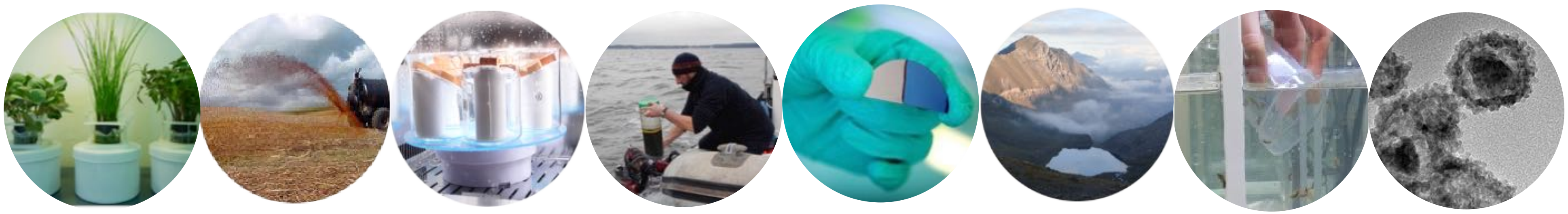
UNIVERSITY AUTONOMA OF MADRID, UNIVERSITY OF STOCKHOLM, AIX-MARSEILLE UNIVERSITY AND ECREEE-AMENET-CIVIS-CERMI AMENET

Impact of renewable energies on the non-renewable resources



J.ROSE (rose@cerege.fr)

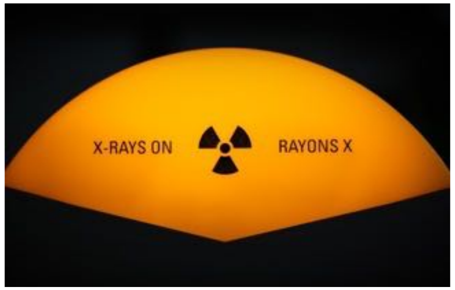
CNRS Senior Scientist

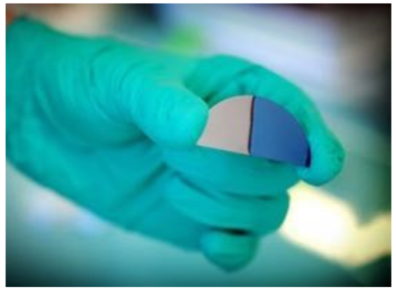
Mediterranean Institute for the Environmental Transition

CEREGE *Sustainable Environment team*

Europole de l’Arbois 13545 Aix

Sustainable Environment group @ CEREGE (AMU-CNRS-IRD-CdF-INRA)





Sustainable Environment group

Our skills : Bio-physical-chemical processes and reaction mechanisms

Our Expertise : **Characterize and Minimize the Impact on the Environment of Anthropic Activities**

with an approach ranging from molecular scale to plots, coupled with flow balances.

Our objects of study :

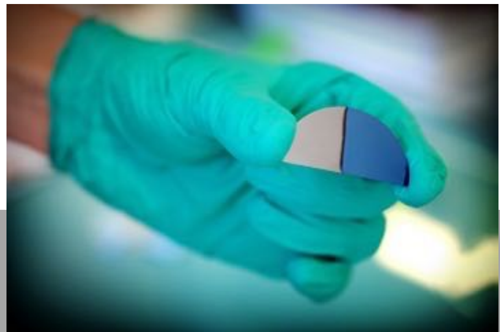
Water
Soil
Sediment
Air
Material

Mineral
Fauna
Flora
Human

Our research themes

Theme 1. Dynamic, cycle, and tracing of elements in ecosystems
Coordinator : Blanche Collin, Zuzana Fekiacova

Theme 2. Reactivity of nanosized phases
Coordinator : Jérôme Labille

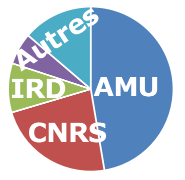


Them 3. Inovation for the Environment
Nanomaterials, metals, soil, water
Coordinator : Clément Levard

Mediterranean Institute for the Environmental Transition

Aix Marseille Université

ITEM is:



240 Faculties and Academic

Institut ITEM

7 Faculties

750 master students

- **Earth/Environment**- 4 masters
- **Arts, Letters, Languages and Human Sciences** - 4 masters
- **Institute of Public Management and Territorial Governance** - 2 masters
- **Medecine** - 1 master
- **Sciences** - 1 master
- **Mediterranean House of Human** - 1 master
- **Law and Political Science** - 1 master

14 Research units

4 Doctoral schools

Environmental Sciences ED 251

55-65 PhD/year

- **Economic and Management Sciences ED372**
- **Spaces Cultures Society ED355**
- **Legal and Political Sciences ED67**

Mediterranean Institute for the Environmental Transition
Aix-Marseille Université

Research Themes

	Topics with high international visibility	Emerging topics to be strengthened	Topics to be highlighted
Analysis of **socio-environmental changes** for a transition strategy	Biodiversity, ecosystem functioning	The biogeochemical cycle of carbon	Water resource in Mediterranean climate
Resource management for an environmental transition	Multiple Contaminations	Resource recyclability	Environment and Health
Resilience of societies to **risks** in a transition context	Risk characterization and diversity of knowledge	Risks and territories in a "multihazard" context	Expertise in tension and participatory sciences

Renewable energies

- Starting point (s) ?

Global warming - Climate change

Global warming - Climate change

Global warming - Climate change

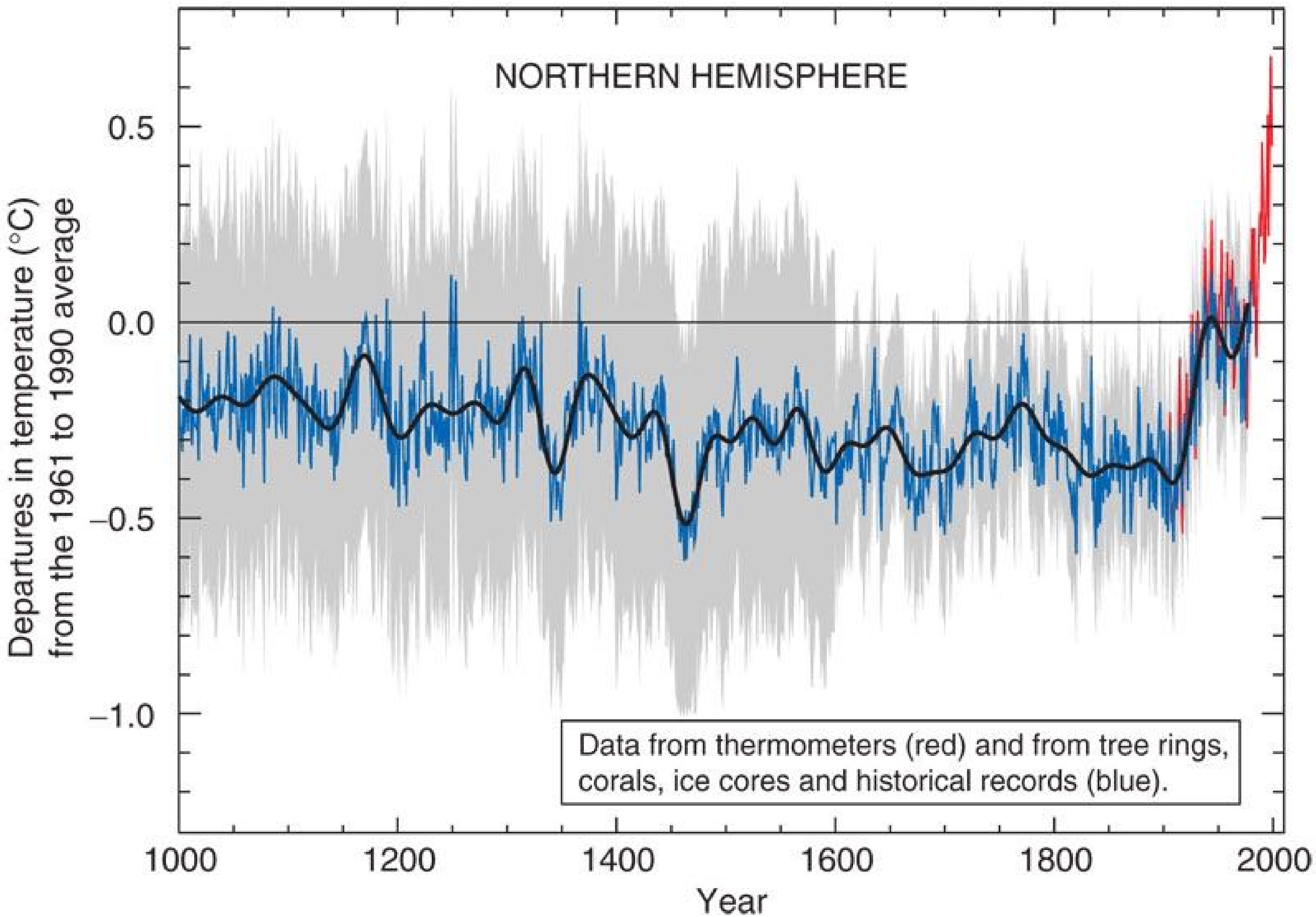
- Alaska Portage Glacier

1914

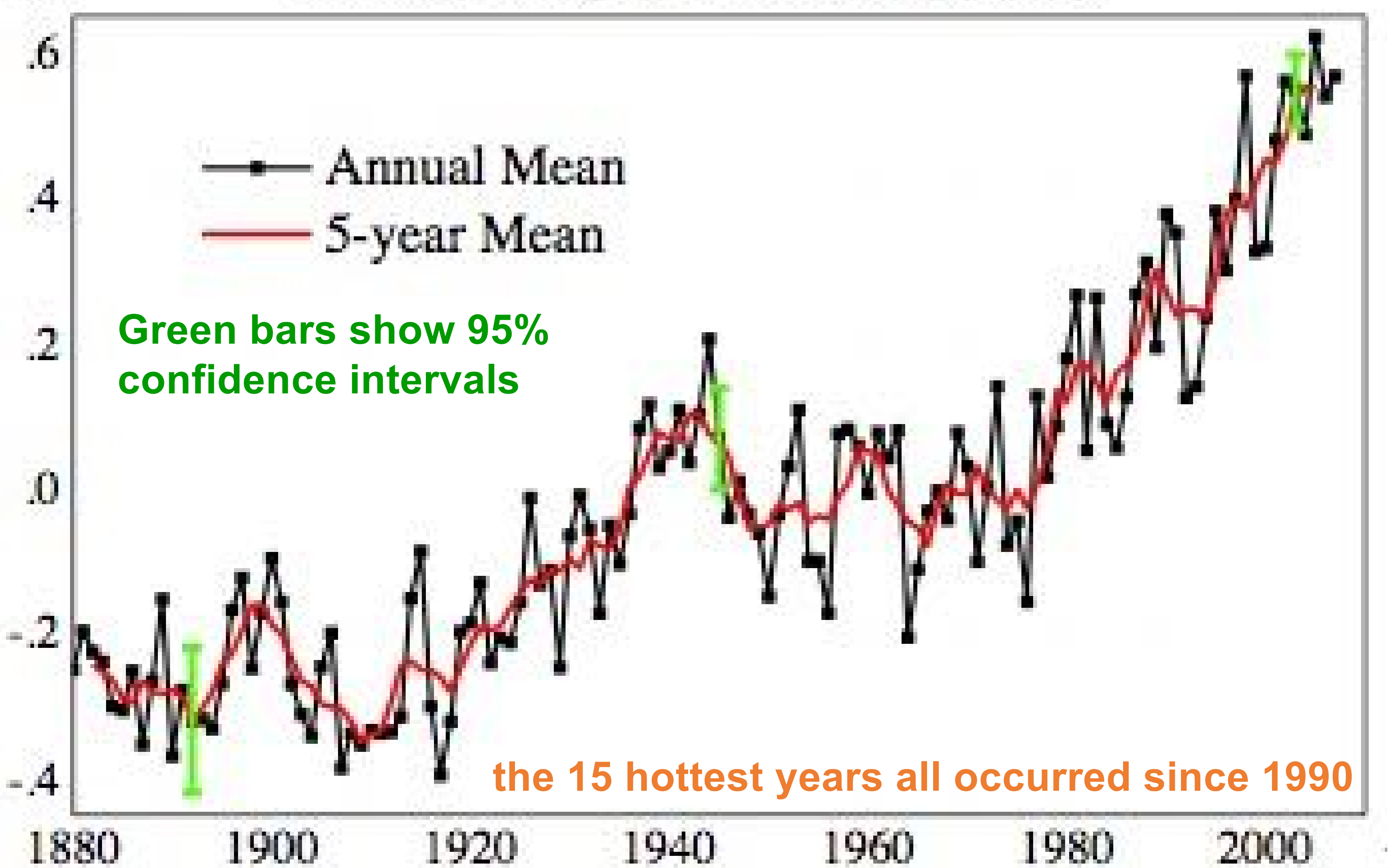
2004

Photos: NOAA Photo Collection and Gary Braasch – WorldViewOfGlobalWarming.org

Are Global Average Temperatures Rising Significantly compared to Recent Geologic History? Yes.



Global Temperatures are increasing



http://data.giss.nasa.gov/gistemp/graphs/

NATURE CLIMATE CHANGE REVIEW ARTICLE

- **Mediterranean**
- Is warming 20% faster than the rest of the planet

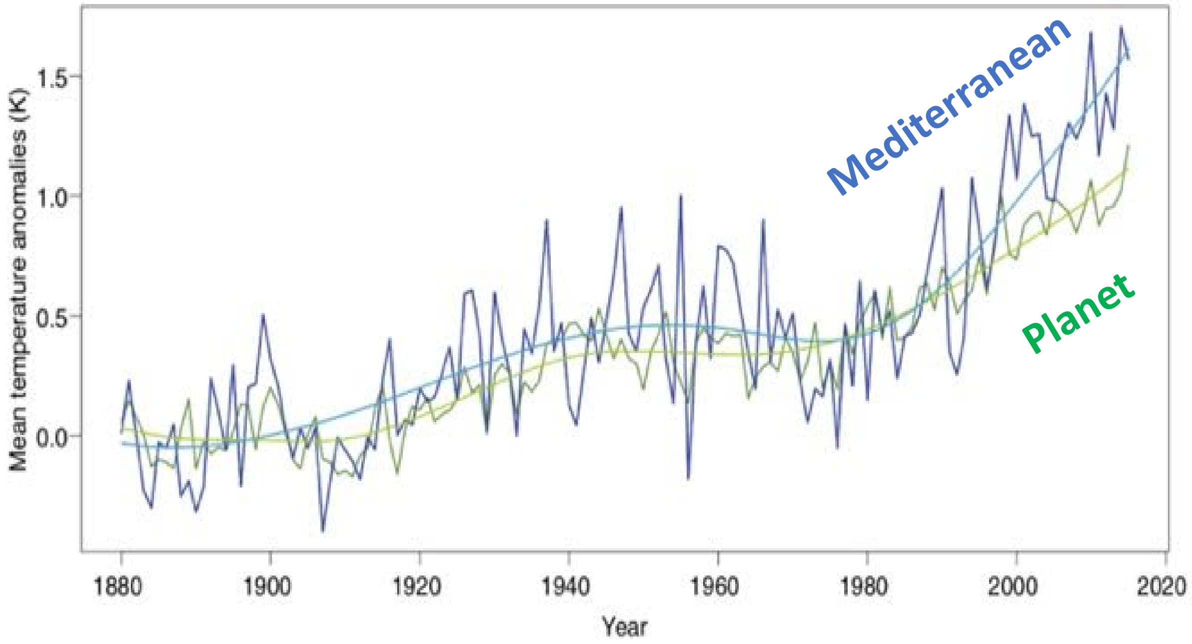


Fig. 1 | Historic warming of the atmosphere globally and in the Mediterranean Basin. Annual mean air temperature anomalies are shown with respect to the period 1880-1899, with the Mediterranean Basin (blue) and the globe (green) presented with (light curves) and without (dark curves) smoothing. Data from http://berkeleyearth.org/

Effects of Global Warming

Rising Sea Level

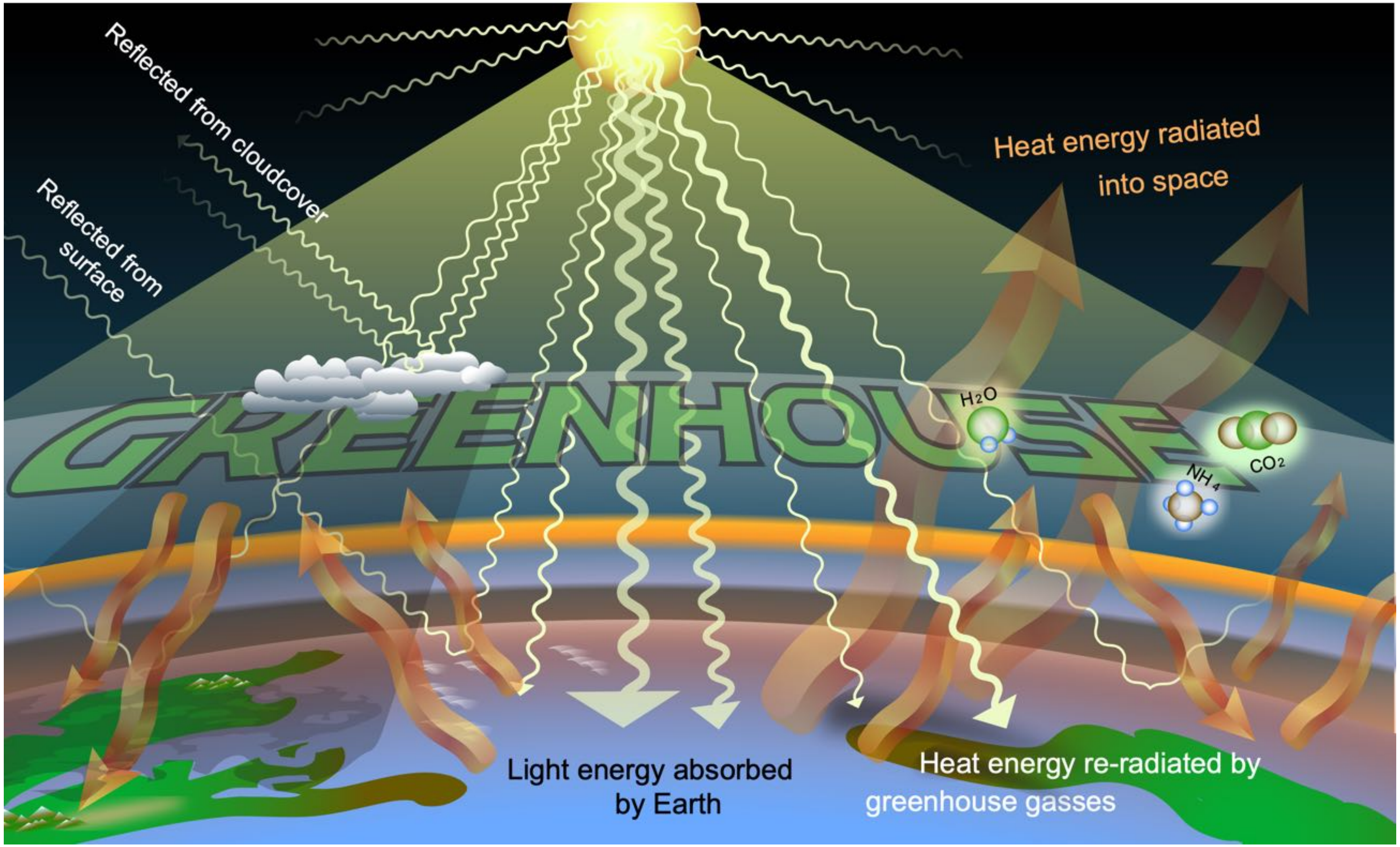
Increased Temperature

Habitat Damage and Species Affected

Changes in Water Supply

Why such global warming?

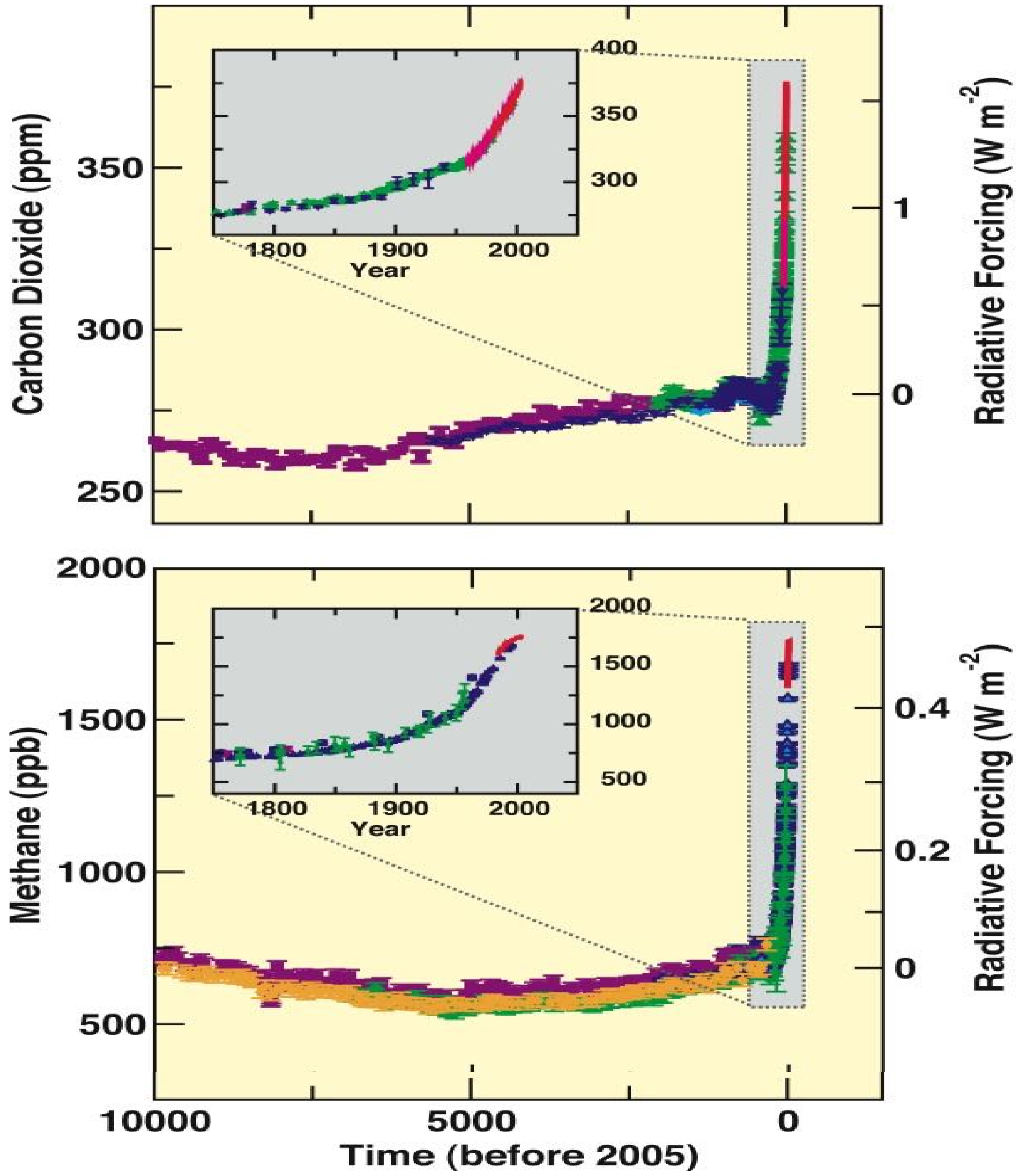
Greenhouse effect



Greenhouse gas concentrations

Compared to natural changes over the past 10,000 years, the spike in concentrations of CO_2 & CH_4 in the past 250 years is extraordinary.

Humans are responsible for the recent dramatic increase emissions. Fossil CO_2 & CH_4 lack carbon-14, and the observed drop in atmospheric C-14 is measurable.



(IPCC AR4 WG1, 2007)

MITIGATING CLIMATE CHANGE

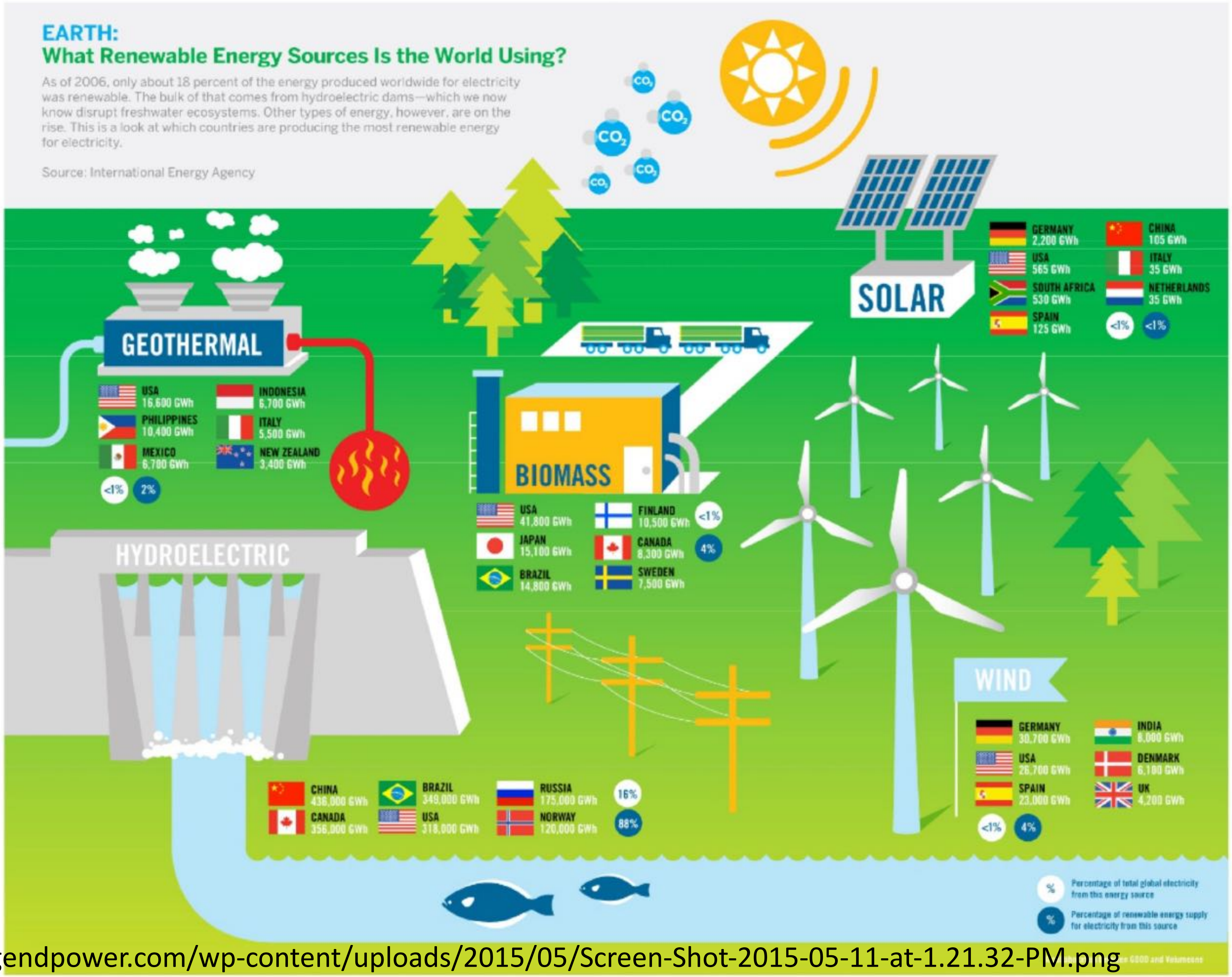
WHAT WE KNOW

The level of greenhouse gases in the atmosphere have increased, causing the Earth's temperature to rise.

One greenhouse gas in particular, carbon dioxide (CO_2) has steadily increased over the past century largely due to human activity (anthropogenic).

We know that emissions have a significant impact on the world around us. How can we reduce the amount of carbon that is emitted?

Renewable Energy sources



https://legendpower.com/wp-content/uploads/2015/05/Screen-Shot-2015-05-11-at-1.21.32-PM.png

Life Cycle Assessment on electricity generation

Sources : Rapport GIEC (2011),
Ademe (2015),
Ecoinvent (données 2011)

Technologie utilisée	Éolien	Solaire	Hydraulique	Nucléaire	Charbon	Gaz naturel	Fioul
Emission directe de CO_2 (gCO_2-eq /kWh)	0	0	0	0	345	272	204

http://www.quiestvert.fr/contenus/electricite-verte/quel-est-limpact-environnemental-des-energies-renouvelables/

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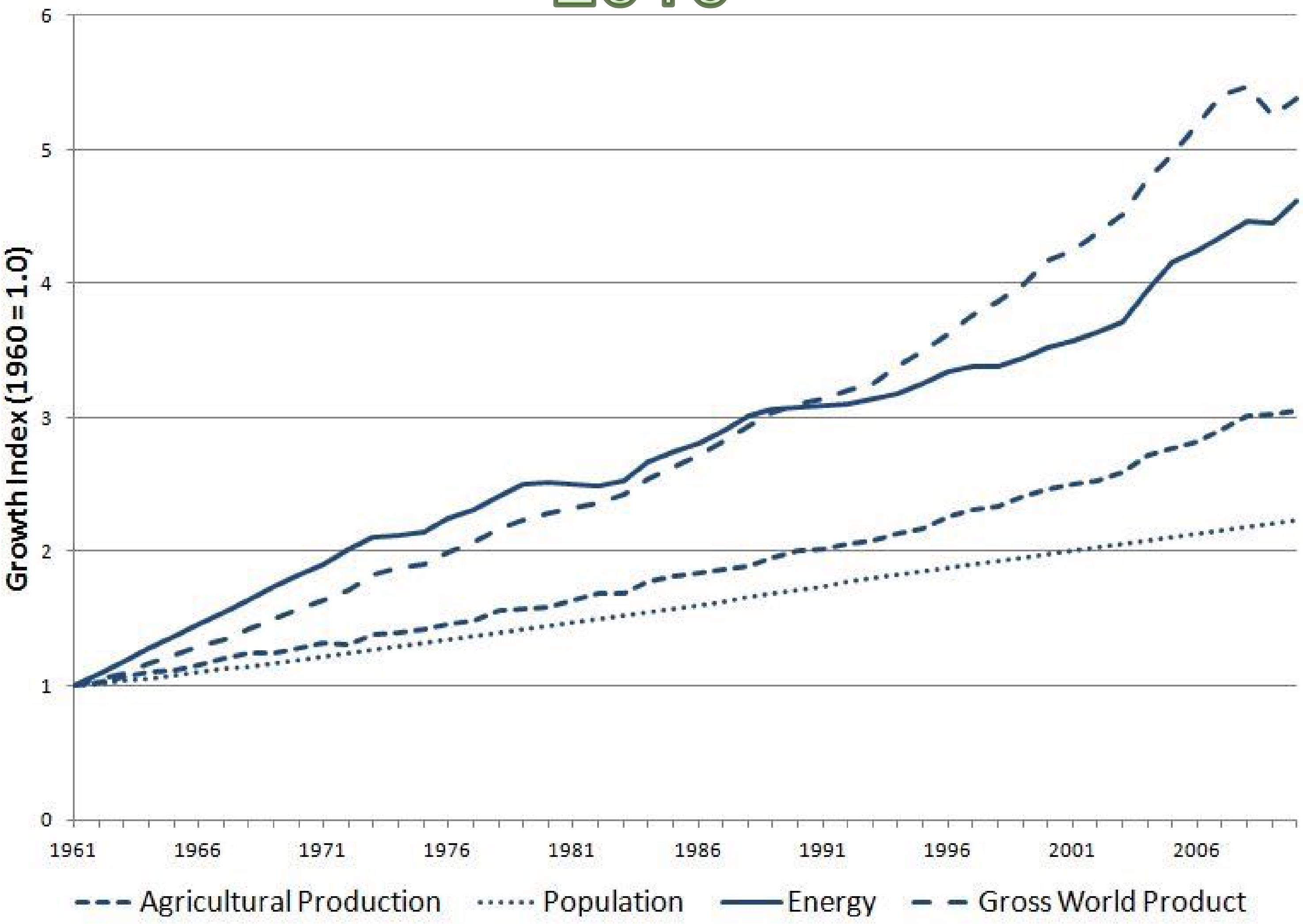
Technologie utilisée	Éolien	Solaire	Hydraulique	Nucléaire	Charbon	Gaz naturel	Fioul
Emission directe de CO2 (gCO2-eq /kWh)	0	0	0	0	345	272	204
Emission directe de CO2 + ACV (gCO2 -eq /kWh)	12,5	55	6	6	1060	730	418

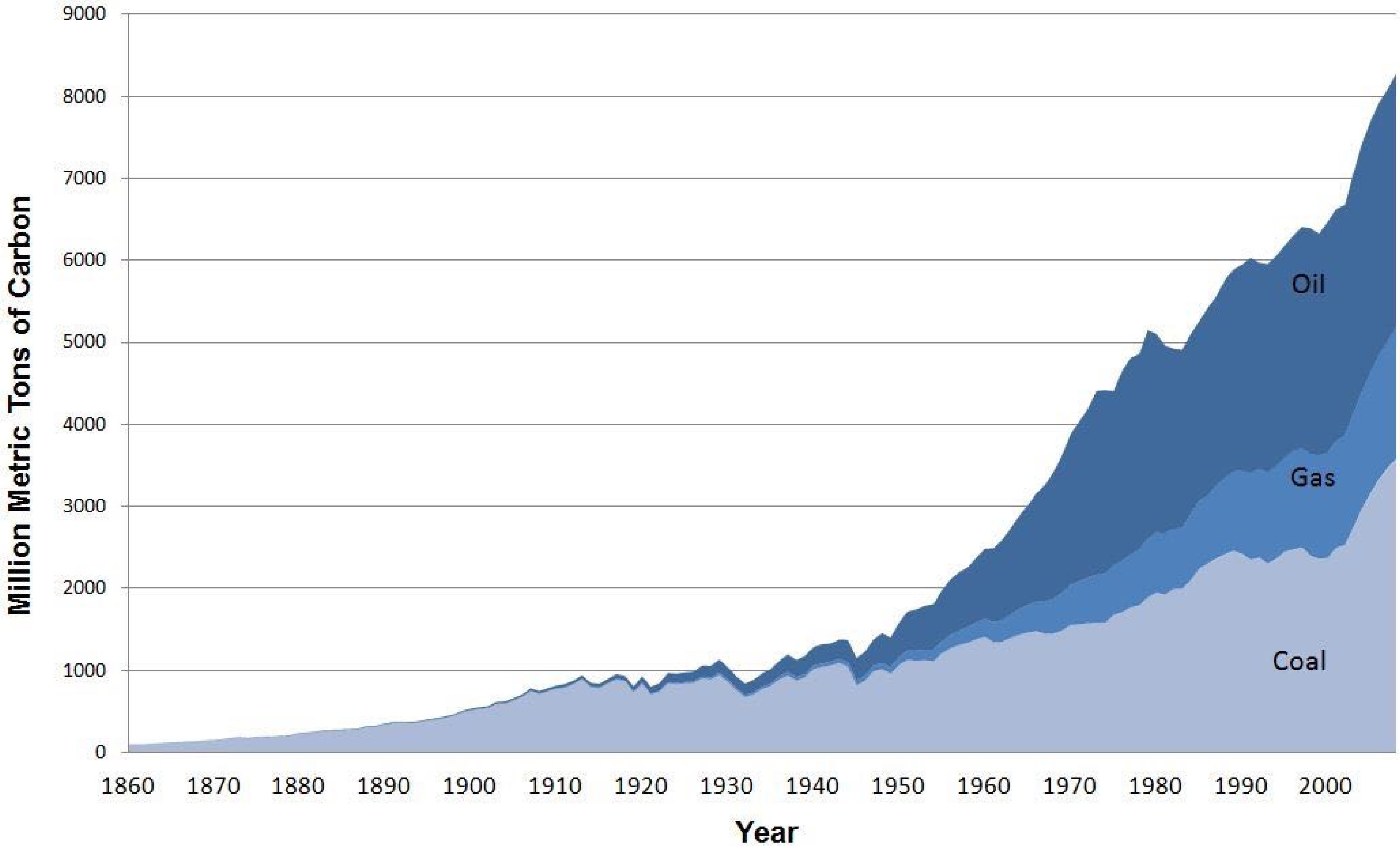
http://www.quiestvert.fr/contenus/electricite-verte/quel-est-limpact-environnemental-des-energies-renouvelables/

Growth in Population, Agricultural Production, and Energy Use, 1961-2010



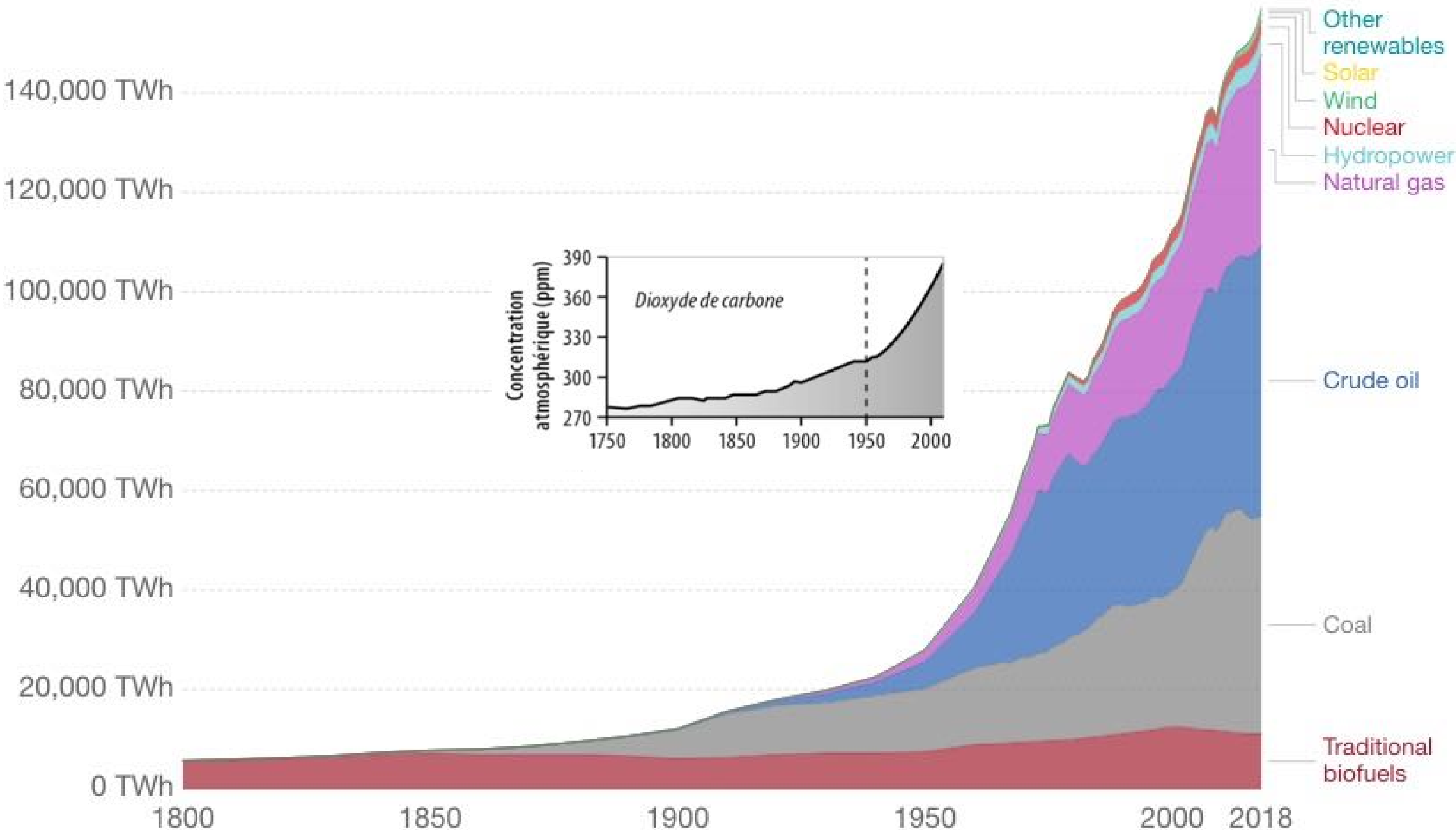
Sources: Population and Agriculture,FAO, 2012; GWP, IMF ww.imf.org; Energy, EIA www.eia.gov

Carbon Dioxide Emissions from Fossil Fuel Consumption, 1860-2008



Source: Carbon Dioxide Information Analysis Center (CDIAC), http://cdiac.ornl.gov/

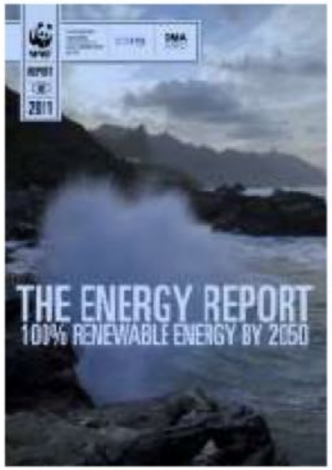
World energy consumption

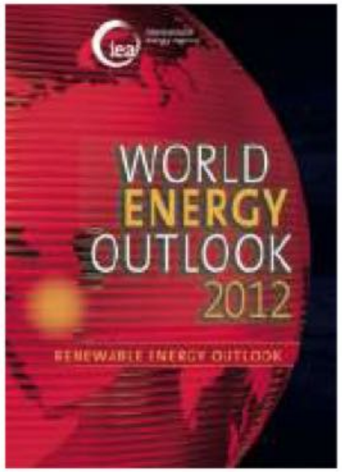


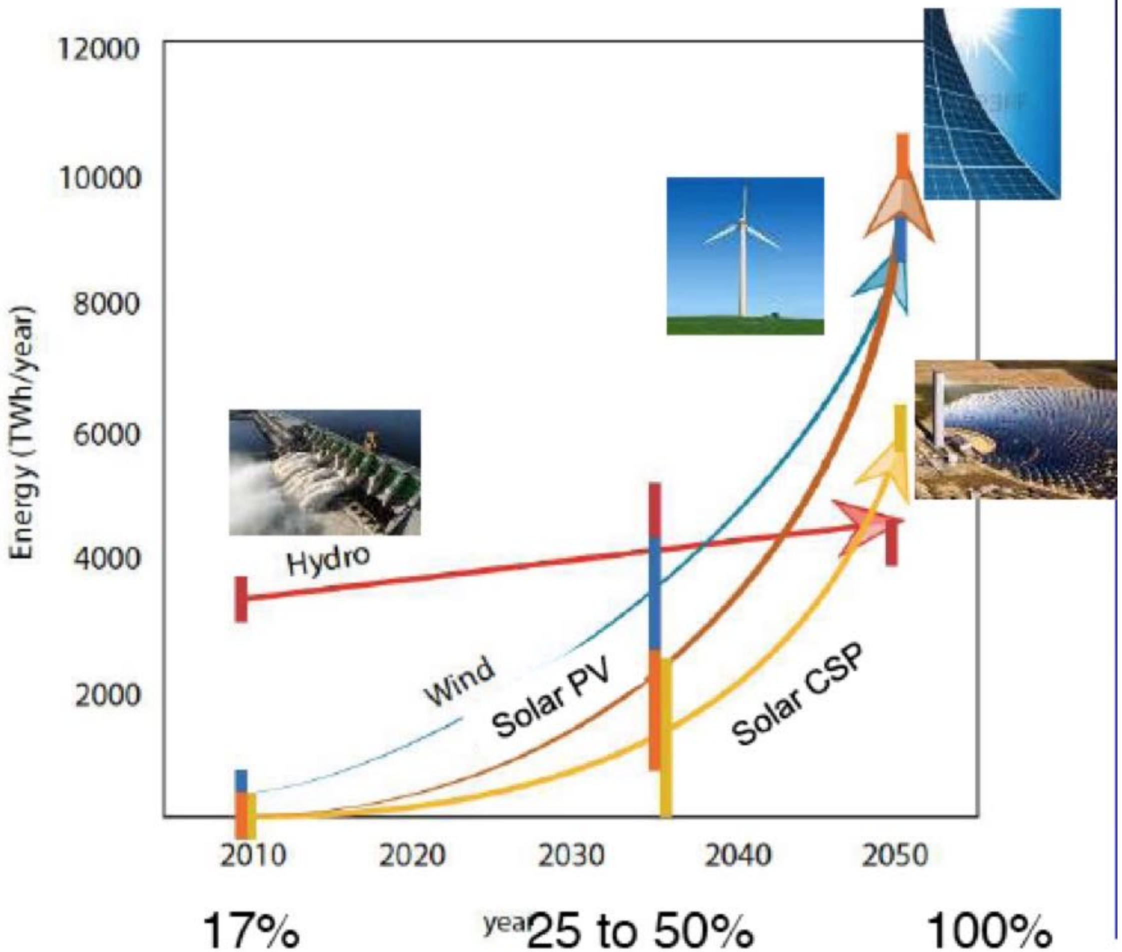
Source: Vaclav Smil (2017) and BP Statistical Review of World Energy

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

The available global energy scenarios rely on a strong increase in the share of solar and wind energy







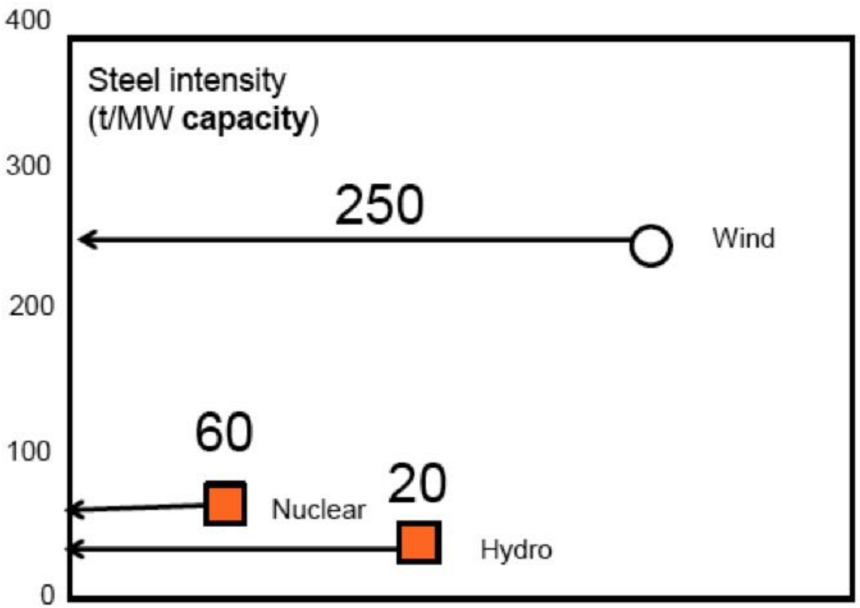
17% 25 to 50% 100%

of global electricity generation
(about 40% of global E demand)

Source: Olivier Vidal, CNRS, ISTERRE France

Solar and wind sources are diluted and require large facilities

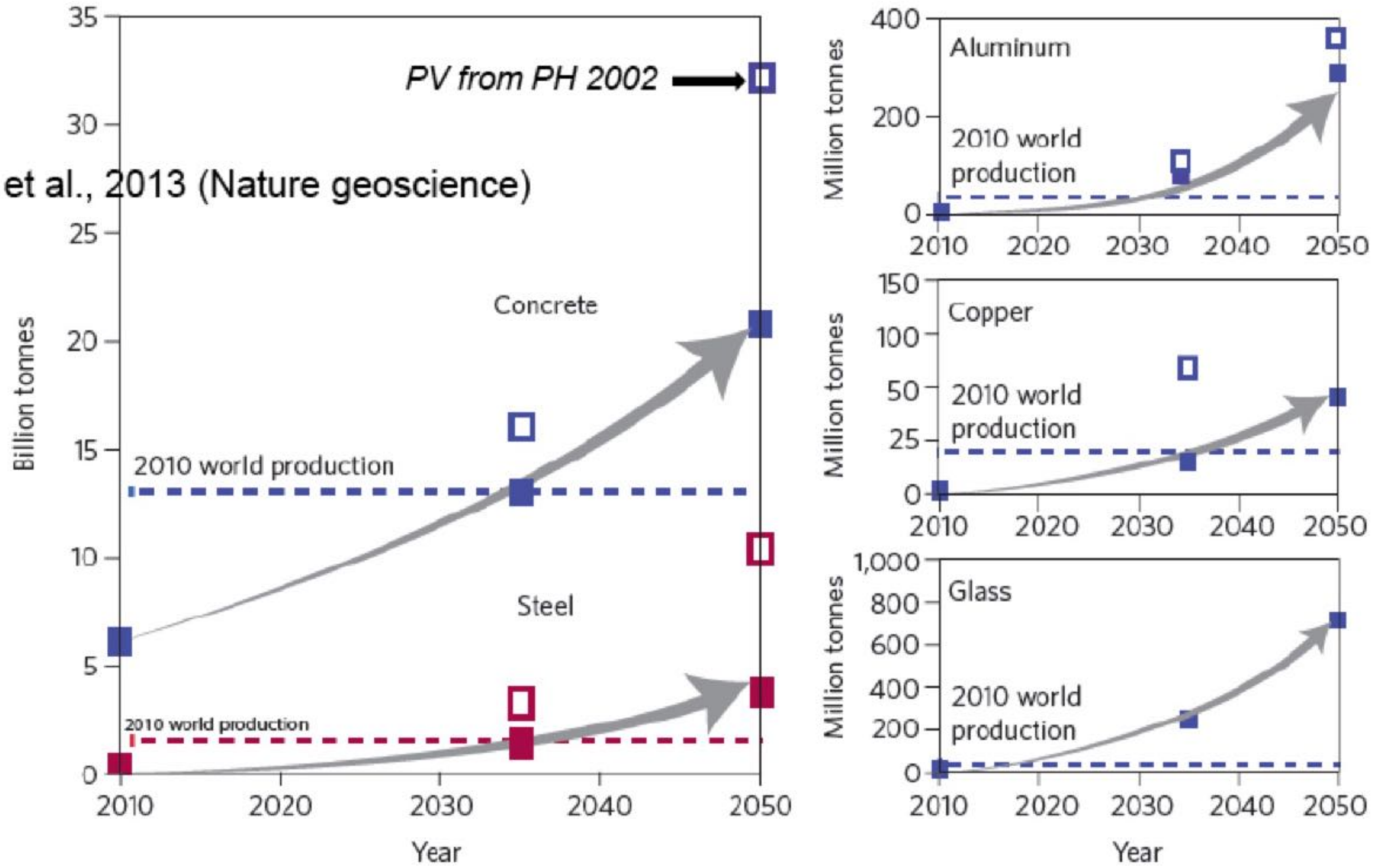
Latest wind turbine generation:
6 Mw, basement at 60 m depth,
rotor > 150 m, >1500 t of steel
>100 kg rare earth elements



800 of such wind turbines are necessary to produce the same energy (Wh) as a 1300 MW nuclear plan

Source: Olivier Vidal, CNRS, ISTERRE

Materials requirements for wind and solar energy production facilities



Vidal et al., 2013 (Nature geoscience)

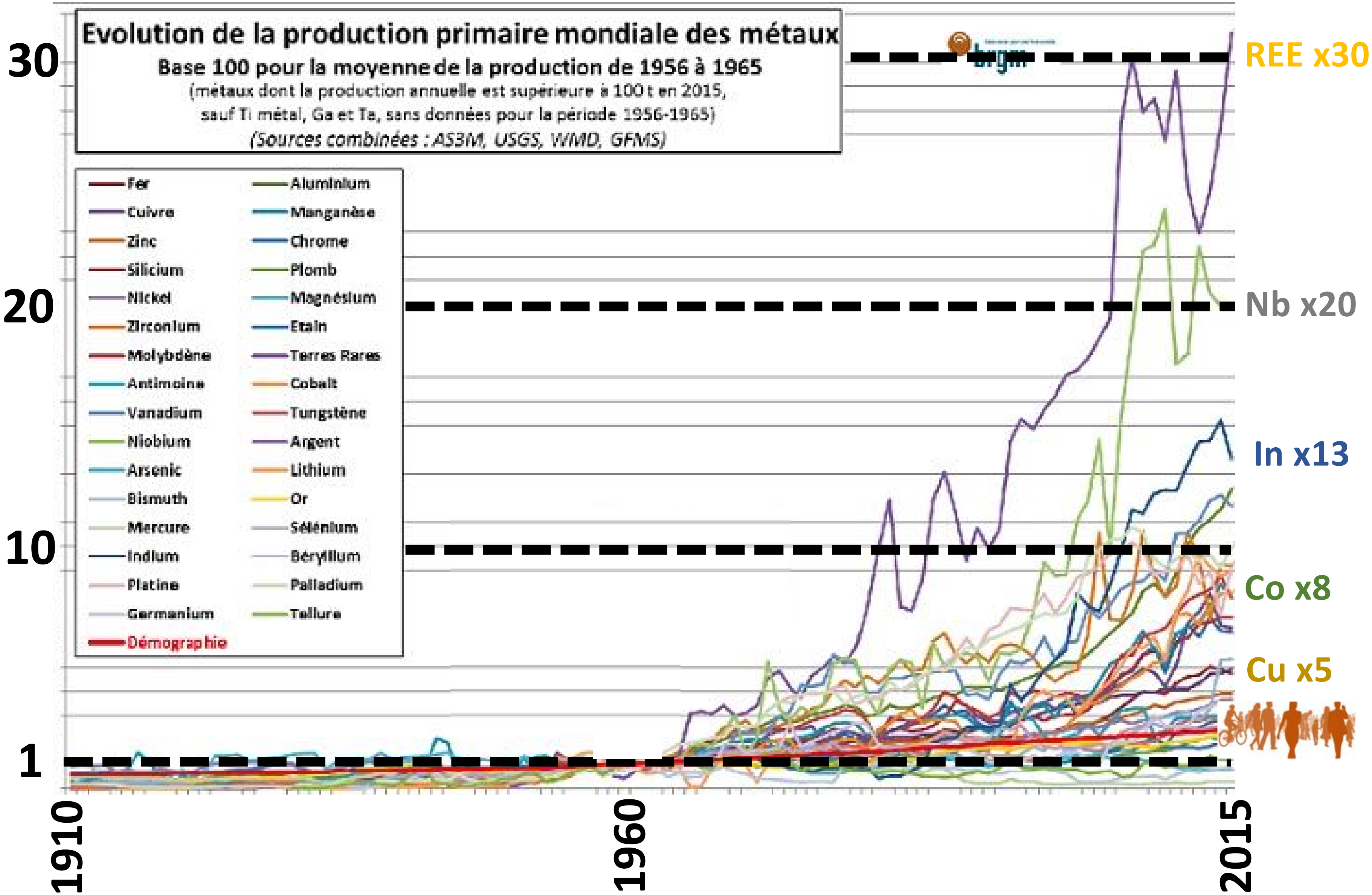
In 2050, the cumulative amount of concrete, steel, Al, Cu and glass sequestered in wind and solar facilities will be 2 to 8 times the 2010 world production

The energy-raw materials nexus

- Need of metals to produce energy
- Need of energy to produce metals

  - "21 % of the global energy consumed by the industry in 2011 was used for the production of steel + cement" (international energy outlook 2013)
  - « Energy consumption and intensity in mining and mineral processing is rising at around 6% per annum » (Australian Bureau of Agricultural and Resource Economics - 2010)
  - "1 tCO_2 is generated for 1t of produced concrete" (Natesan et al., 2003) and about 2 t CO_2 are generated for 1 t of produced steel.

Evolution of world primary metal production



CHALLENGES

- 1.Future demand
- 2.Future supply
- 3.Uneven geographical distribution
- 4.Energy and mining
- 5.Environmental and social impact
- 6.Lack of geological data

Technology	Metals Requirement	Lifespan
Wind	Dysprosium, Manganese, Neodymium, Molybdenum, Nickel, Chromium, Copper, Concrete	25 years with normal maintenance and inspection.[11]
Solar PV	Tellurium, Indium, Tin, Silver, Gallium, Selenium, Cadmium, Copper, Lead, Silicon	Standard solar panel warranty is 25 years and the average life of a solar system is 30 years. The average lifespan of PV batteries is between 6 and 12 years.[12]
Electricity Grid	Copper, Lead	N/A
Biofuel	Ruthenium, Cobalt	N/A
Plug-in hybrids (PHEV) & electric vehicles (BEV)	Lithium and Cobalt (Batteries), Neodymium, Terbium, Dysprosium and Lanthanum (Permanent Magnets)	From 5 to 20 years. Tesla's vehicles come with an 8 years battery warranty.[13]

From Katarina Kertysova
The Hague Centre for Strategic Studies (HCSS)
8 November 2017

Emerging elements

- Critical
- Strategic
- Emerging
- "High-Tech"

Elements $\boxed{\textbf{high economic importance}}$

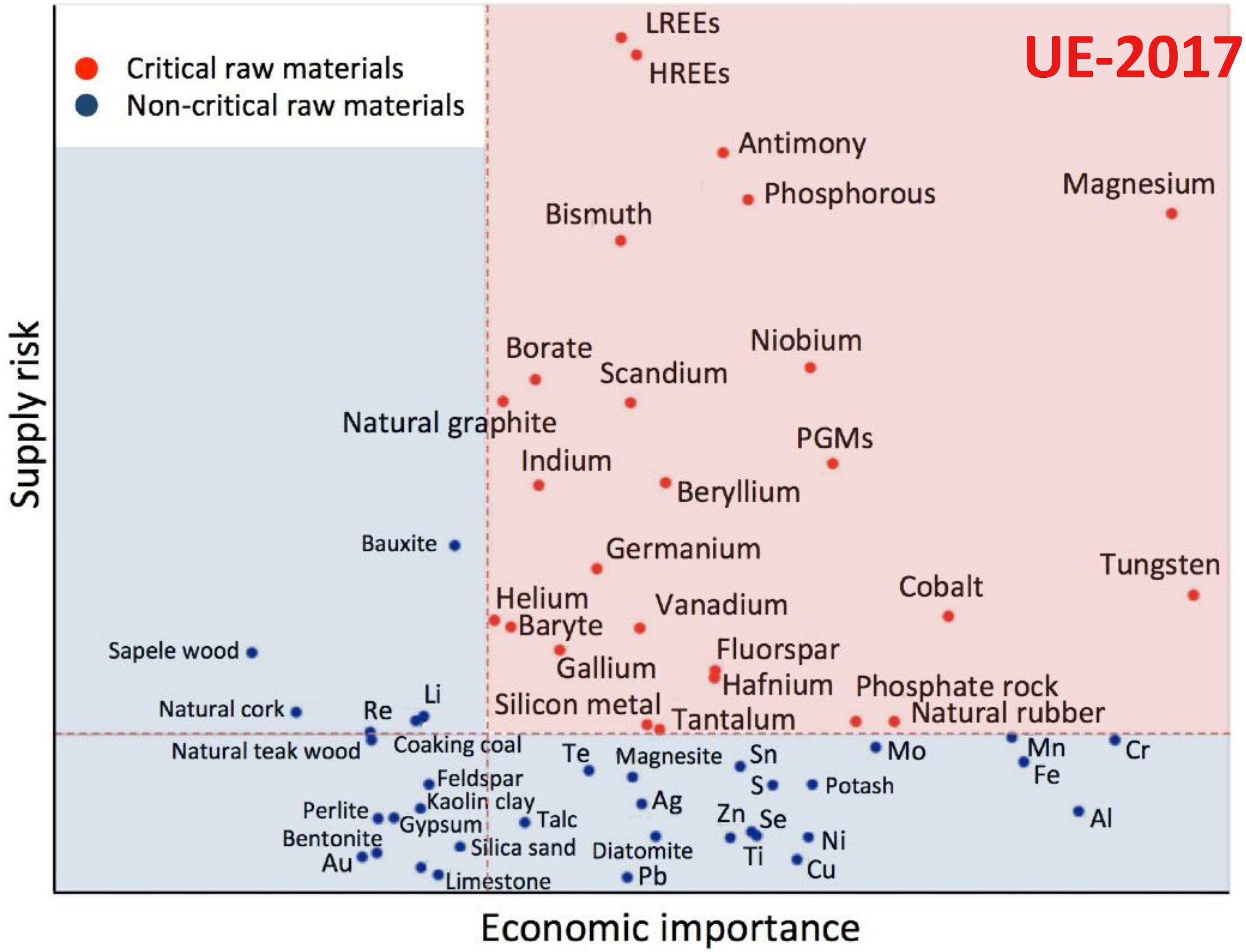
Critical metals: definition

The so-called critical elements are elements that are both:

Deemed strategic for a country's economy, as they may affect the competitiveness of the industries that depend on them

Subject to supply risks or high price volatility

Critical metals: definition



Critical metals

éléments critiques, des éléments stratégiques!

Emerging elements

- New technologies:
  - Photo-voltaic: Cd, Ga, Ge et Te
  - Thermo-emittors (thermo-photovoltaic): W…
  - Wind, electric cars = supers-magnets: Nd & other REE…
  - Super Isolants: Ba….
  - Light emitting diodes (LED) & Semi- conductors : Ga, Sb, Sn, Ag…
  - Medical Imaging: Tl, Ba,
  - etc

Emerging elements

- Critical
- Strategic
- Emerging
- “High-Tech”

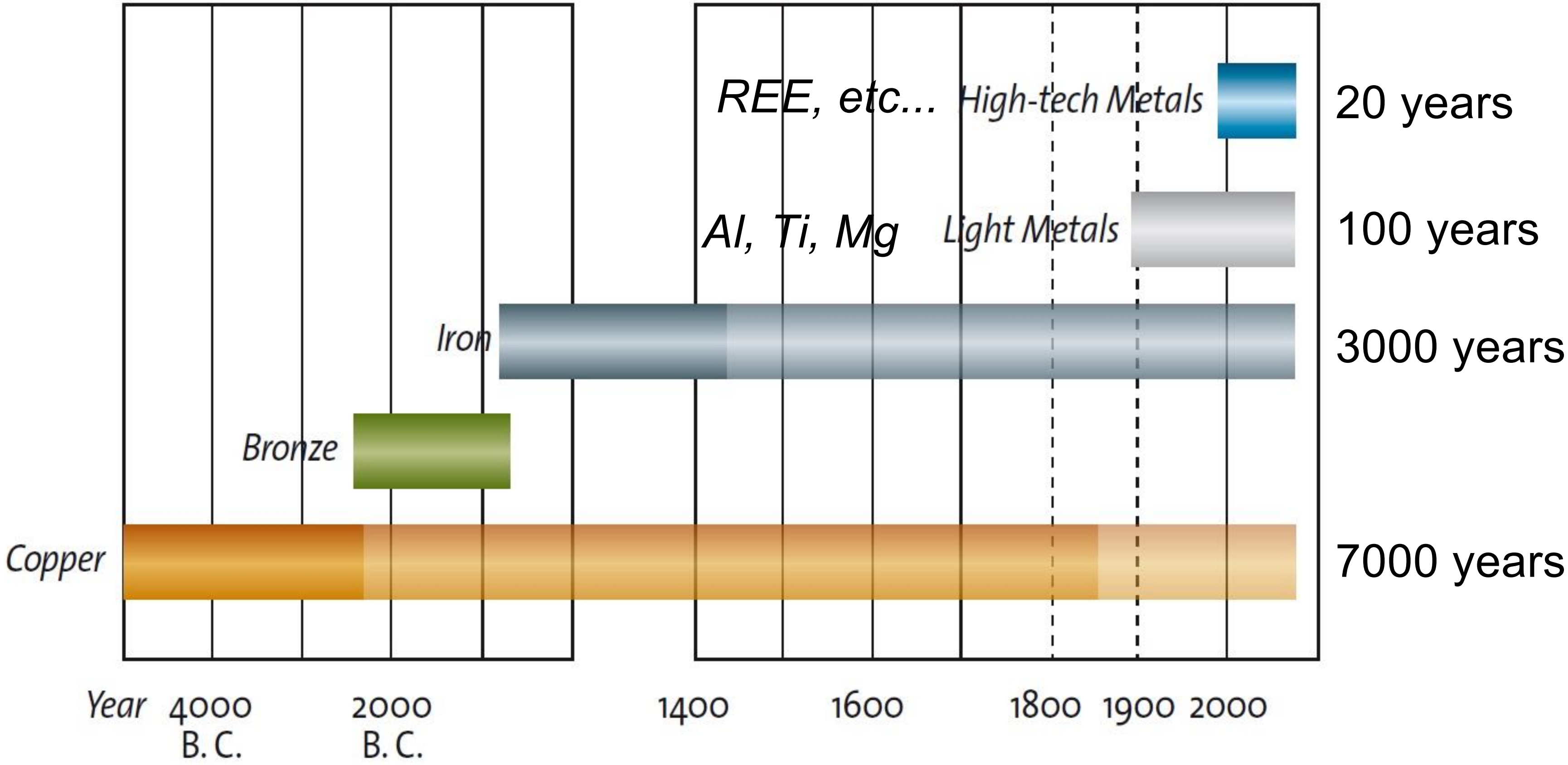
Elements

high economic importance combined with a high risk associated with their supply.

Recent needs in “non-conventional” elements

«High-Tech » metals

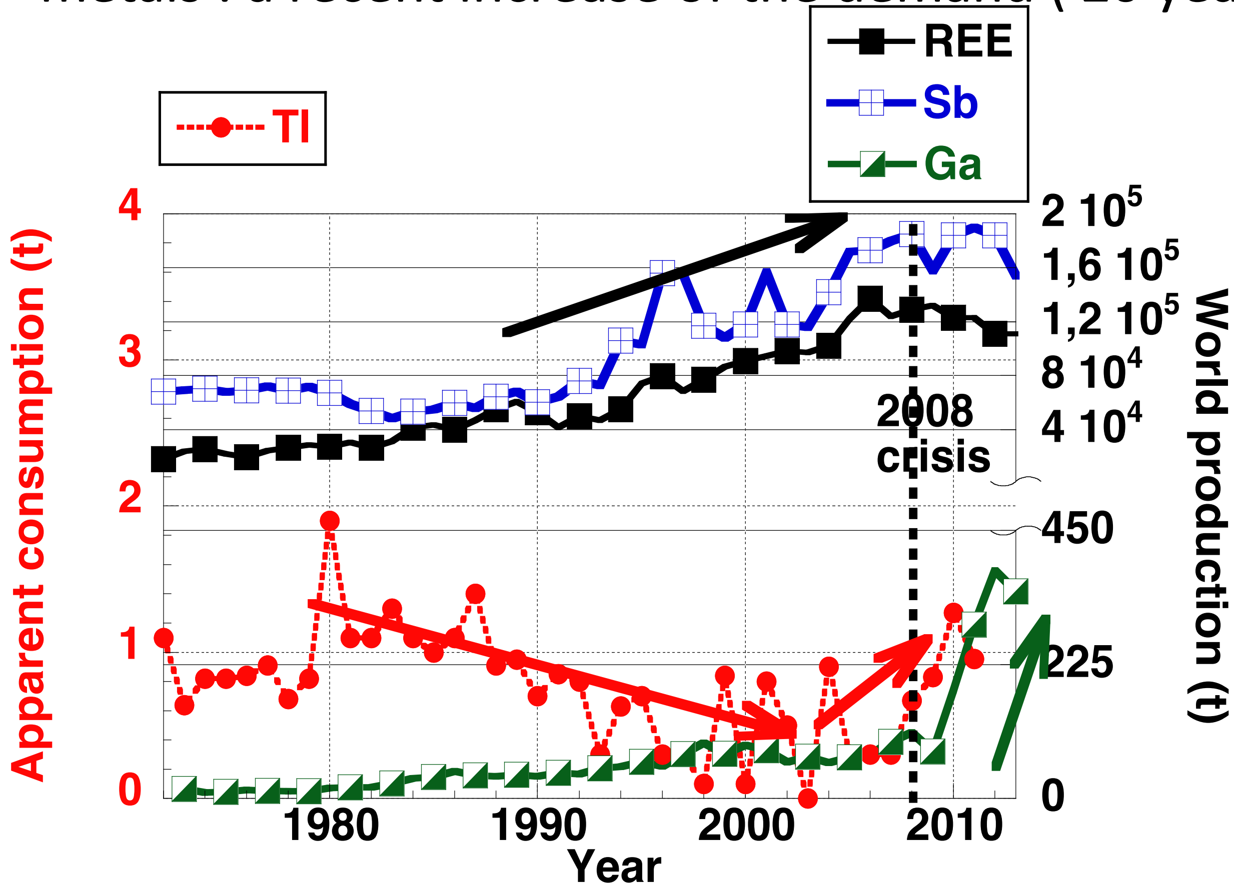
- « High-Tech » metals (HTM): recent needs



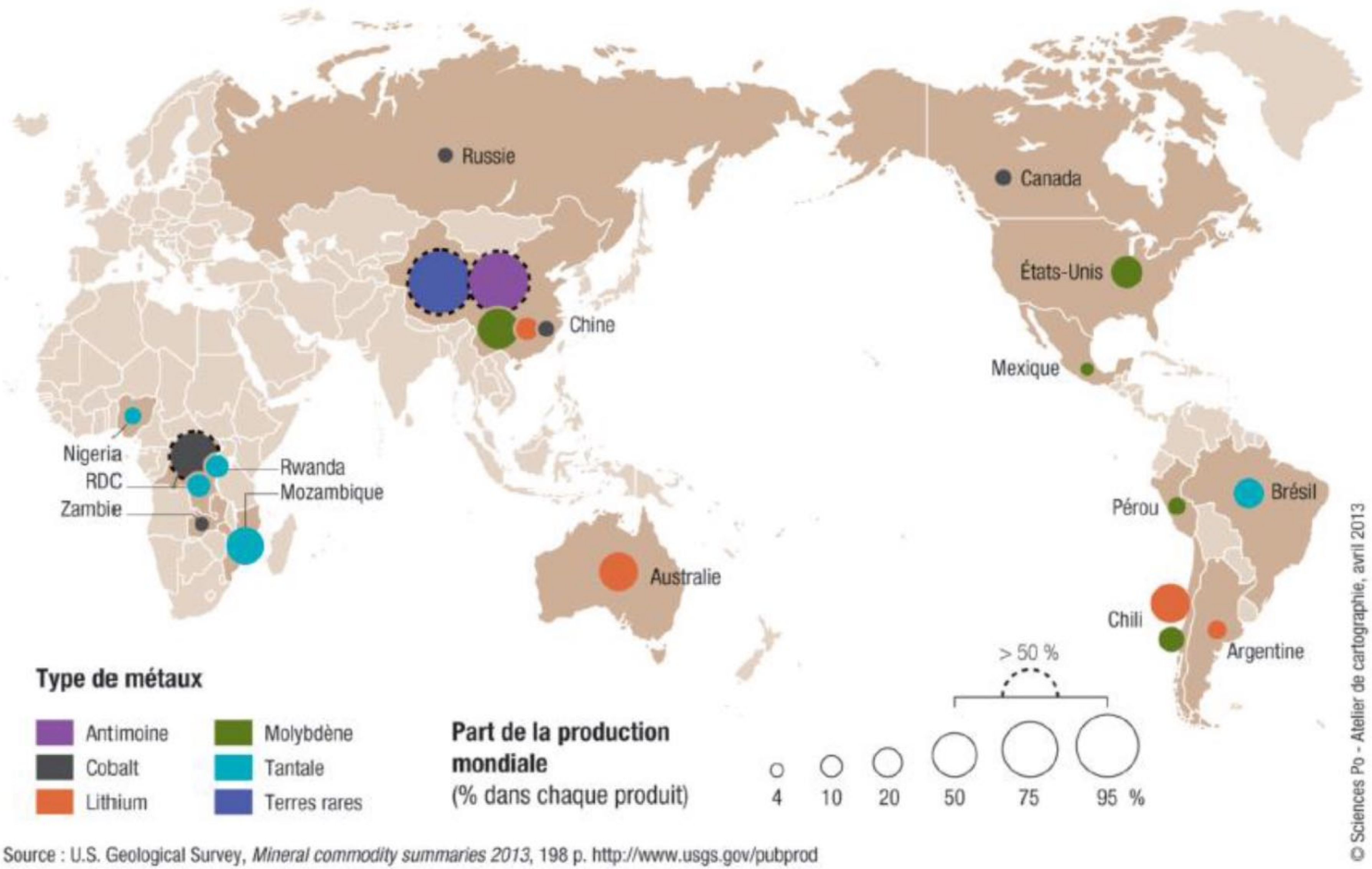
Timeline depicting the use of metals from prehistoric to modern times in Central Europe. From Wellmer and Steinbach, 2011.

«High-Tech» metals

- « High-Tech » metals : a recent increase of the demand (20 years).

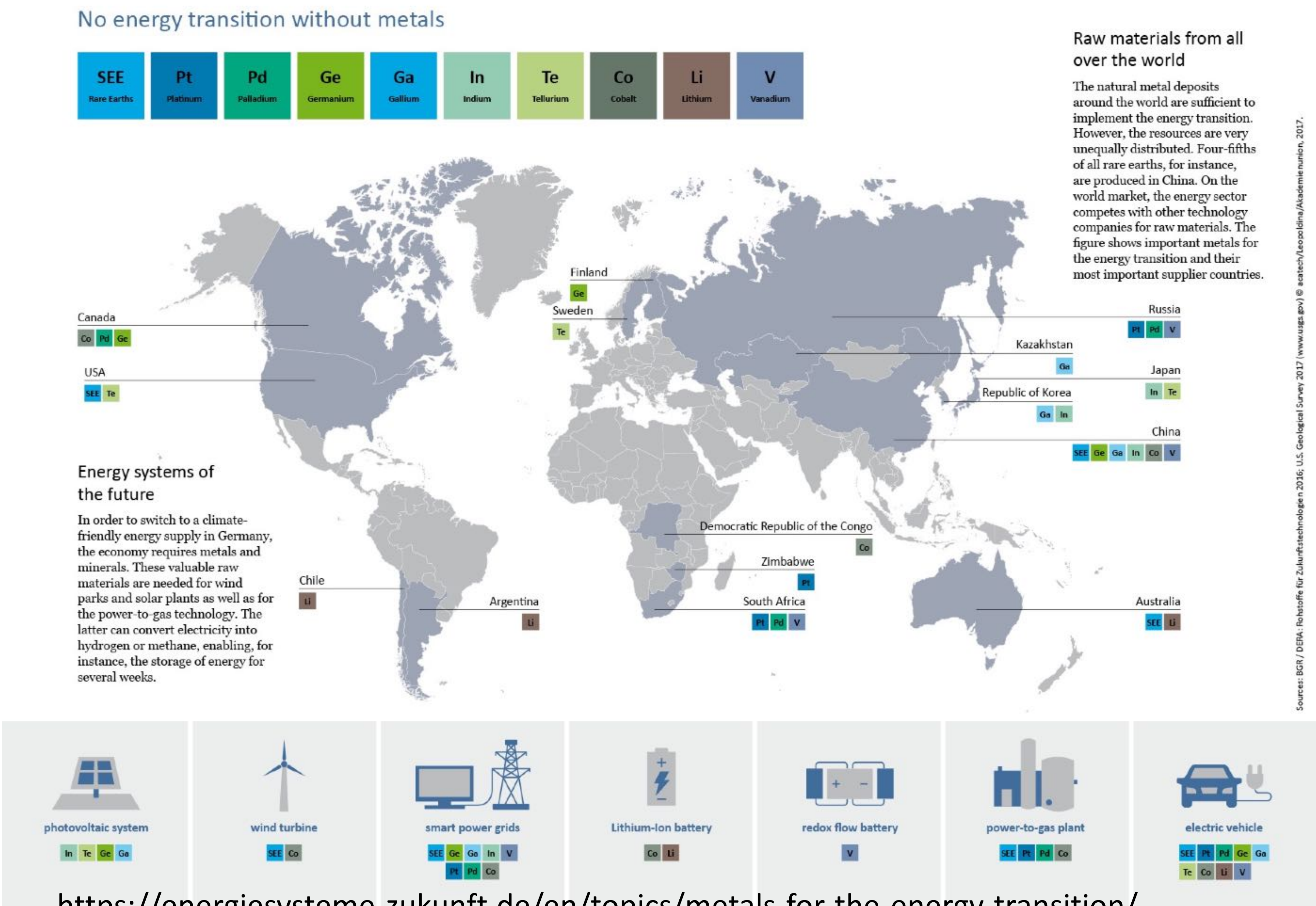


Societal and Geo-political impacts



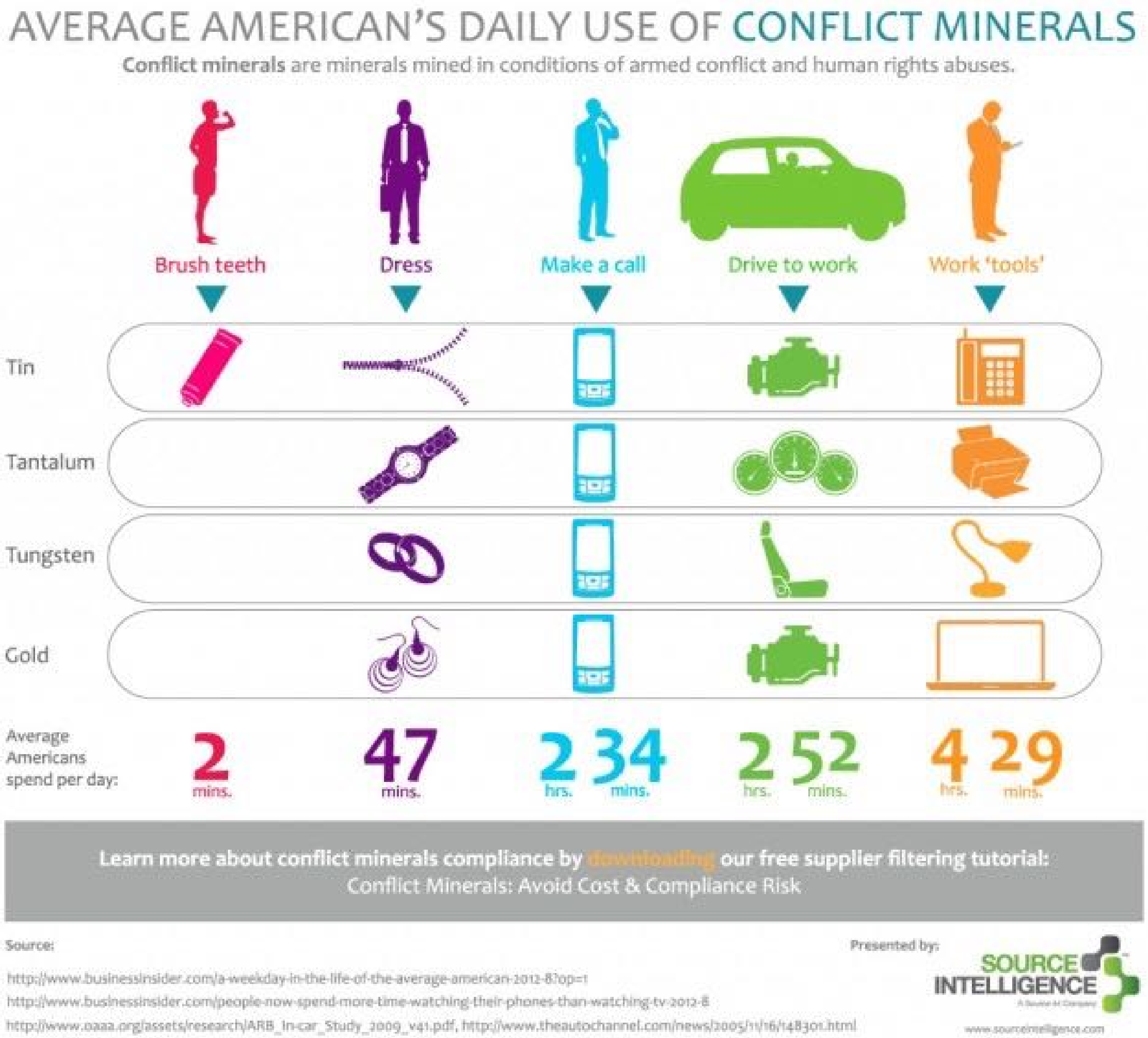
Source : U.S. Geological Survey, *Mineral commodity summaries 2013*, 198 p. http://www.usgs.gov/pubprod

Societal and Geo-political impacts



https://energiesysteme-zukunft.de/en/topics/metals-for-the-energy-transition/

Societal and Geo-political impacts



Then?

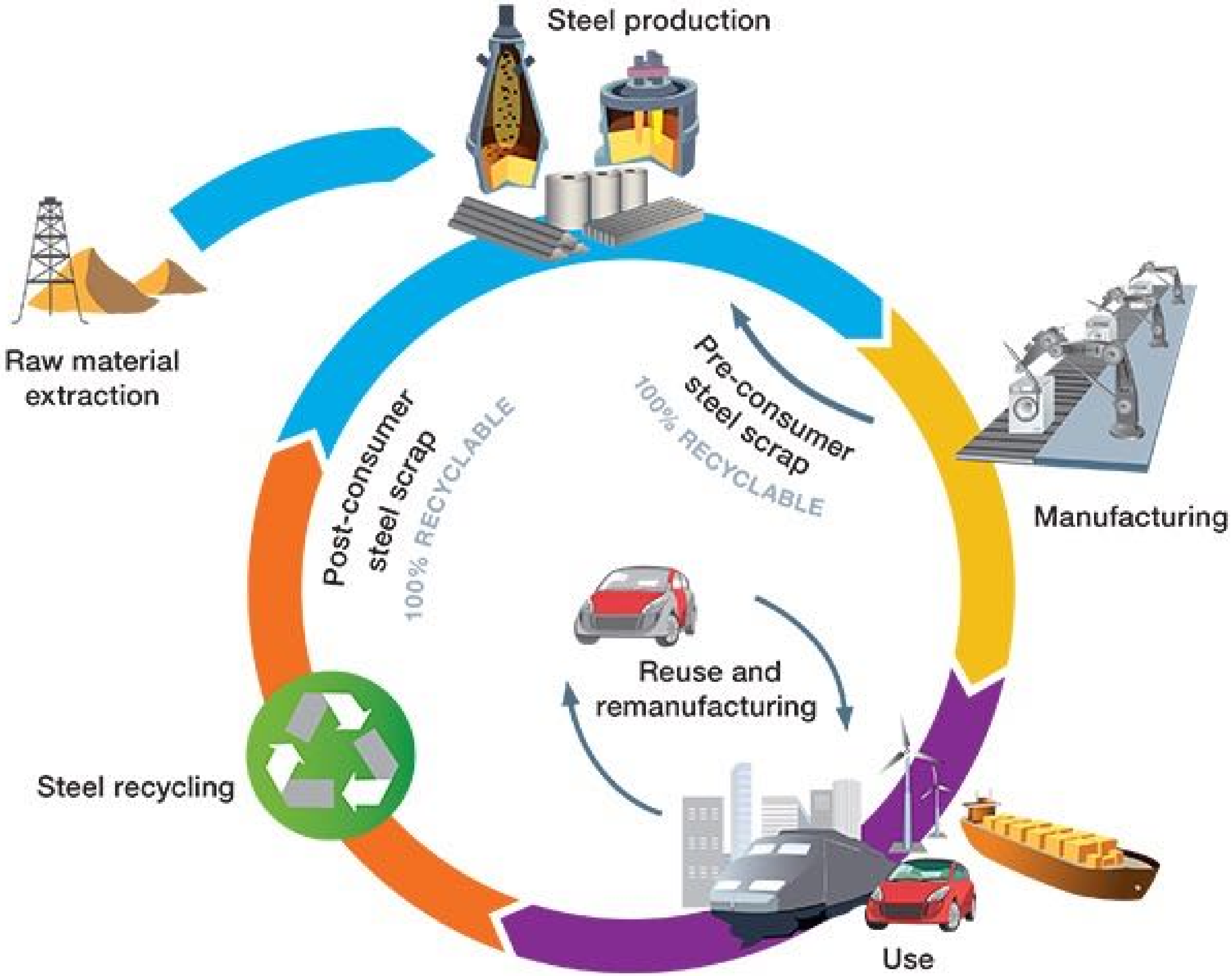
How can we reduce the human pressure on this strategic resource while reducing the environmental impact?

How can we reduce our dependence on producing countries?

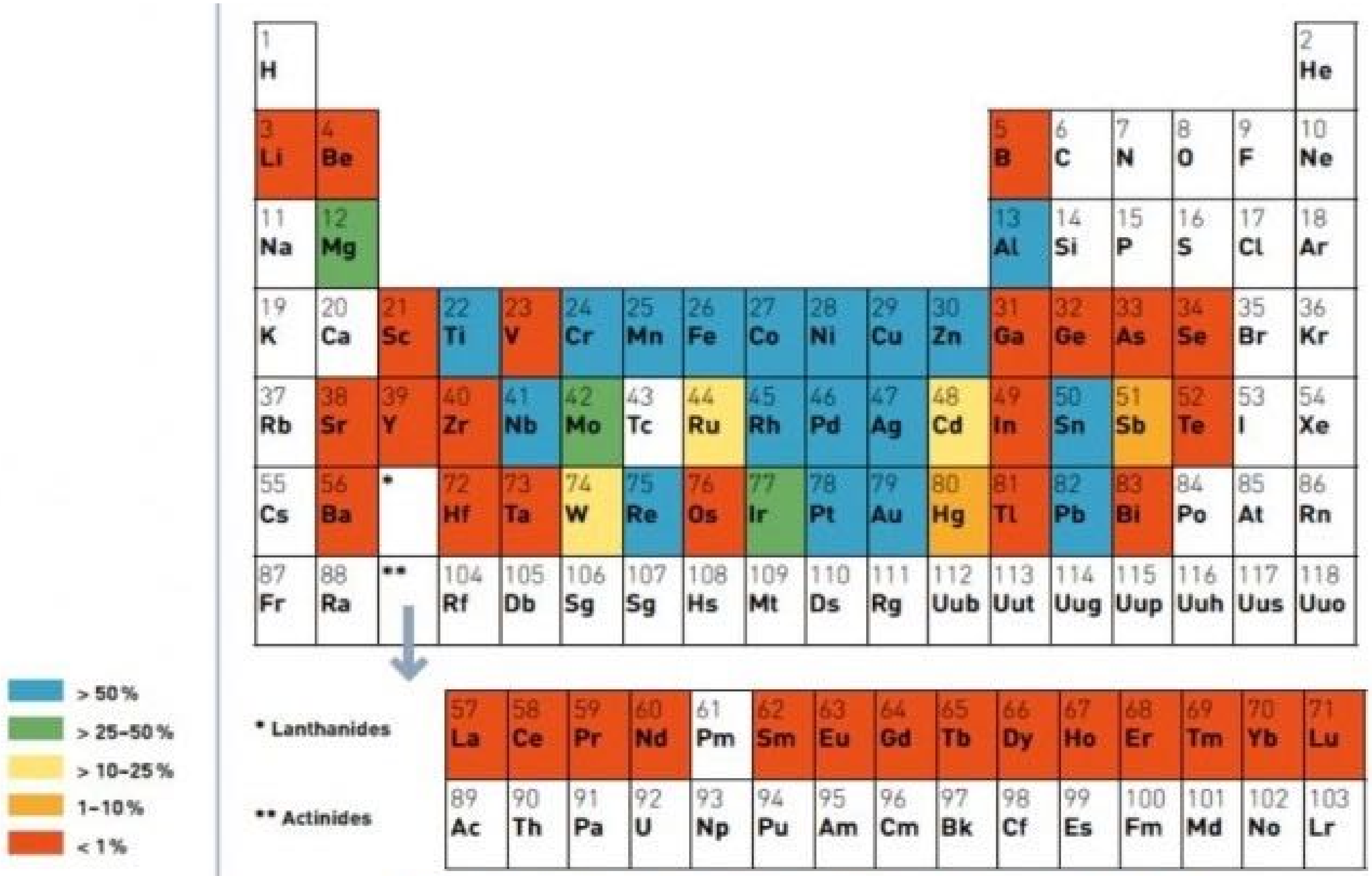
=> Exploitation of secondary sources = recycling?

In contrast to oil & gas, metals can be recycled (secondary reserves)

In contrast to oil & gas, metals can be recycled (secondary reserves)



In contrast to oil & gas, metals can be recycled (secondary reserves)



Taux de recyclage de 60 éléments à partir de produits en fin de vie.
(UNEP - 2011 - Recycling rates of metals - Graedel et al.)

Cerege

Potential for urban mining

How can we reduce the human pressure on this strategic resource while reducing the environmental impact?

How can we reduce our dependence on producing countries?

=> Exploitation of secondary sources: the urban mine

Potential for urban mining

End of life products, e.g. smartphones

- 1.5 billion phones sold worldwide in 2017!
- In France 15% of phones are recycled
- Currently only Au, Ag, Cu are recycled…

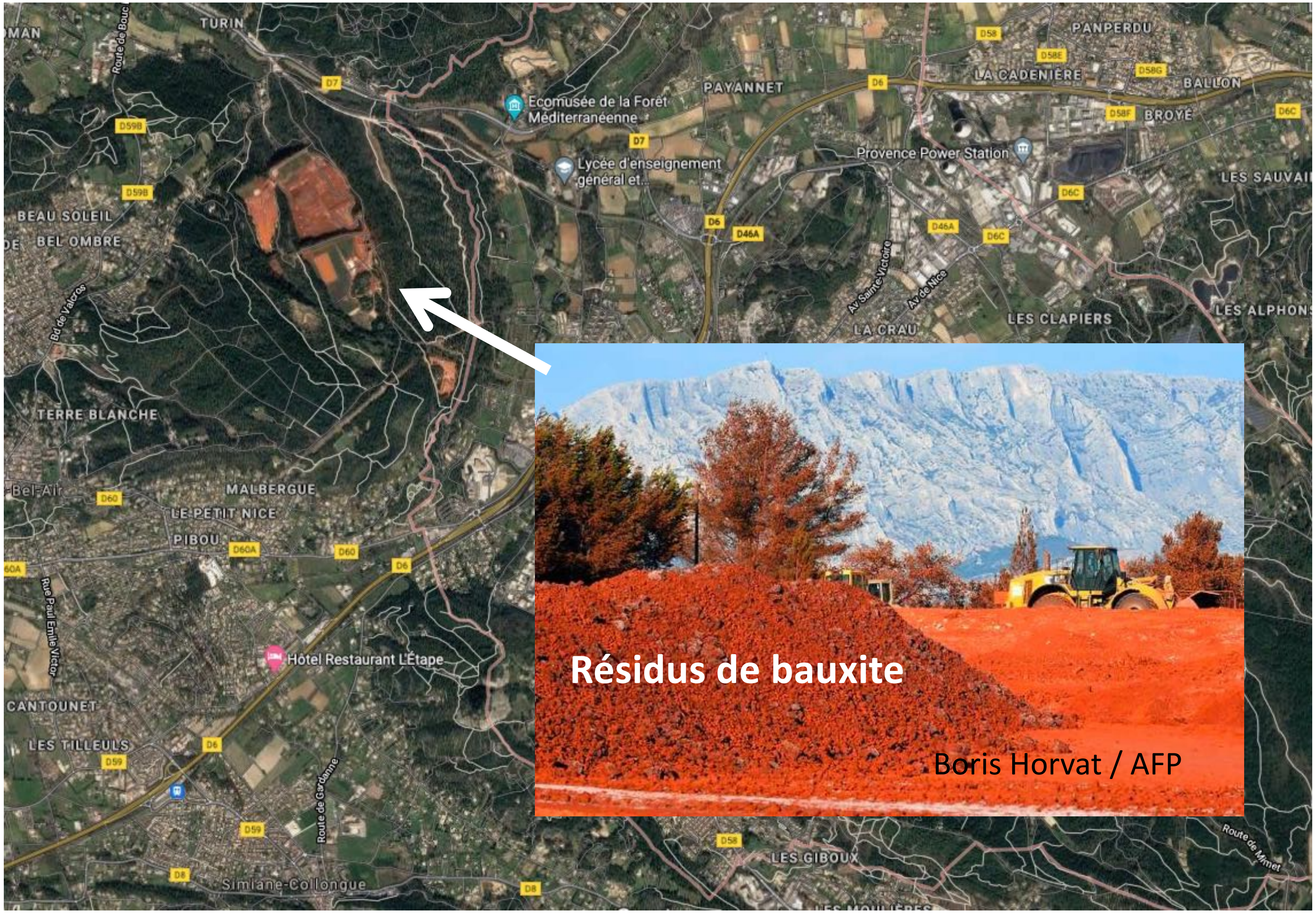

Photo: Lucas Jackson

By-products e.g. mining and industrial waste

- Very large and non-recovered tonnages
- No or little pre-treatment required before extraction
- Limited impact on the landscape

Potential for urban mining

Potential for urban mining



Issues and objective

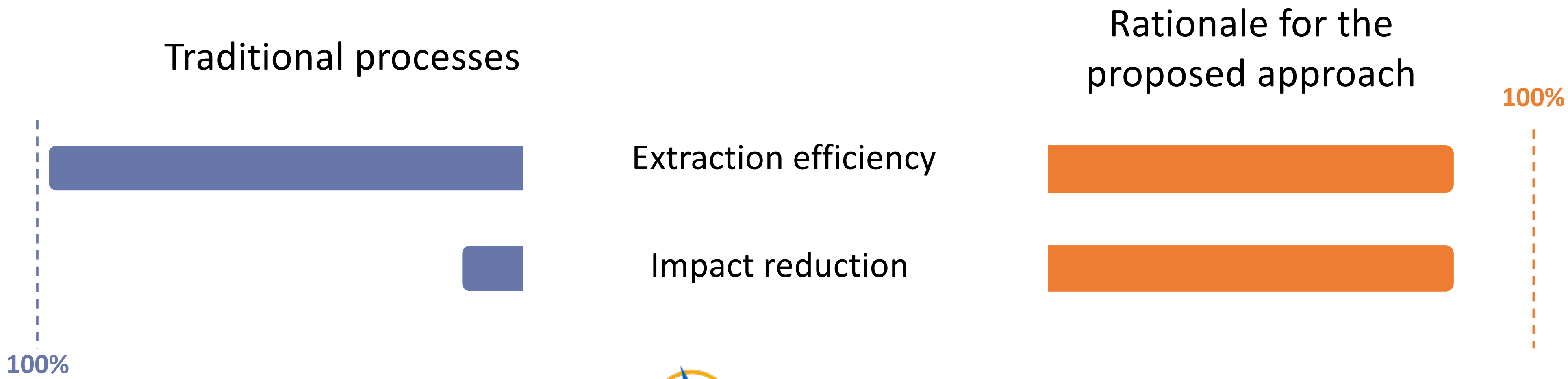
SOBRIETY !

- **Sobriety in our consumption of resources**

- **Sobriety in our production methods**
- **Sources of metals: primary sources secondary sources**
- **Extraction: Hydro-, Pyrometallurgy more sober processes**

Development of lean processes for the recovery of critical metals from secondary sources

Development of lean processes for the recovery of critical metals from secondary sources

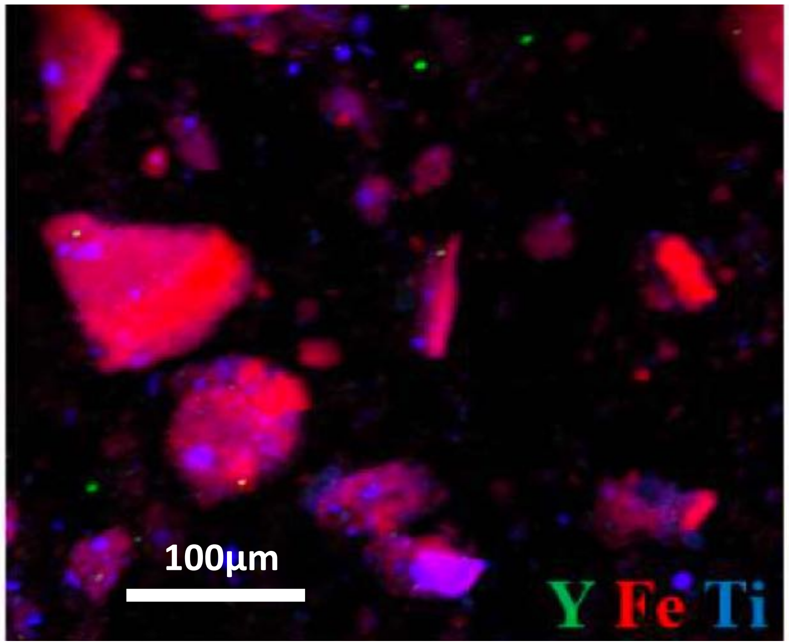


How to implement sobriety? Selectivity, bio-mimicry

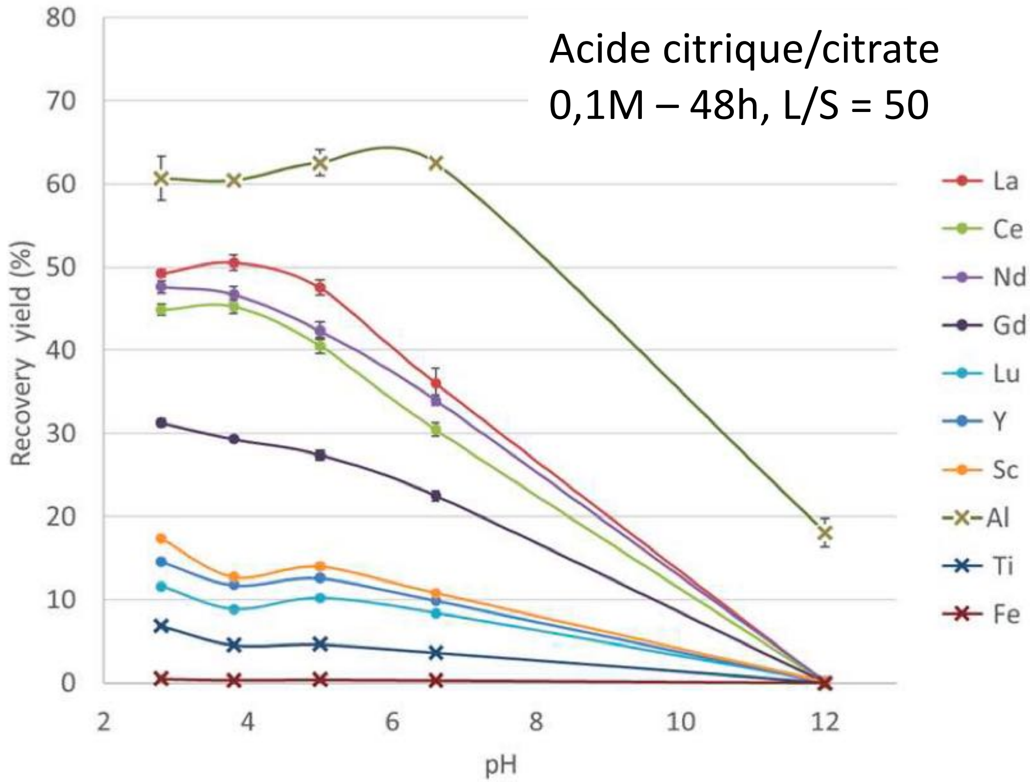
Selectivity: Reduces the number of steps
Bio-mimicry: work under environmental conditions with natural extractants

Ultimate goal: coupling of the 2: selective and bio-inspired processes

Valorisation of rare earths and iron in bauxite residues



ANR RECALL 2021-2025
Valorisation intégrée des résidus de bauxite



Comment améliorer la sélectivité ?

Ability of living organisms to selectively use/concentrate critical metals

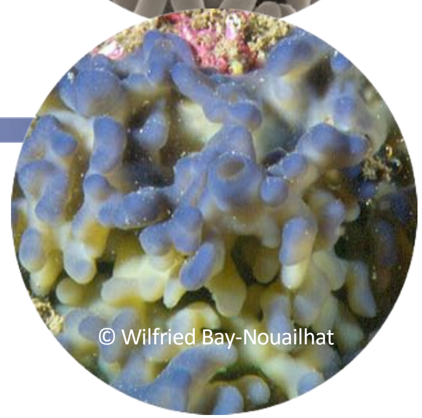
Dicranopteris linearis

- Hyper accumulator of rare earths
- Accumulates up to several thousand ppm in the leaves

Pseudomonas Putida

- Use of light REE (l) for enzymatic reactions
- Ln-dependent enzyme identified

Oscarella lobularis



- Sponge that bioconcentrates vanadium
- Bioconcentration mechanism not studied

The mineral resource, interdisciplinary issues

How to turn a threat into an opportunity?

- Low societal acceptability of industrial activity
- Potential contamination by dust contamination
- Strong public mobilisation against tailings storage

- Abandonment of the population at the closure of the mine
- Health impacts on local populations
- Environmental contamination

MITIGATING CLIMATE CHANGE: we can find solutions!

Les arbres à la rescousse de la biodiversité et des rendements agricoles

http://www.up-magazine.info/index.php/planete

Les réseaux sociaux au secours des océans du monde

Pour lutter contre la surpêche, diversifions nos assiettes

Protection du littoral : Wave Bumper, l'innovation anti submersion marine

50 mesures pour une consommation et une production durables

Les jeunes qui ont manifesté ce 15 mars dans tous les grands pays du monde pour le climat ont montré leur détermination mais aussi leur sens des formules chocs. L'une d'entre elles fleurissait sur les pancartes brandies. Nous l'adoptons pour rendre compte d'un rapport (un autre, encore) publié par l'ONU sur l'état de l'Arctique. Un rapport alarmant qui ne peut malheureusement se résumer que par une formule : c'est cuit. Il est déjà trop tard pour l'Arctique qui se réchauffera de 3 à 5° C d'ici seulement 25 ans, le temps d'une génération. De cette génération qui s'insurge contre un scénario inéluctable : montée des eaux, emballement climatique et menaces sur l'ensemble de la planète.

http://www.up-magazine.info/index.php/planete/climat/8519-les-calottes-sont-cuites

Thank you !

http://www.aixenprovence
tourism.com

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