Mineral resources availability & recycling limits : A constraint for ambitious & sustainable energy scenarios

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Les Houches
March 9th, 2016

Agenda

What means a sustainable scenario?

Interaction between energy and resources

Recycling limits

Takeaways for any (ambitious) deployment scenario

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What means a ‘sustainable’ energy scenario ?

We can achieve, sufficiently rapidly, a ‘climate friendly’ energy mix

We should (try to) avoid that this new mix has other bad environmental consequences

e.g. pollution, biodiversity loss

We can maintain this mix / system for a ‘certain’ duration

‘Long term’ : One or two generations, 21st century, more ?

Main ‘mistakes’ of current studies

Several studies conclude that there is no constraint on resources
- **Wind Water Sun (Stanford)**
- **Future of Solar energy (MIT)…**

However they have (generally) strong methodological limits…

… on materials considered :
- **e.g. lithium only, not cobalt, for batteries**

… on scope :
- **devices or devices + subsystems + grids**
- **need for other ‘technical macrosystems’ (metal / chemical industries)**
- **other markets demand**

… on geological production capabilities, vs. costs and energy

Let’s assume ‘a first deployment’ is feasible : we must then maintain it
- **Additional new resources, and/or**
- **Partial / total recyclability of installed systems**

Agenda

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Resources :
How critical / close may be the problem ?

\+ -

Which risk on the availability in the mid term ?

Visibility on reserves

Concentration of production

Demand's growth

Substitution

Recycling rate

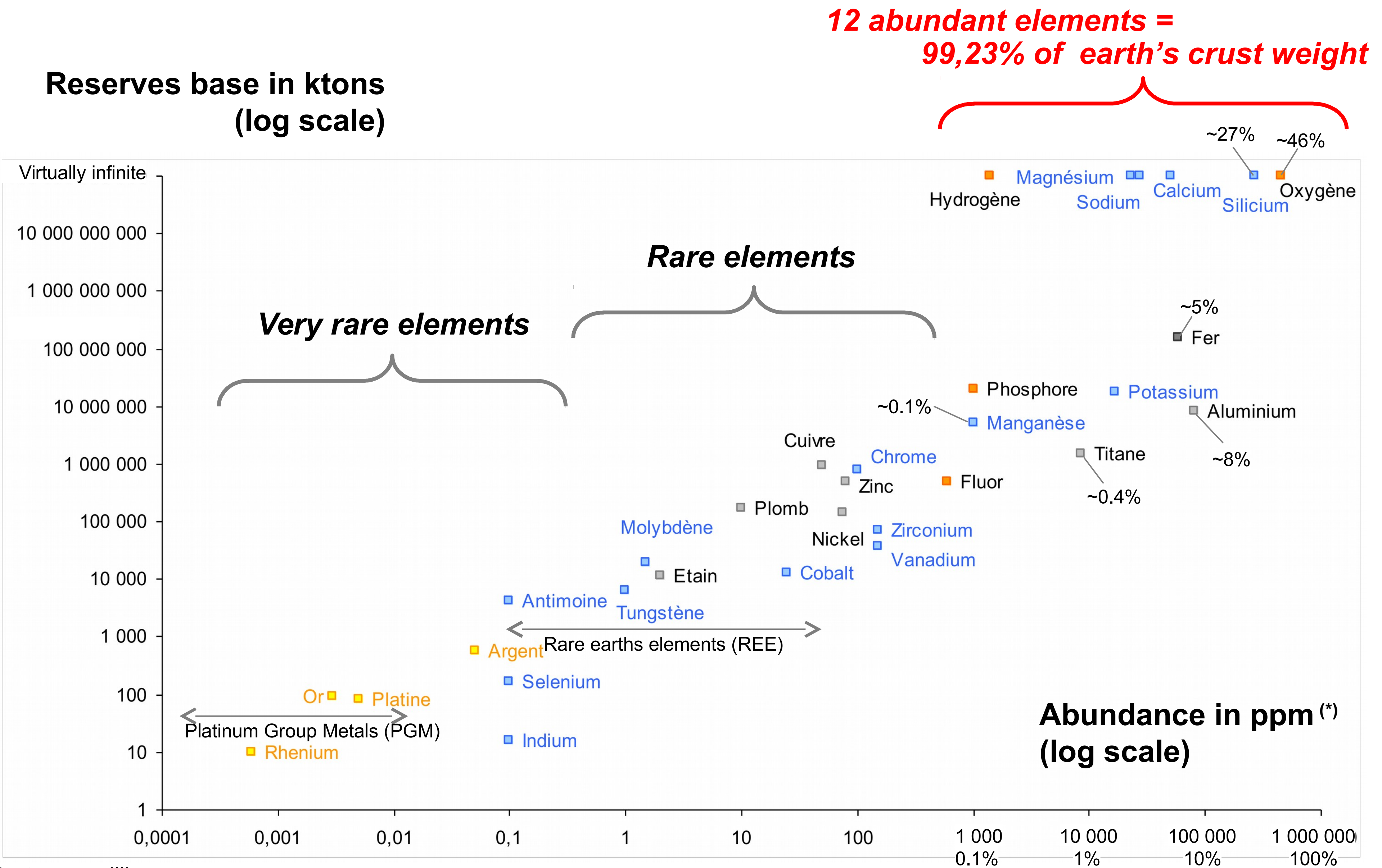
Which impact ?

Economical impact (Macro / Micro)

Risk on supply chain

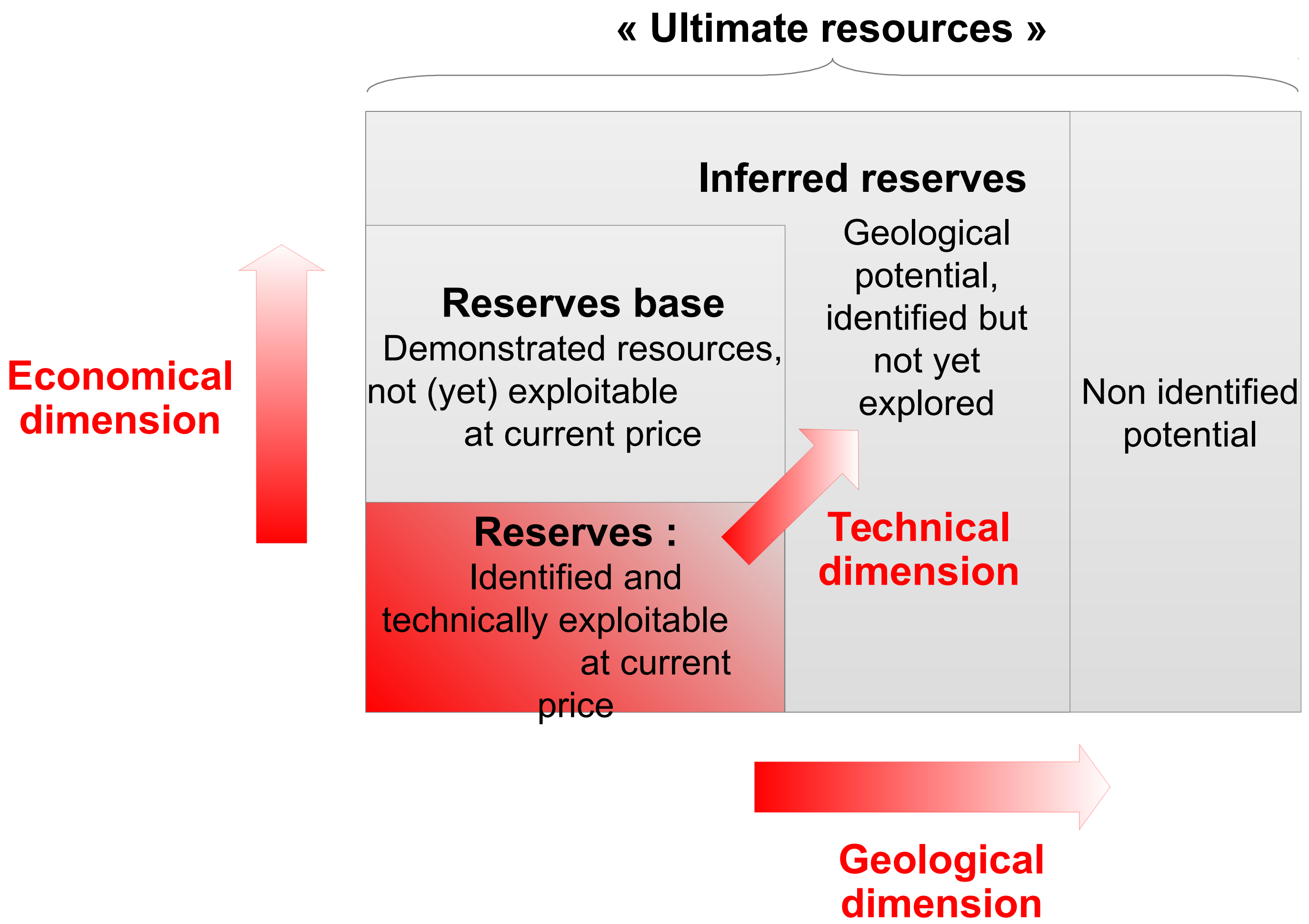
Deployment of innovations

Mineral resources : our playing field

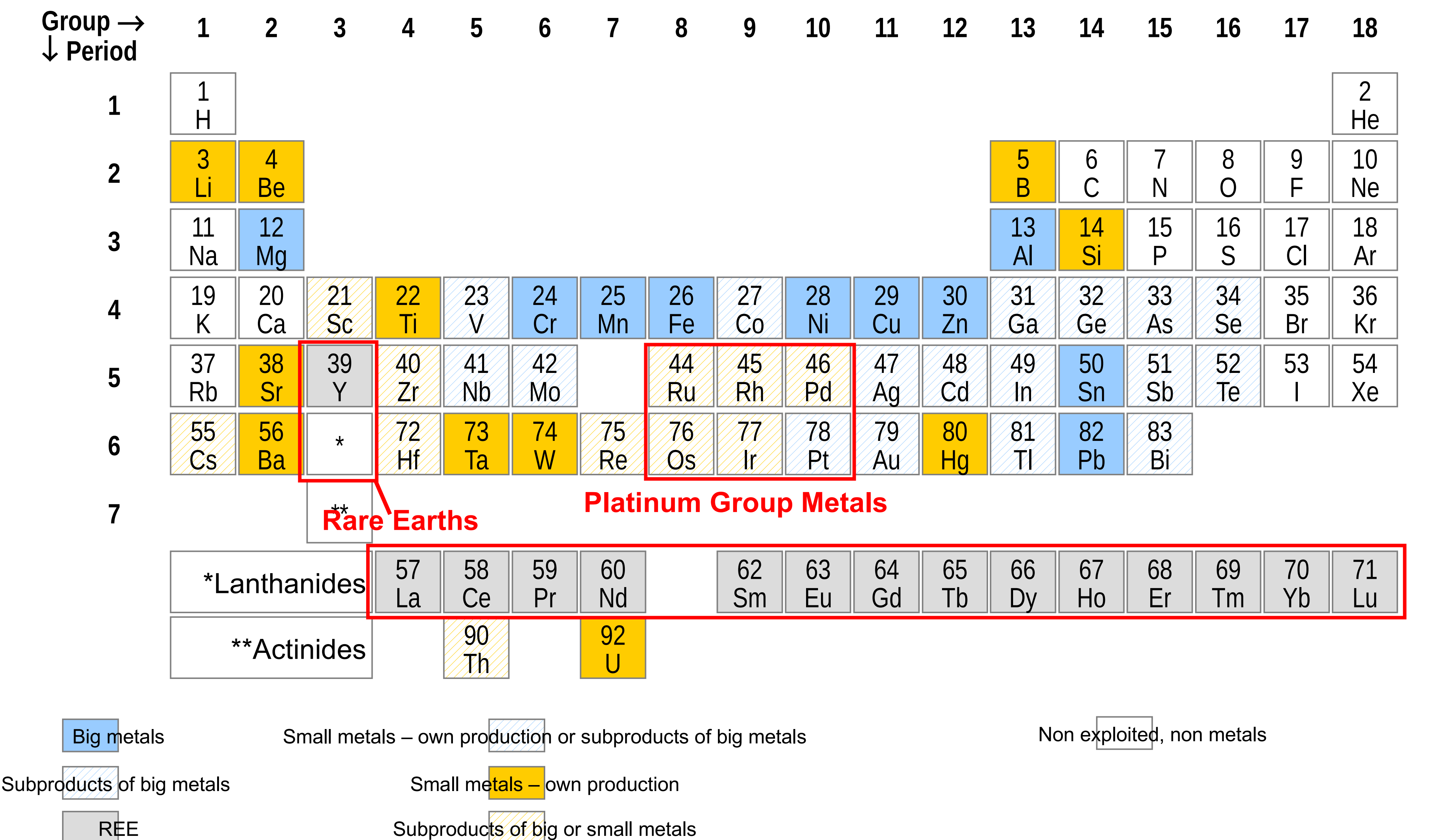


(*) Parts per million
Sources : BRGM, USGS 2007

Reserves or resources : no geological limit



By the way, not so easy to assess reserves…



Interaction between energy and metals

Less and less concentrated minerals

Extraction of materials requiring more energy

Energy production requiring more materials

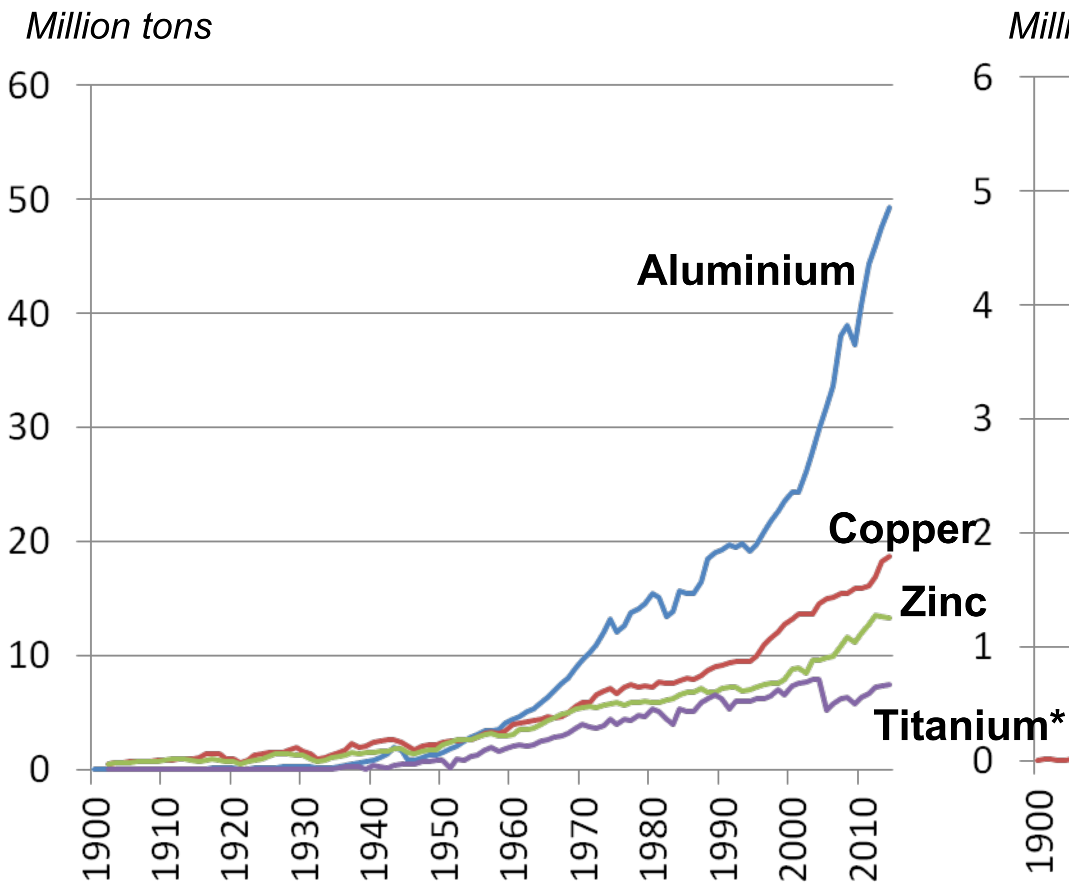
Less and less accessible energy

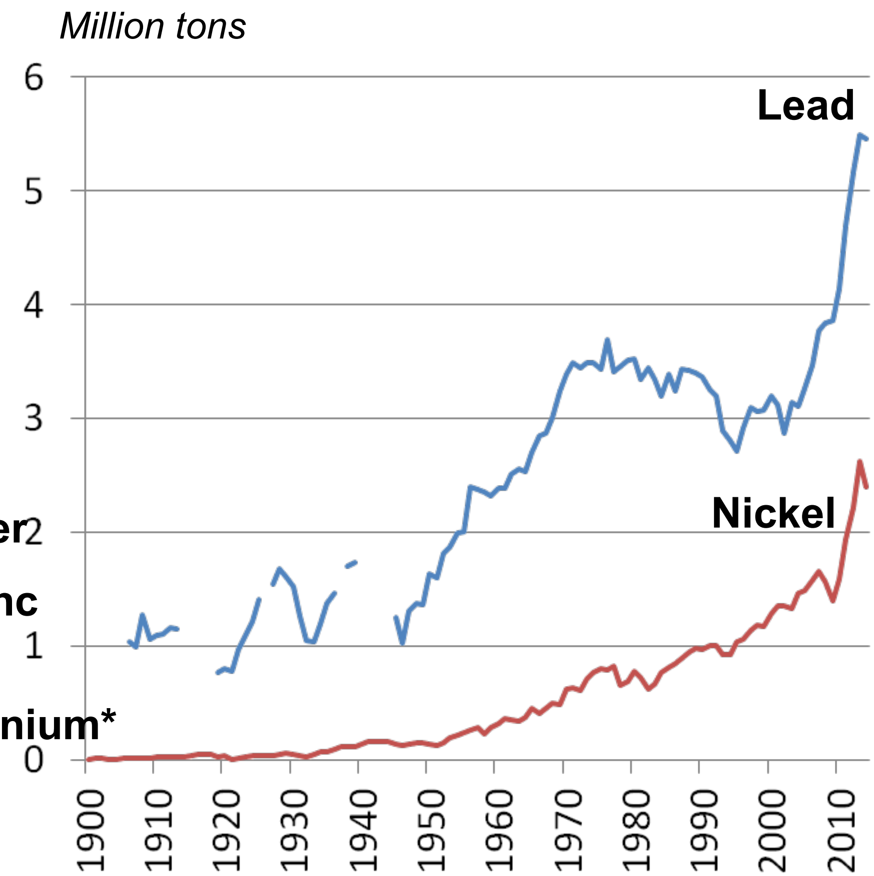
Some metals required by “new energies”

Group → / ↓ Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo		44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi			
7			**															
	*Lanthanides (Terres rares)			57 La	58 Ce	59 Pr	60 Nd		62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
	**Actinides				90 Th		92 U											

World consumption : industrial metals

World production1900 – 2014e

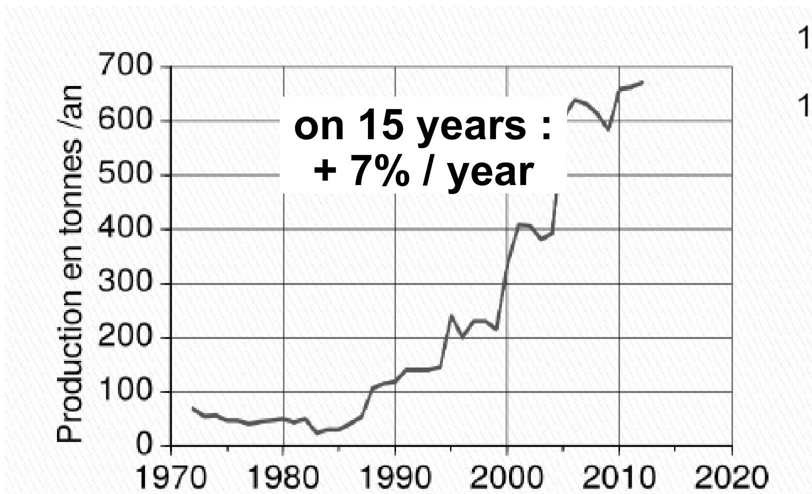




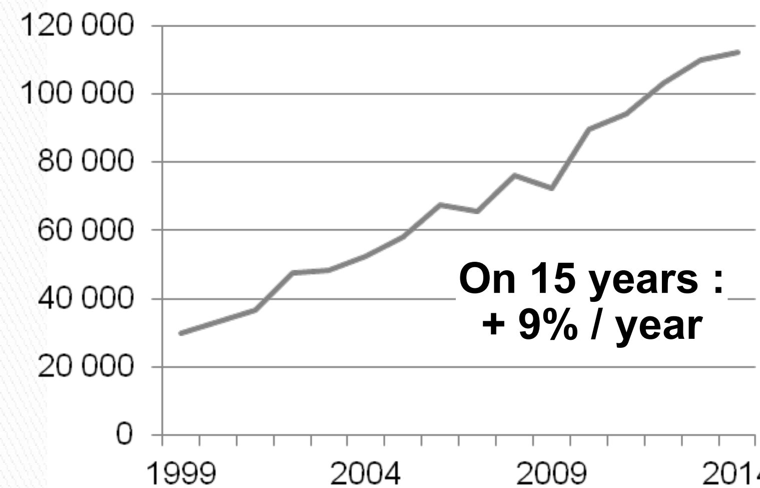
ces : USGS
* : Titane concentrates (ilménite / ruménite)

World consumption : specialty metals

Indium production



Cobalt production



52 Te

n memories, solar PV…

32 Ge

Wifi…

65 Tb

63 Eu

Compact fluorescent lamps…

49 In

Flat screens…

73 Ta

Micro capacitors…

Hard disks…

44 Ru

66 Dy

60 Nd

57 La

Offshore wind, hybrid cars…

Batteries…

27 Co

3 Li

31 Ga

LED…

rces : USGS

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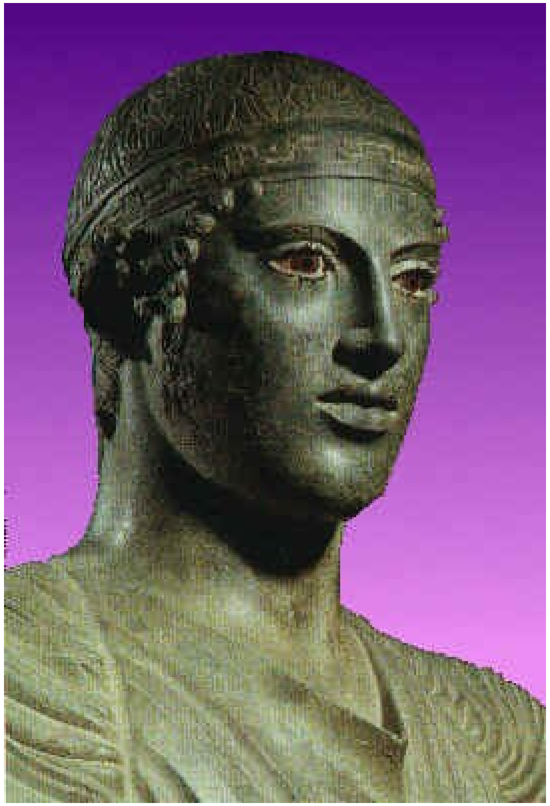
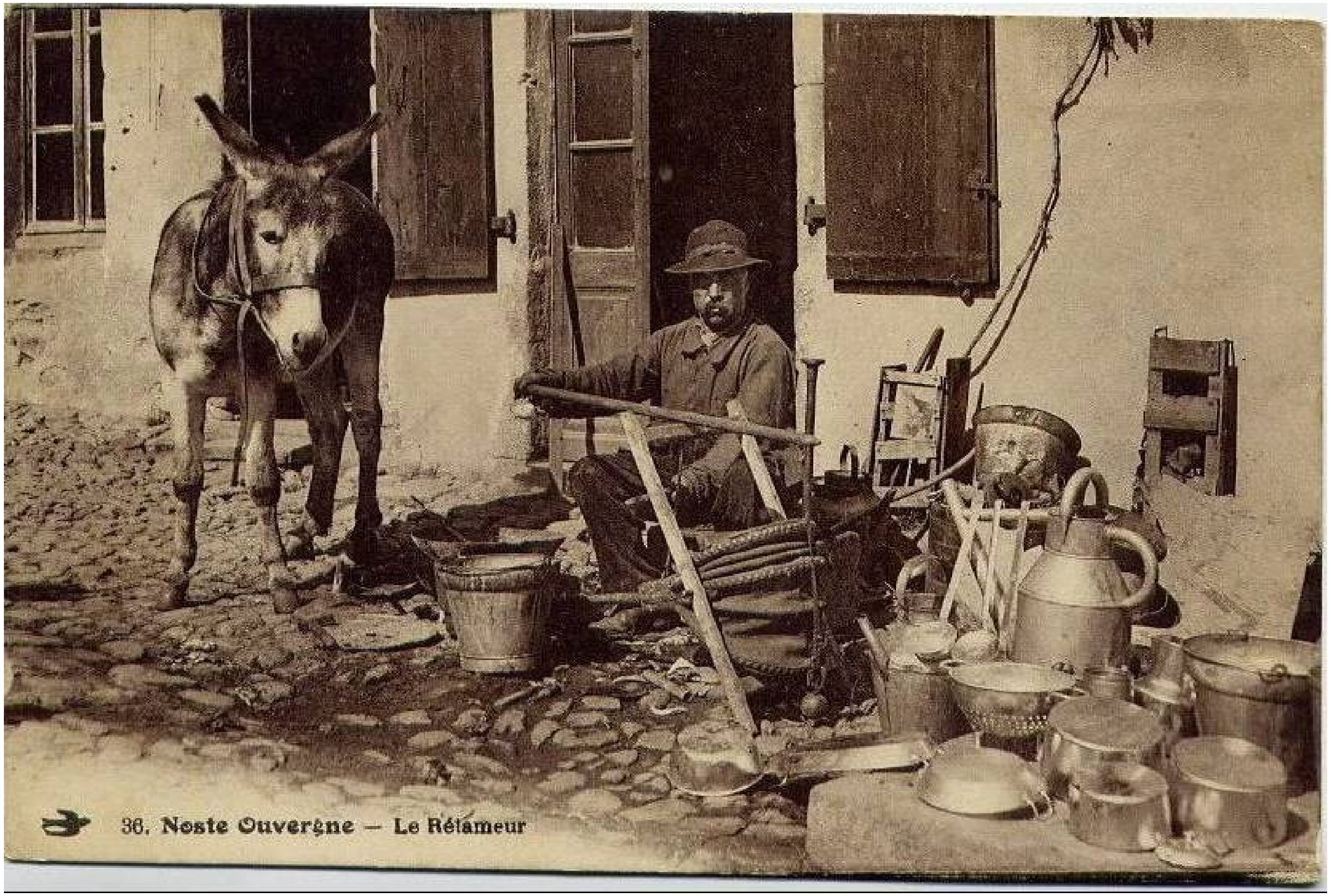
For metals, we talk about flows, but also stocks



Croesus, King of Lydia
(from 561 to 547 BC)

Coin in Gold of Pactolus

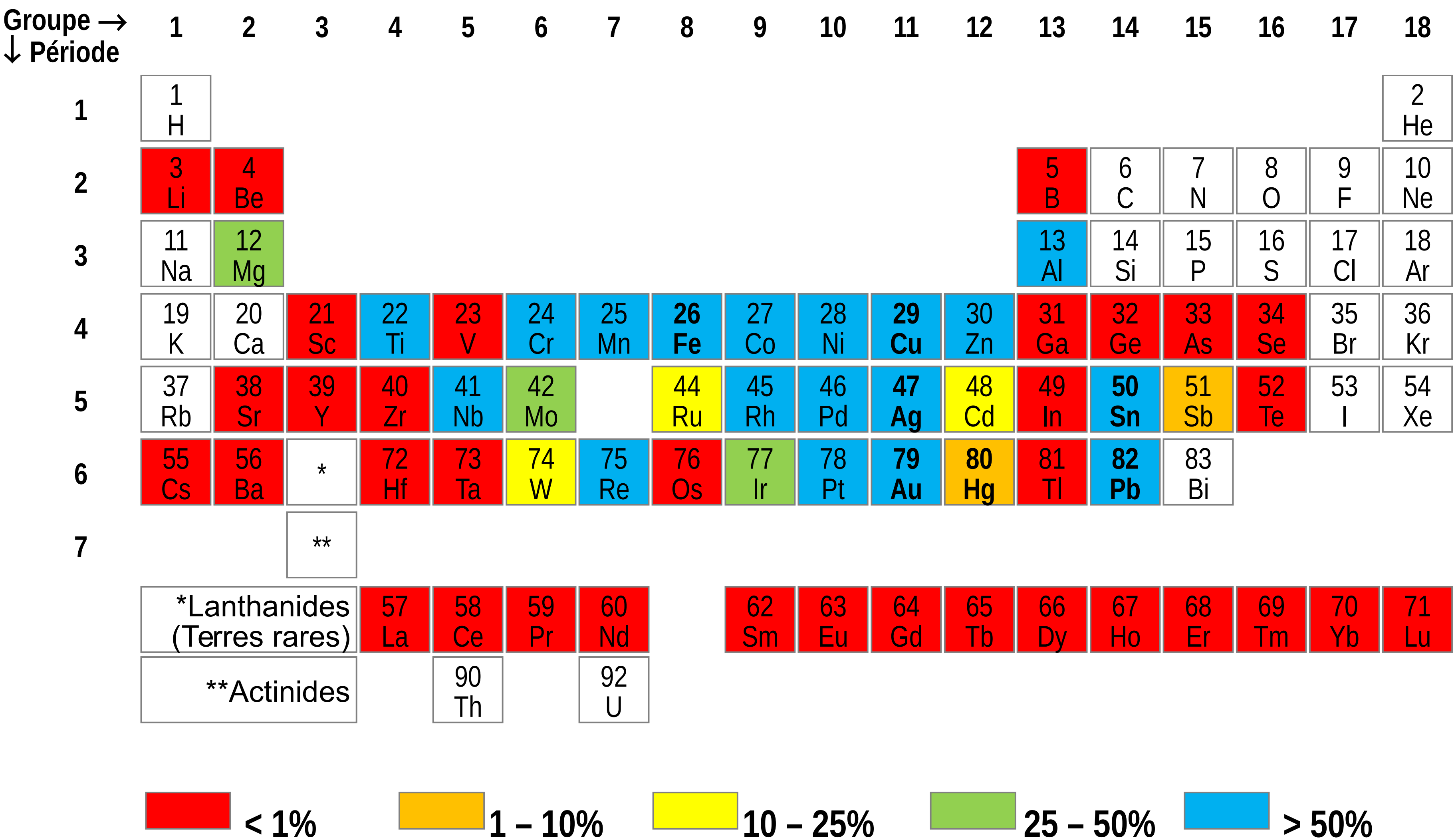
Limits of recycling #1… thermodynamics



The disappeared job of tin-plater

99% would be already great

Recycling rate of metals



Source : UNEP / Recycling rates of metals 2011

Limits of recycling #2…
the dissipative usages

Cosmetics, Health

Paints & Dyes

Inks

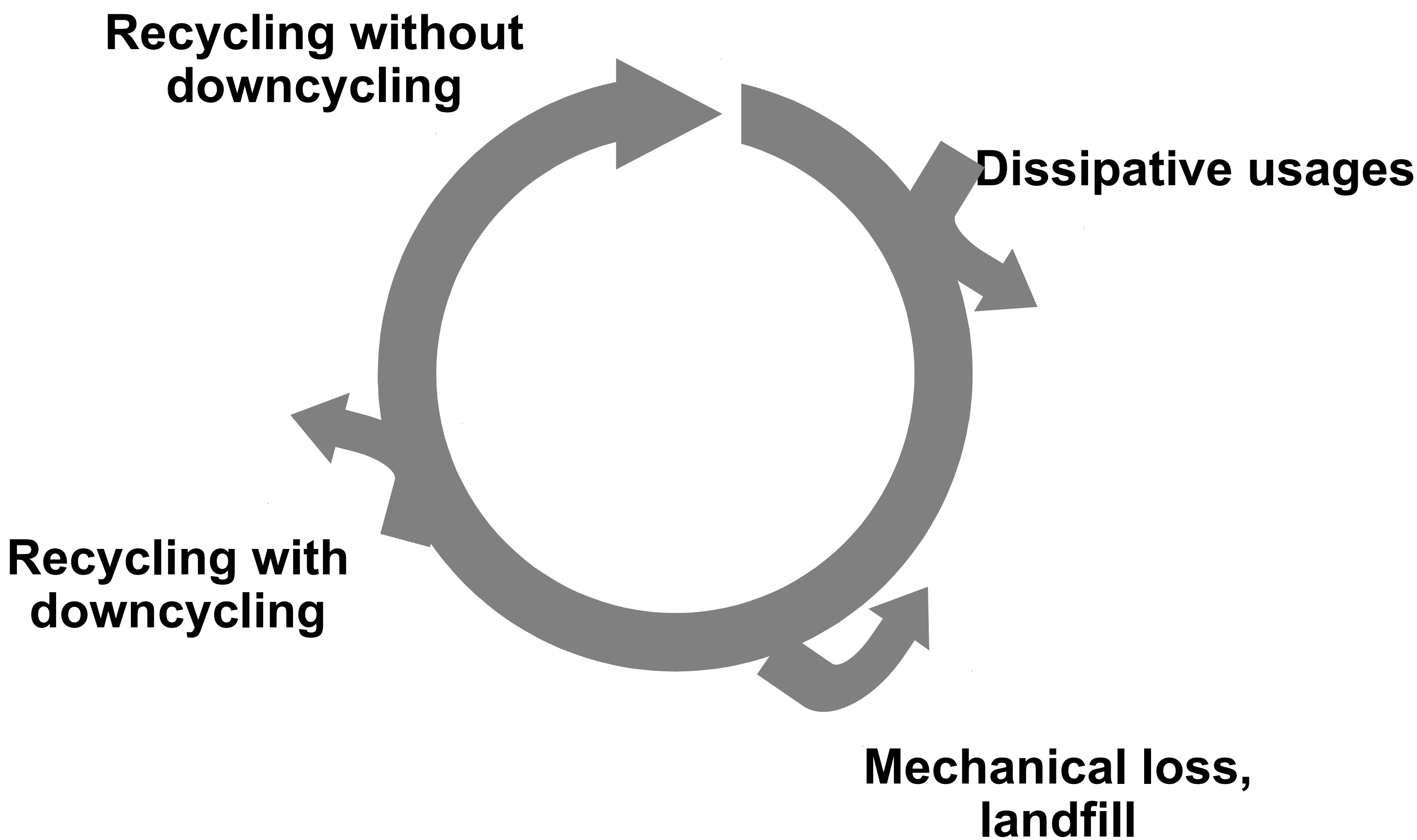
Fireworks, weapons

Agriculture

Paper

Limits of recycling #3…
alloys, purity and « downcycling »

The « vertuous circle » of recycling



« Green growth » is accelerating these 2 issues

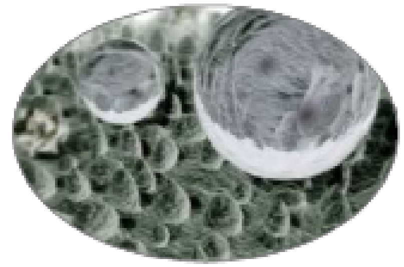
Looking for a « clean car »

« High tech struggle » against CO2 emissions

Smart grids

And this is only the start…

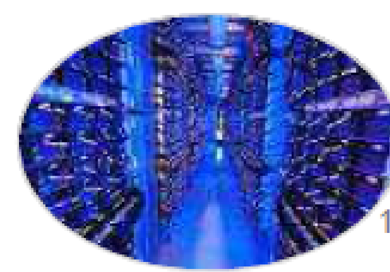
Nanotechnologies… and dissipative usages




Hyperconnectivity, machines vs. humans, “electronisation”


Technical obsolescence by research of performance


IoT, robots, drones, big data…

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The « green growth » will NOT make it

The gap is too big :
We must work on demand, not just offer

Engineers will not make miracles

There is no « exit by the top »…
- **High-tech is worsening the picture**
- **There is no Moore's laws in energy. Electron ≠ Byte**

We need innovation and smart ideas :
but not the ones we have had up to now

We must bet on LOW TECH, not HIGH TECH

First, work on demand's side…

Cars
- **Lighter vehicles, speed limit reduction**
- **Biking**

Buildings
- **Better insulation**
- **Lower heating – No air conditioning**
- **Less m2 per person**

Energy intensive industries
- **Ban disposable objects**
- **Reusable packaging – local exchanges**
- **& less cars, less buildings…**

Internet ?

Then, think about material usage & recyclability

Devices should be:

- Repairable
- Modular
- Reusable
- Easy to dismantle
- …

Choices should based on :

- Robustness
- Simplicity
- Single material based
- Avoiding rare metals (if possible)
- Avoiding electronics (as much as possible)
- …

What does it mean for energy scenarios ?

We have to keep in mind that our (at least current) industrial system cannot build solar panels from solar panels, wind turbines from wind turbines, etc.

‘100% renewable’ seems anyway difficult

What about each technology ?

- **Solar thermal > Solar PV**
- **Small is (seems) beautiful**
- **Performance requests kill us**

Balance performance and resources' consumption ?

vs.

?

+

- High tech, Worldwide technologies
- Production of subsystems and spare parts
- Resources
- Adaptation of transportation networks
- Logistic bases
- Access roads
- …