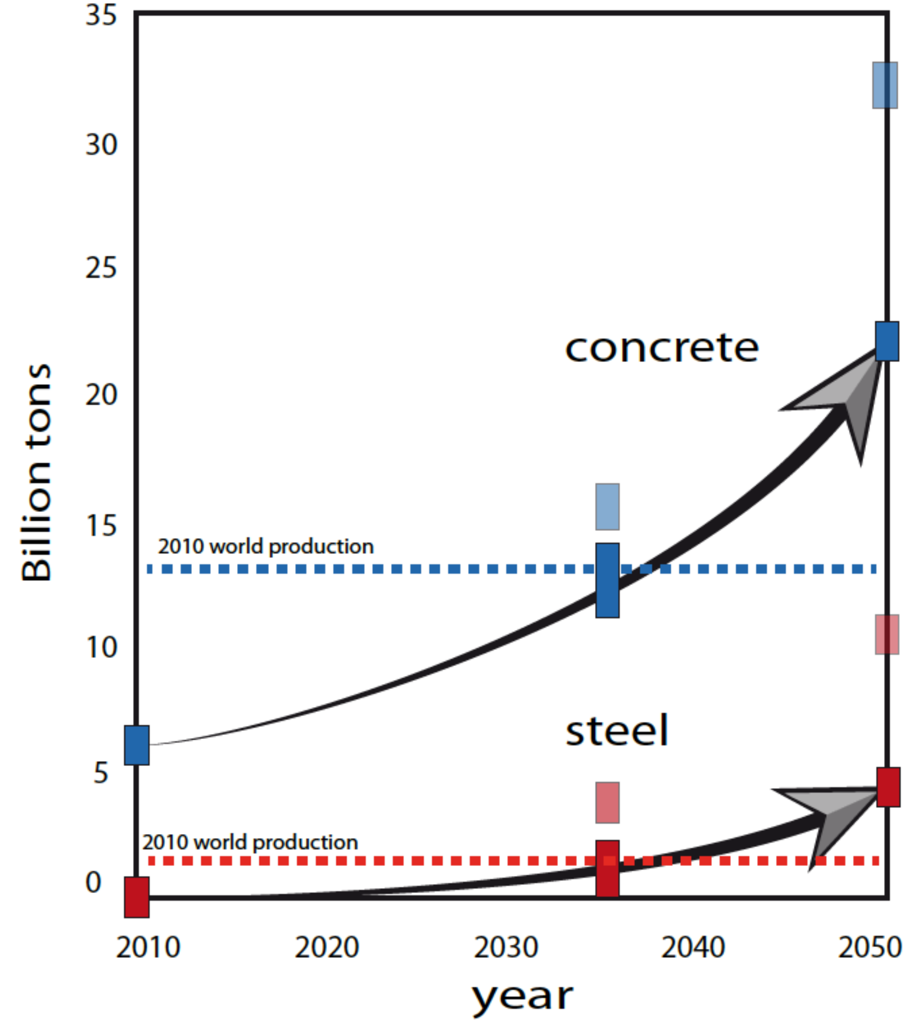
Comprehensive and « precise » estimates are necessary to define the best scenario

Difficulties: 1) access to the data (comprehensive material content), 2) no inter-consistency and **huge** uncertainties, 3) technologies in fast development,

Uncertainty in material content



Vidal et al., 2013



Uncertainty in energy intensity

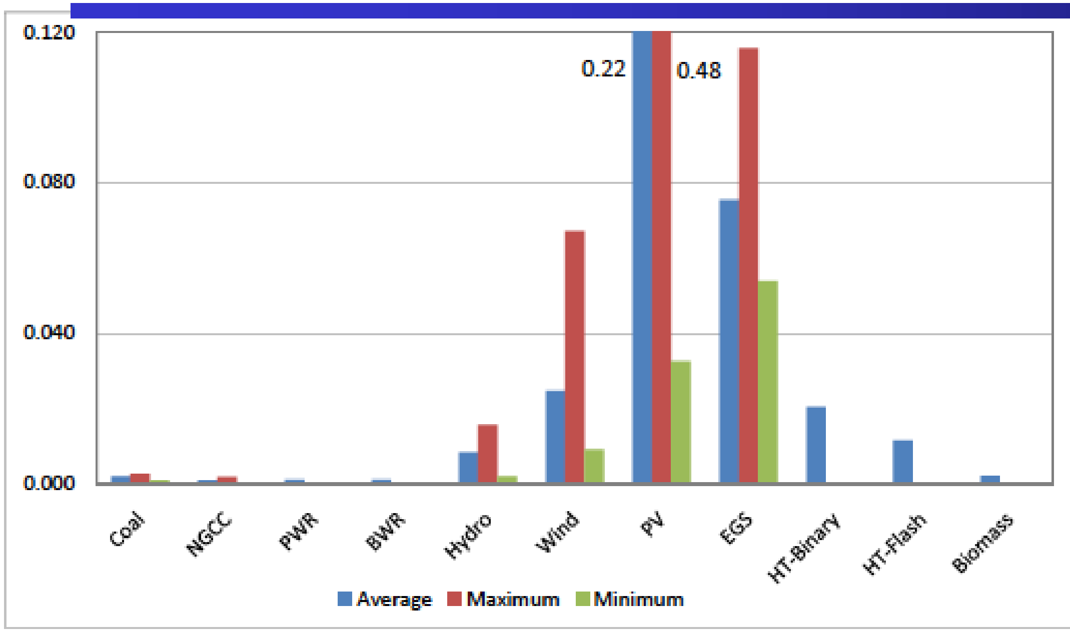


FIGURE 9 E_{pc}/E_{out} Values for the Power-Generating Technologies Covered as Determined from GREET

$$E_{in}/E_{out}$$

3 to 50% !!!

Souce: Sullivan et al. (2010): Life-Cycle Analysis Results of Geothermal Systems in Comparison to Other Power Systems. Argonne National Laboratory

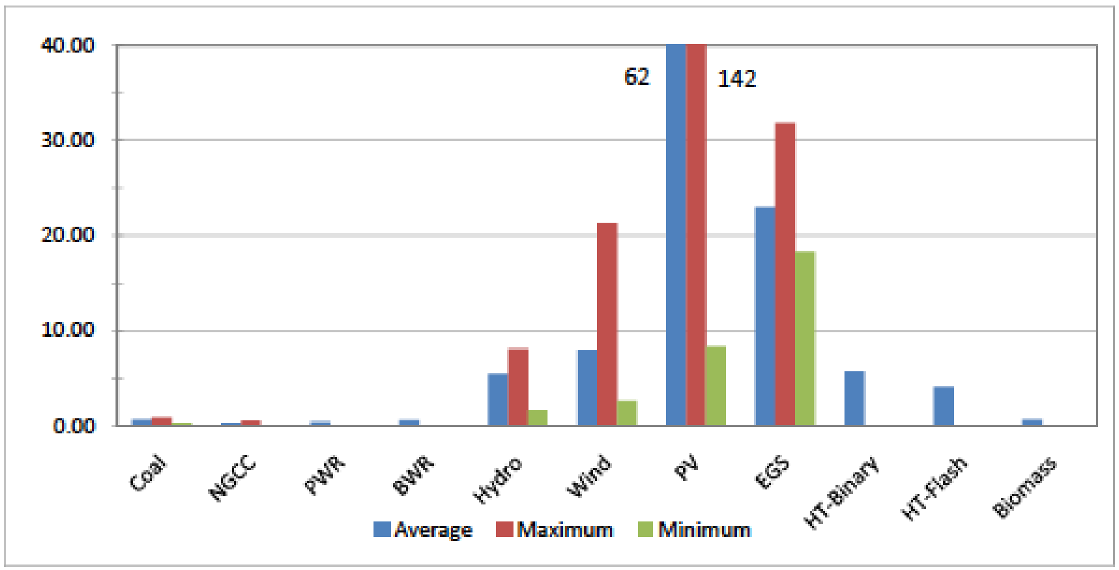


FIGURE 10 GHG_{pc}/E_{out} in g of CO_2eq per kWh for the Power-Generation Technologies Addressed as Determined from GREET

Production of Greenhouse gas
7 to 140 g eq CO2/Wh !!!!

Uncertainty in energy intensity

Impact of producing 12,3 kg of steel tailored welded blank for the automative industry

		Energy (MJ)	CO2-equiv. (kg)
Manufacturing	Material	553,7	43,1
	Transport	3,7	0,27
	Assembly	11,7	0,5
	Processing	42,1	1,79
Sum without recycling		611,2	45,66
Recycling credit		-234,5	-25,5
Sum with recycling		376,7	20,16

' http://www.eaa.net/upl/4/en/doc/EAA_Environmental_profile_report_May08.pdf

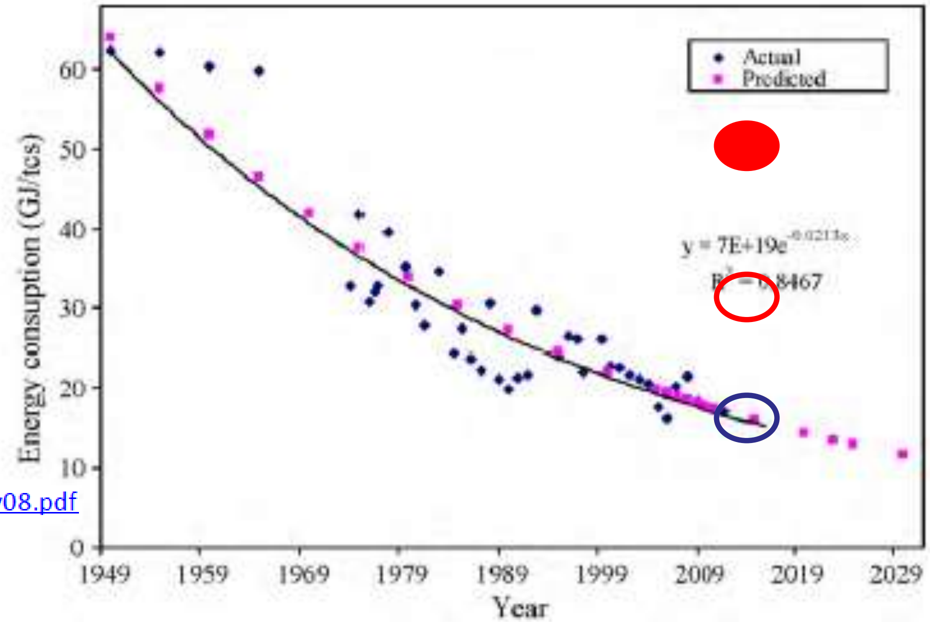


Fig. 5. Actual and projected specific energy consumption in the steel industry (world average).

Mohan Yellishetty[a,*], P.G. Ranjith[a], A. Tharumarajah[b]

Resources, Conservation and Recycling 54 (2010) 1084–1094

20 or 50 MJ/kg ?

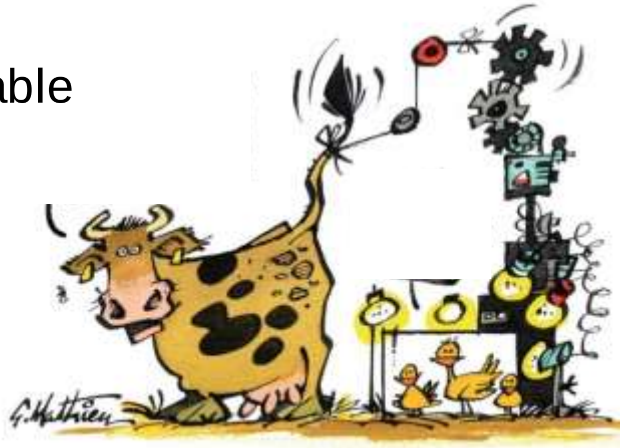
Conclusions

The shift to renewable energy will need huge amounts of minerals, metals and fossil energy. The lifetime of solar and wind facilities is about 30 years, during which recycling won't be possible, and primary resources will have to be extracted to build the infrastructures of clean energy

A precise and comprehensive evaluation of the energy and RM requirement in the energy scenarios is necessary

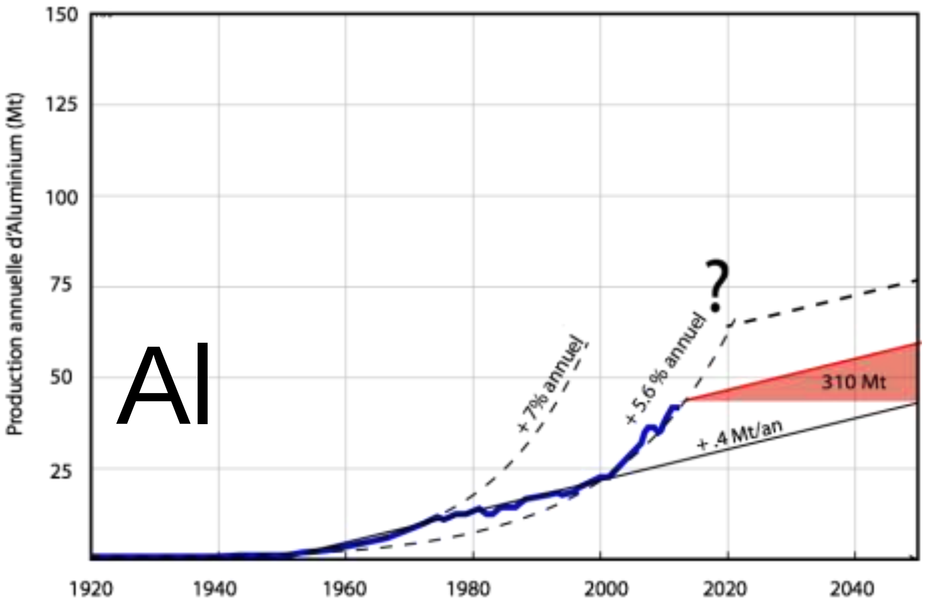
A clear definition of the criteria to be minimized (e.g. CO_2 generation, cost of electricity, type of energy generation, national dependency, etc) is also necessary

- Avoid developing unsustainable technologies (and gadgets) decoupled from the reality of raw materials supply,
- Optimize the ratio efficiency/materials requirement of renewable energy infrastructures and their design to facilitate recycling,
- Quantify the impact of novel technologies prior to their large scale industrial implementation
- Find new resources and improve the efficiency of metal extraction and refining



Thank you for your attention

Which technology ?

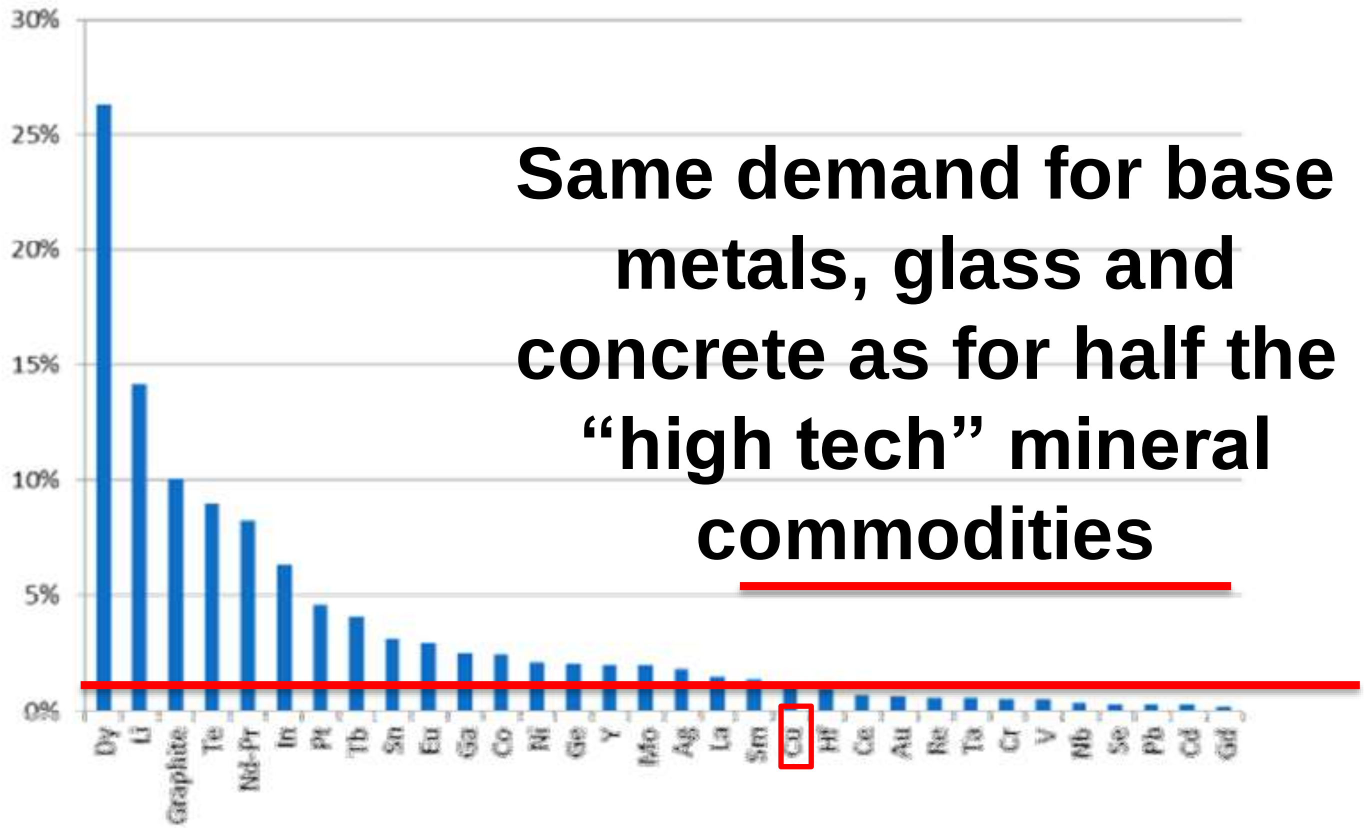


Werner (2010):
if CSP with 34.5% of Al frames and PV with12% Al (current guesstimate from an industry source), 460.10^{6}t Al should be produced by 2050 =150% of what we have estimated using the material requirement of other technologies that use more steel

CIGS PV panels are more efficient than Si PV panels
Wind turbines with a permanent magnet (REE) are more efficient than those with a gear box (No REE)

More or less consumed energy and GHG emission in 2050 ?
The energy scenarios should consider this kind of questions

Figure 40: Annual EU metals demand from decarbonisation technologies, % of expected supply 2020-2030



Same demand for base metals, glass and concrete as for half the "high tech" mineral commodities

Yearly growth rate in Al, Fe, glass, concrete

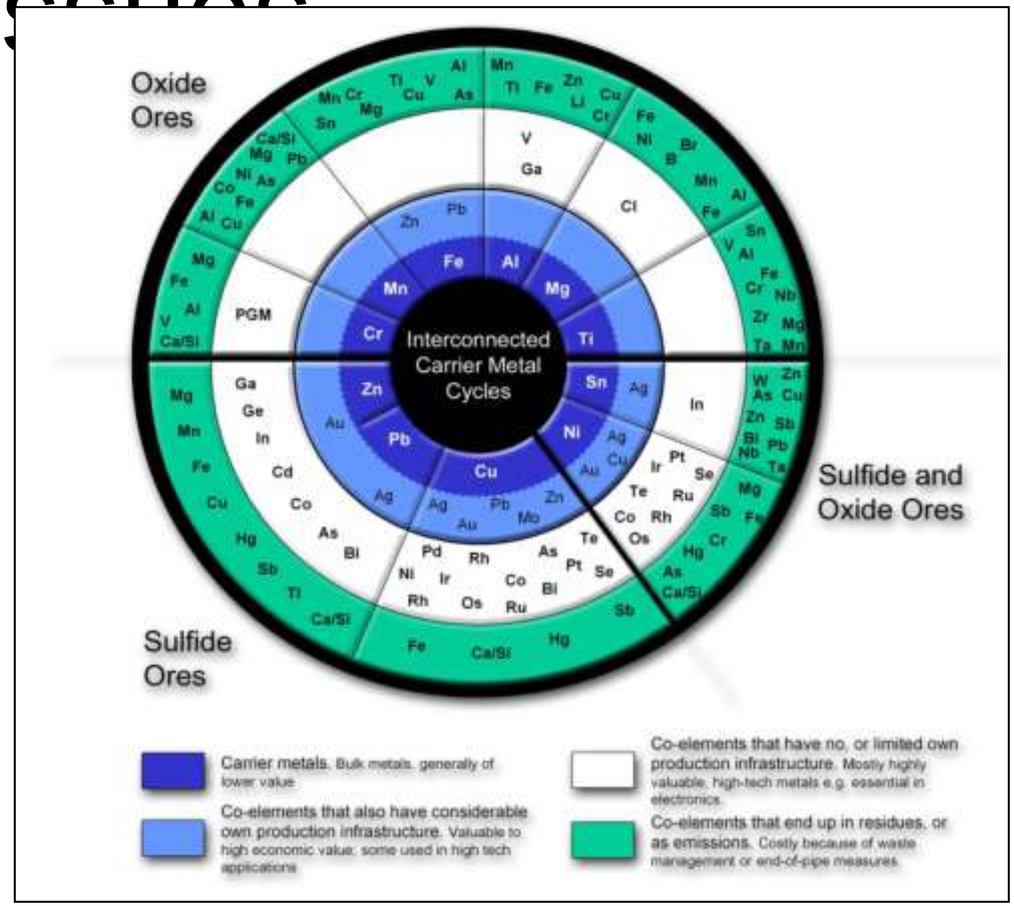
Critical Metals in the Path towards the Decarbonisation of the EU Energy Sector

Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies

JRC SCIENTIFIC AND POLICY REPORTS

European Commission

Base and rare metals: Two different … but to some extend connected issues



Several of the materials identified as critical are by-products of base metals (Co, Ga, Ge, In, and REEs and PGMs to some extent).

-> there are significant quantities of by-product metals not currently being recovered (economical, technical and geological reasons)

SEVENTH FRAMEWORK PROGRAMME

ERA·MIN

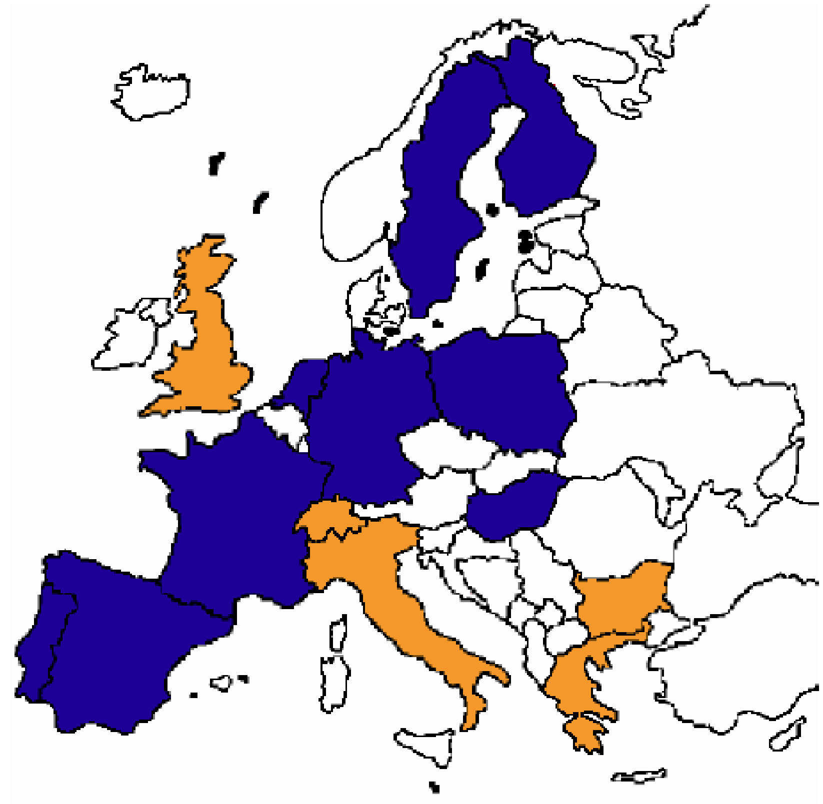
NETWORK ON THE INDUSTRIAL HANDLING
OF RAW MATERIALS FOR EUROPEAN INDUSTRIES

2011-2015

Olivier Vidal, CNRS,
olivier.vidal@ujf-grenoble.fr

The ERA-MIN network: 15 partners (funding agencies, ministries) from 14 European countries

Finland	- TEKES
France	- CNRS and Ademe
Germany	- BMBF and Juelich
Hungary	- MBFH
Netherlands	- M2i
Poland	- NCBiR
Portugal	- FCT
Spain	- CDTI
Sweden	- VINNOVA, SGU



Greece, Turkey, Bulgaria, Italy, UK

E R A·M I N

NETWORK ON THE INDUSTRIAL HANDLING OF RAW MATERIALS FOR EUROPEAN INDUSTRIES

Background of ERA-MIN - objectives

To foster research in the industrial production and supply of mineral products, in line with the "*EU Raw Materials Initiative*".

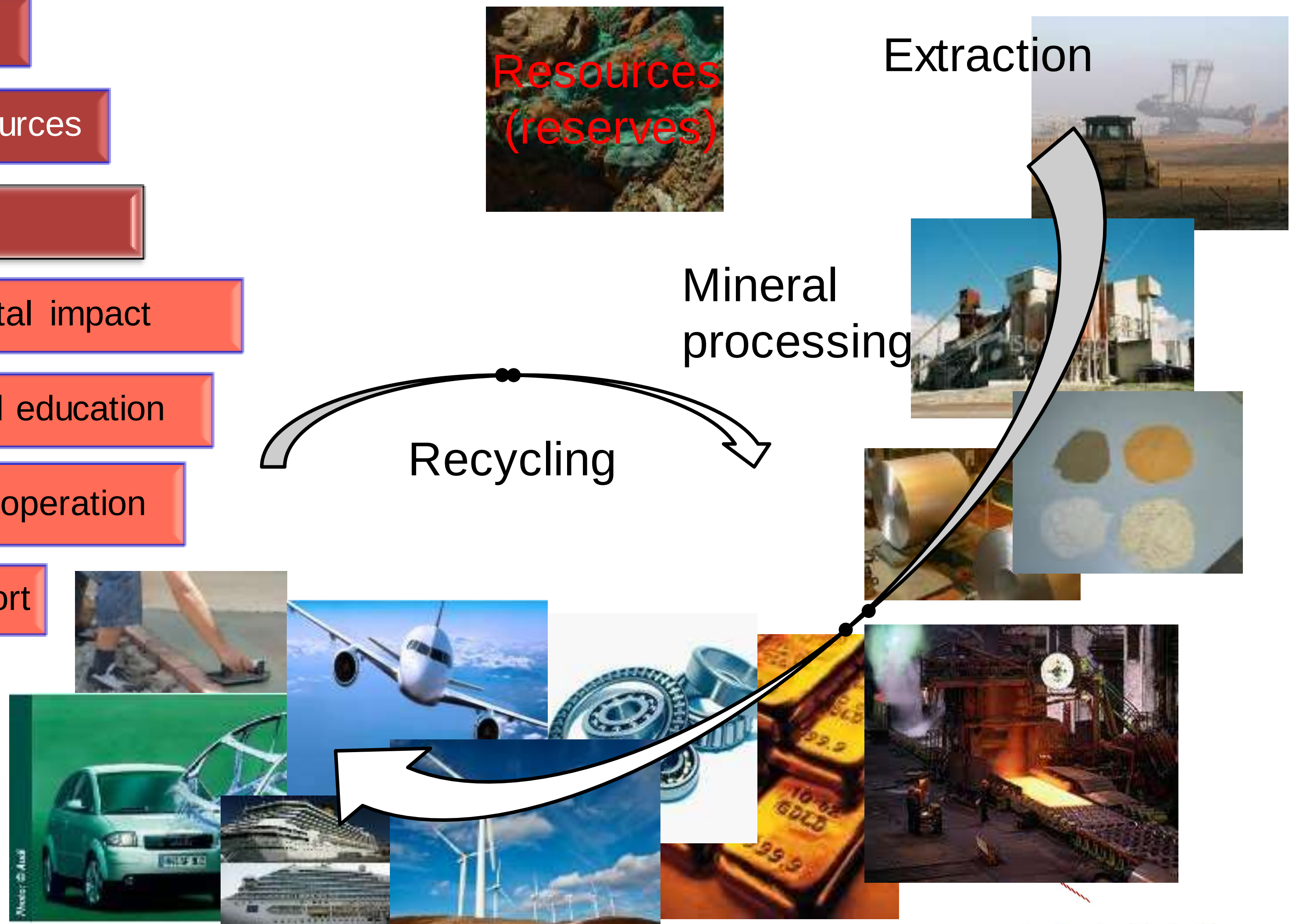
By creating networks between:

- national research programmes (to reduce fragmentation and duplication)
- European industry, research, education and policy-makers
- all segments of the raw materials cycle (exploration, mining, recycling, substitution, remediation)

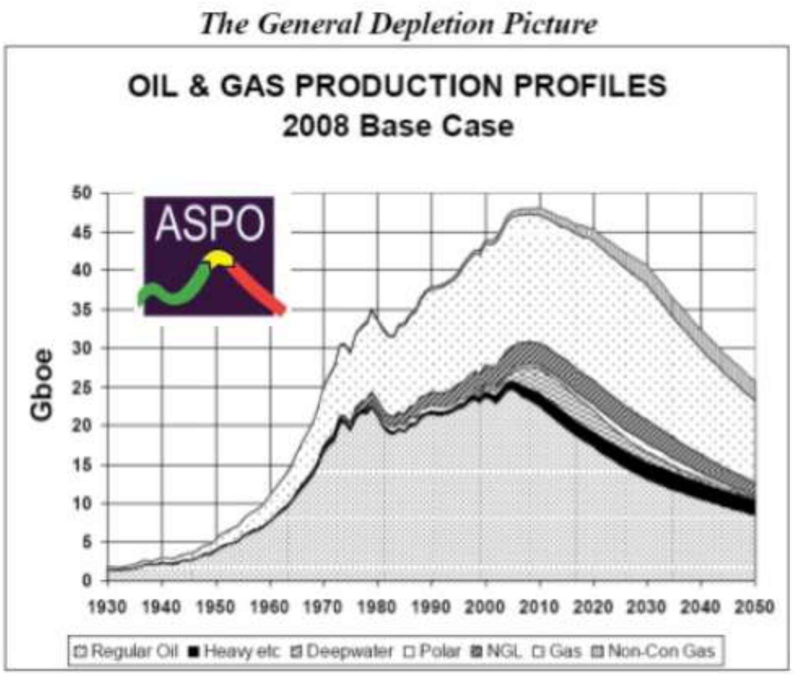
The ERA-MIN topics

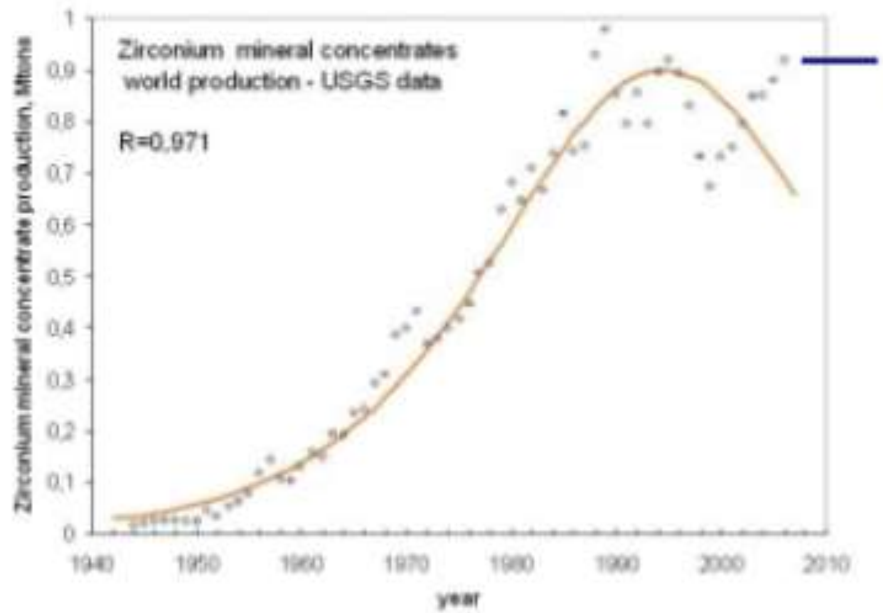
cover the entire raw materials value chain including exploration, mining, processing, substitution & recycling, and cross-cutting issues

- Primary resources
- Secondary resources
- Substitution
- Environmental impact
- Teaching and education
- International cooperation
- Public policy support

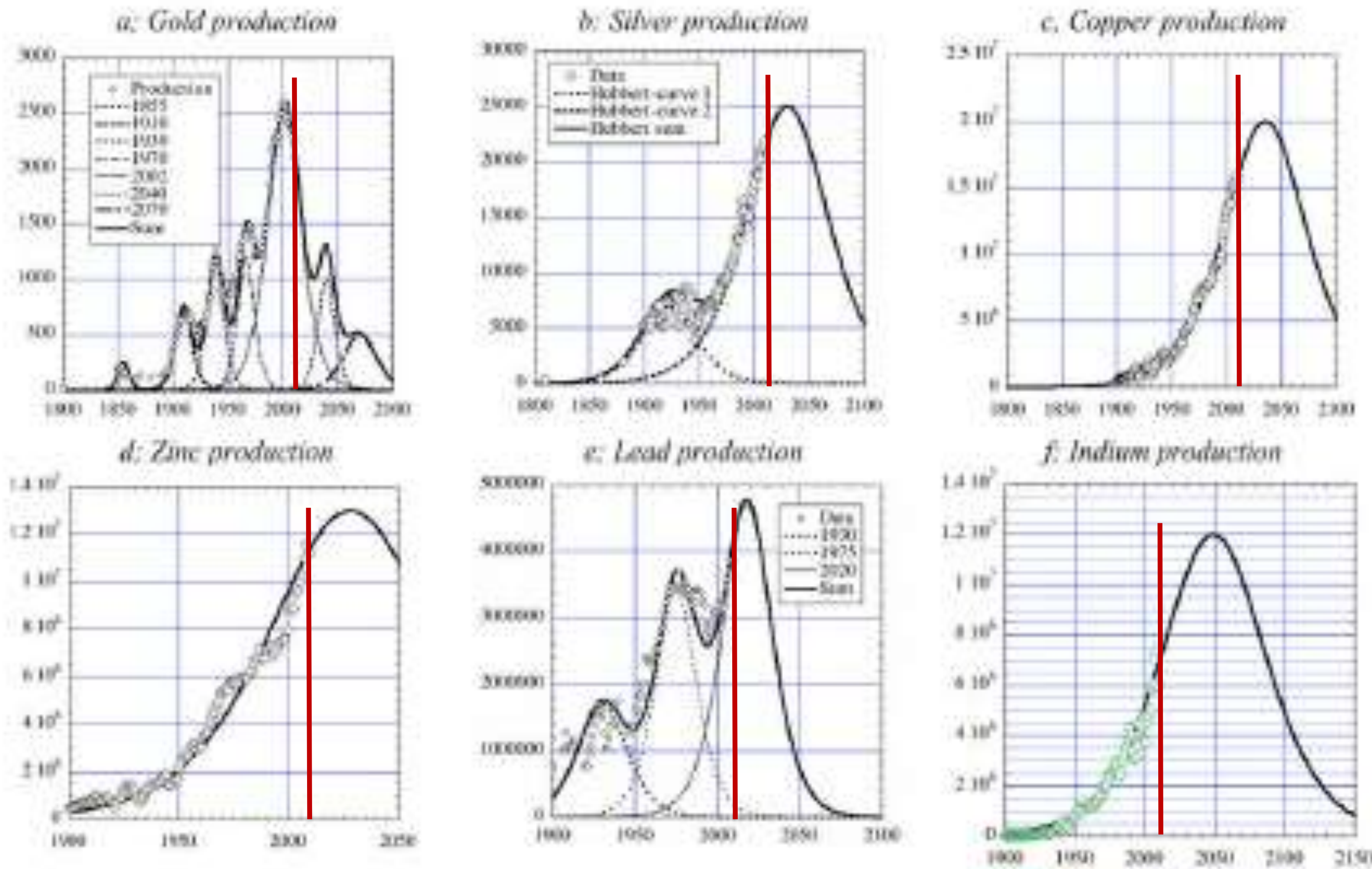


Par exemple, sur la base des méthodologies d'évaluation des réserves développées pour le pétrole (Hubberts, 1966) , Harald Sverdrup propose un 'peak' matière première

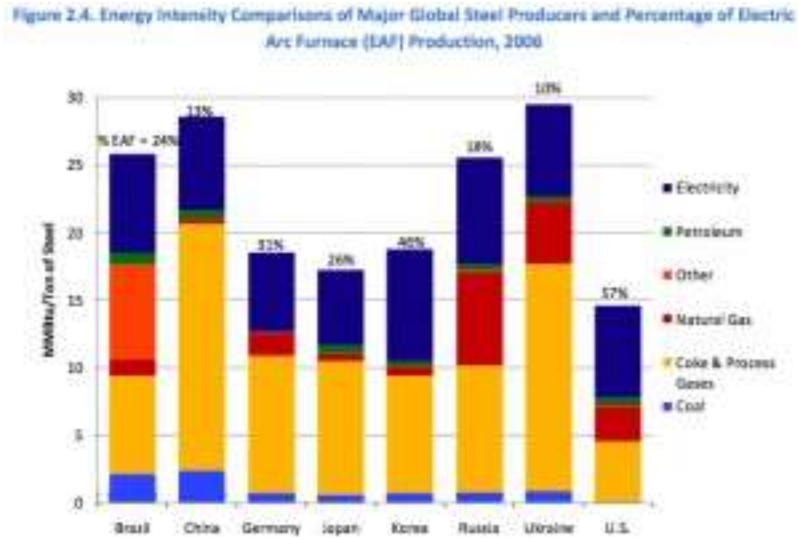




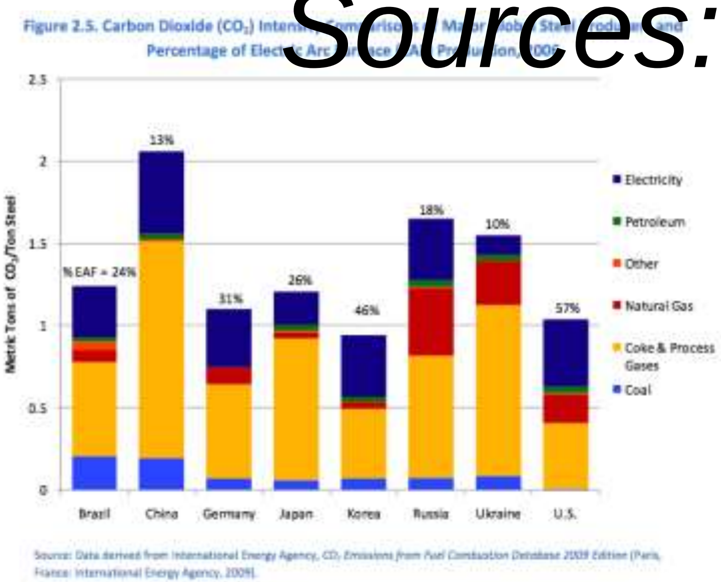
Source: Bardi en Pagali, 2007



Methodologie criticable ?



Sources: DO



STAGE	CONSUMPT.	UNITS
perforation	1.8	MJ/t
blasting	3.06	MJ/t
loading	6.66	MJ/t
transport to treatment	53.66	MJ/t.km
primary crushing	0.83	MJ/t
coarse screening	0.036	MJ/t
secondary crushing	2.2	MJ/t
grinding	69.66	MJ/t
magnetic separation	3.6	MJ/t
fines screeening	0.72	MJ/t
agglomeration	1,500	MJ/t
transport to port (railway)	0.18	MJ/t.km
transport to mkt (ship)	0.003	MJ/t.km

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