Matières premières et énergie

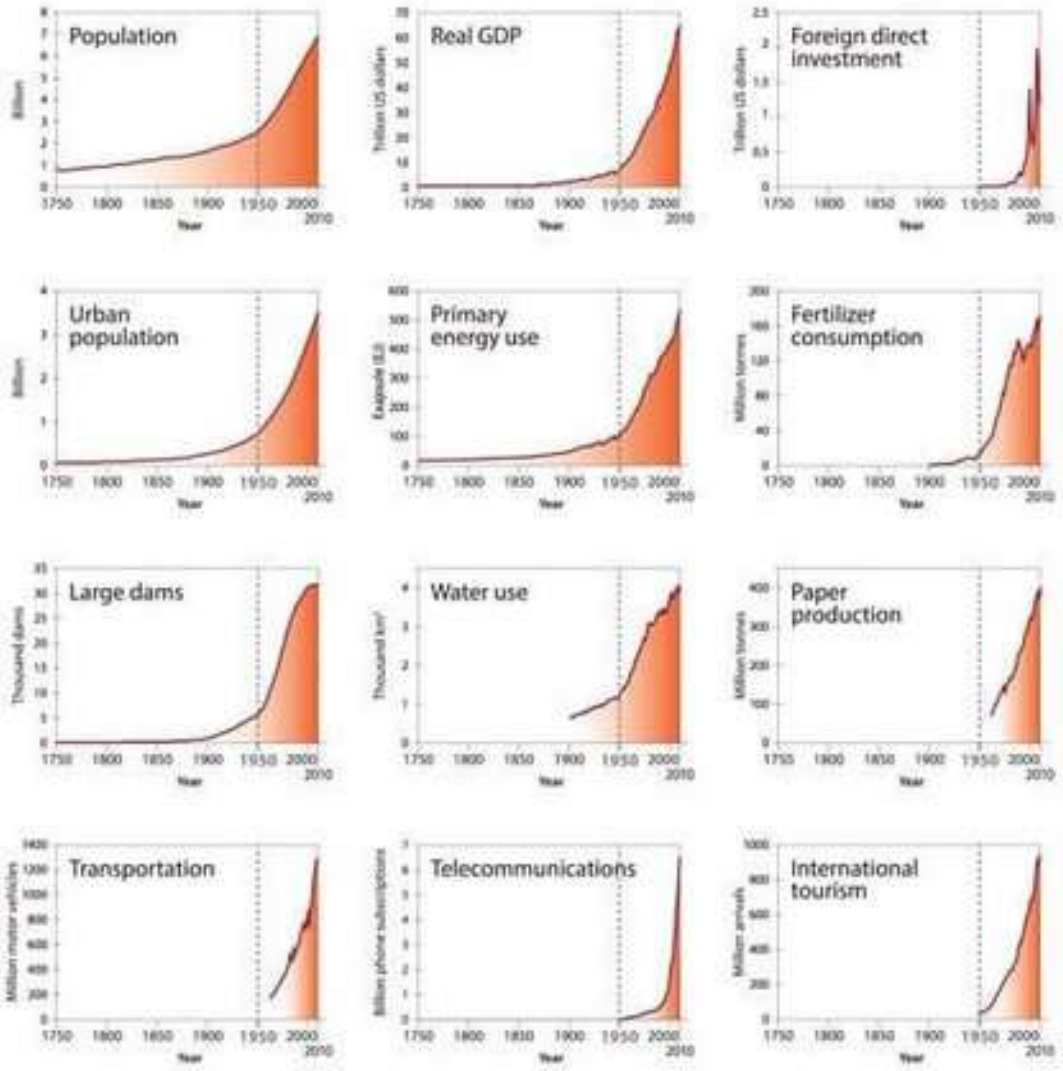
Colloque des départements MT2E

9 juin 2022

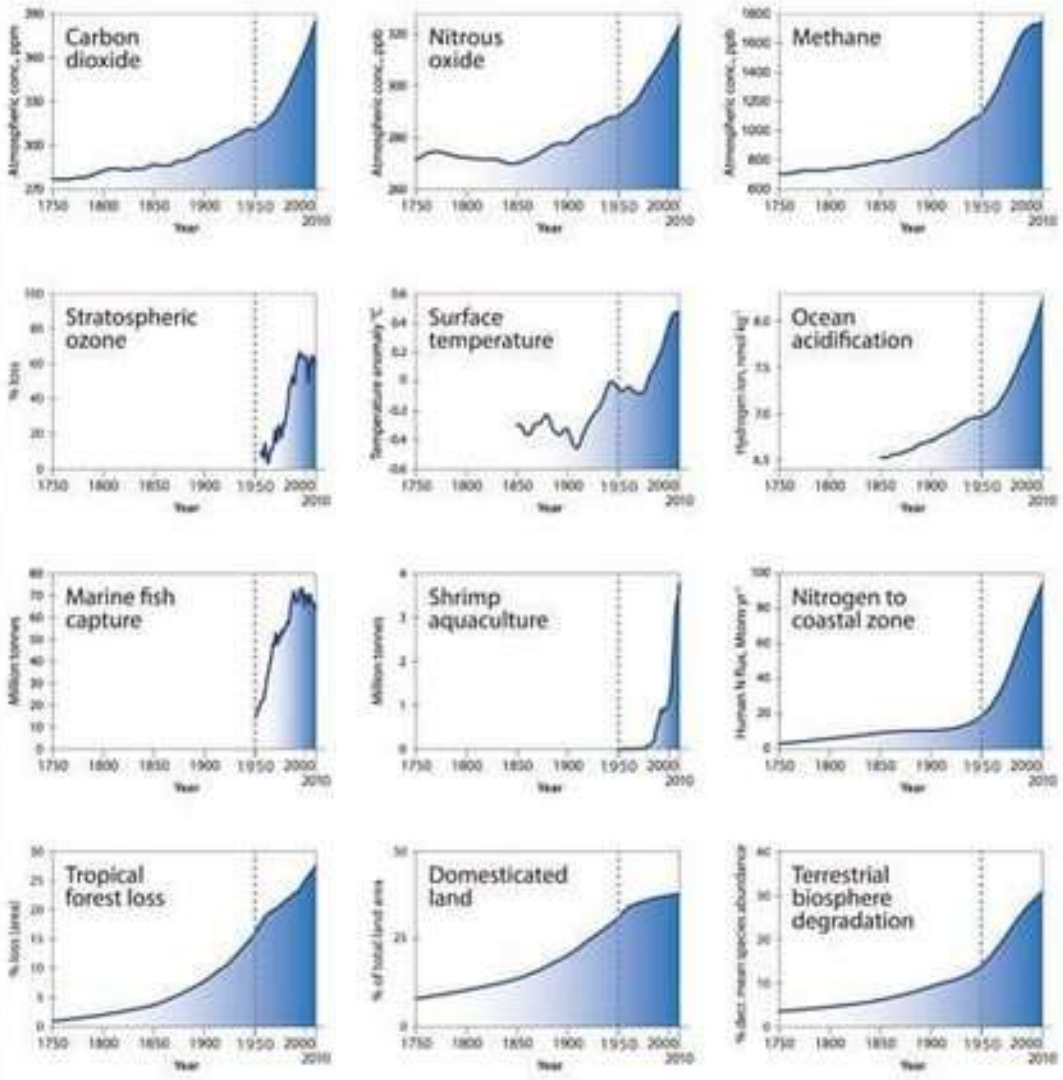
Baptiste Andrieu
baptiste.andrieu@theshiftproject.org

Dillon Marsh – Mine de cuivre Nanabeep (Afrique du Sud)

Socio-economic trends



Earth system trends



Updated Great Acceleration Graphs

Source: Will Steffen et al. "The trajectory of the Anthropocene: The Great Acceleration." The Anthropocene Review, March 2015


GLOBAL ANNUAL PRODUCTION
CEMENT
Height 1,195 m
Volume 1.7 billion m³
Weight 4.1 billion tonnes
Burj Khalifa, Dubai
830 m
STEEL
Height 610 m
Volume 227.8 million m³
Weight 1.8 billion tonnes
SAND/GRAVEL
Height 555 m
Volume 171.0 million m³
Weight 265 million tonnes
Cement makes up the concrete foundations of our buildings along with the streets and sidewalks we drive and walk on.
Steel's strength is essential for the frames and roofs of buildings, along with bridges, tunnels, and railways.
Industrial sand/gravel contains silica which allows it to make glass along with other construction materials like metal castings, flooring compounds, and roofing shingles.
Source: U.S. Geological Survey
ELEMENTS
The Earth's natural resources power our everyday lives. VC Elements breaks down the building blocks of the universe.
We live in a material world.

All the Metals We Mined

IN ONE CHART

Total Metals 3,248,814,334 tonnes

Metals are the building blocks of the global economy,
From iron ore to rare earths, here are all the metals we mined in 2019.

Metals vs. Ores

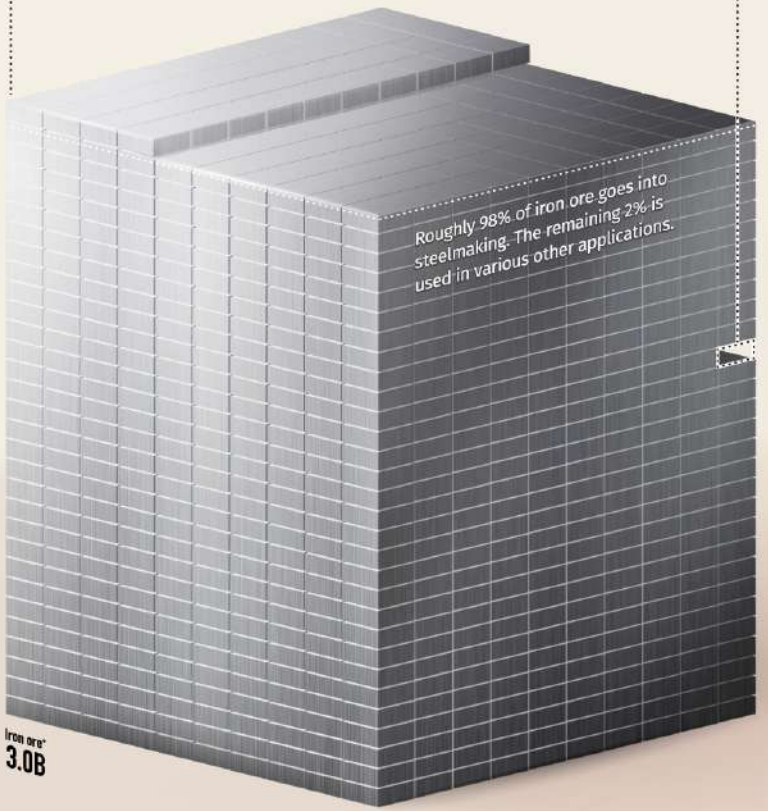
Ores are naturally occurring rocks that contain metals or metal compounds.

Metals are the valuable parts of ores that can be extracted and sold.

Iron ore*
3,040,000,000 tonnes

Iron ore made up roughly 94% of the 3.2 billion tonnes of metals mined in 2019.

= 1,000,000 tonnes



Industrial metals
207,478,486 tonnes

Aluminum is the world's second-most used metal after iron, found in everything from electronic devices to aircraft parts.

Copper production is one-third that of aluminum, though it has several uses ranging from wiring to construction.

Manganese is mainly used in iron and steel manufacturing and is a key ingredient in lithium-ion batteries.

Chromium enhances the hardenability and corrosion resistance of stainless steel.

Tech and precious metals
1,335,848 tonnes

Niobium is a rare metal used in superalloys for jet and rocket engines.

Lithium and cobalt are critical ingredients of lithium-ion batteries for electric vehicles.

Indium is used to make indium tin oxide, an important part of touch screens, TVs, and solar panels.

ELEMENTS
elements.visualcapitalist.com

The Earth's natural resources power our everyday lives. VC Elements breaks down the building blocks of the universe.

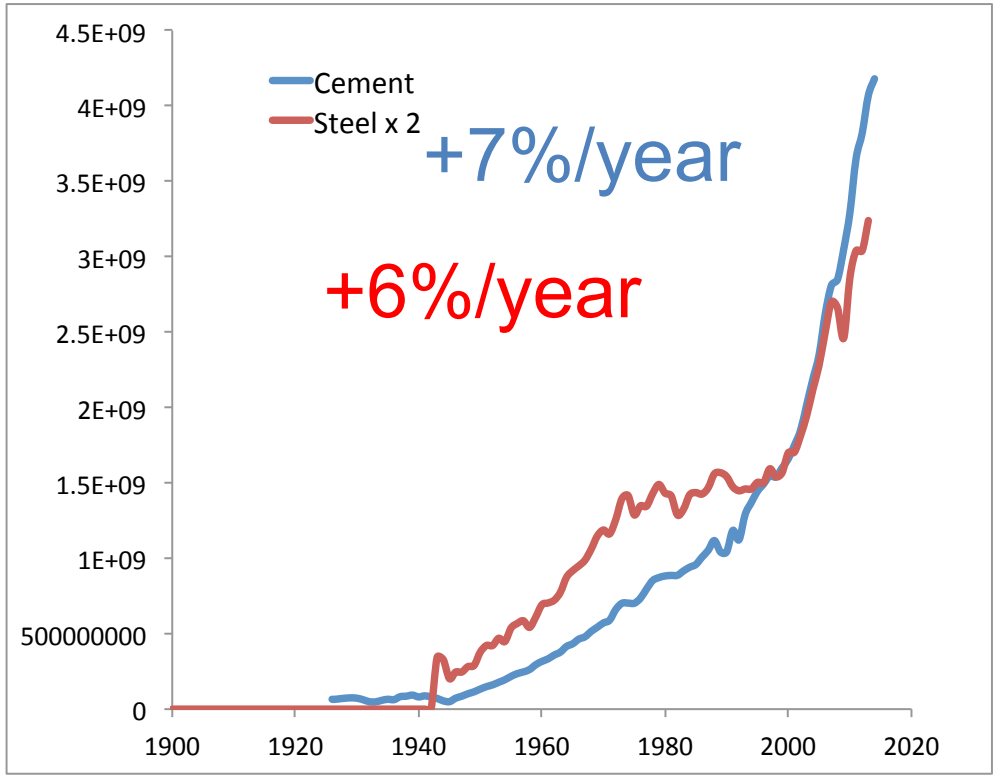
Source: British Geological Survey (2019), USGS Mineral Commodity Summaries (2021)

**Ore production does not reflect actual metal production as metals only make up a certain portion of ores. Graphic excludes semi-metals and metalloids. Hafnium is contained in Zircon.*

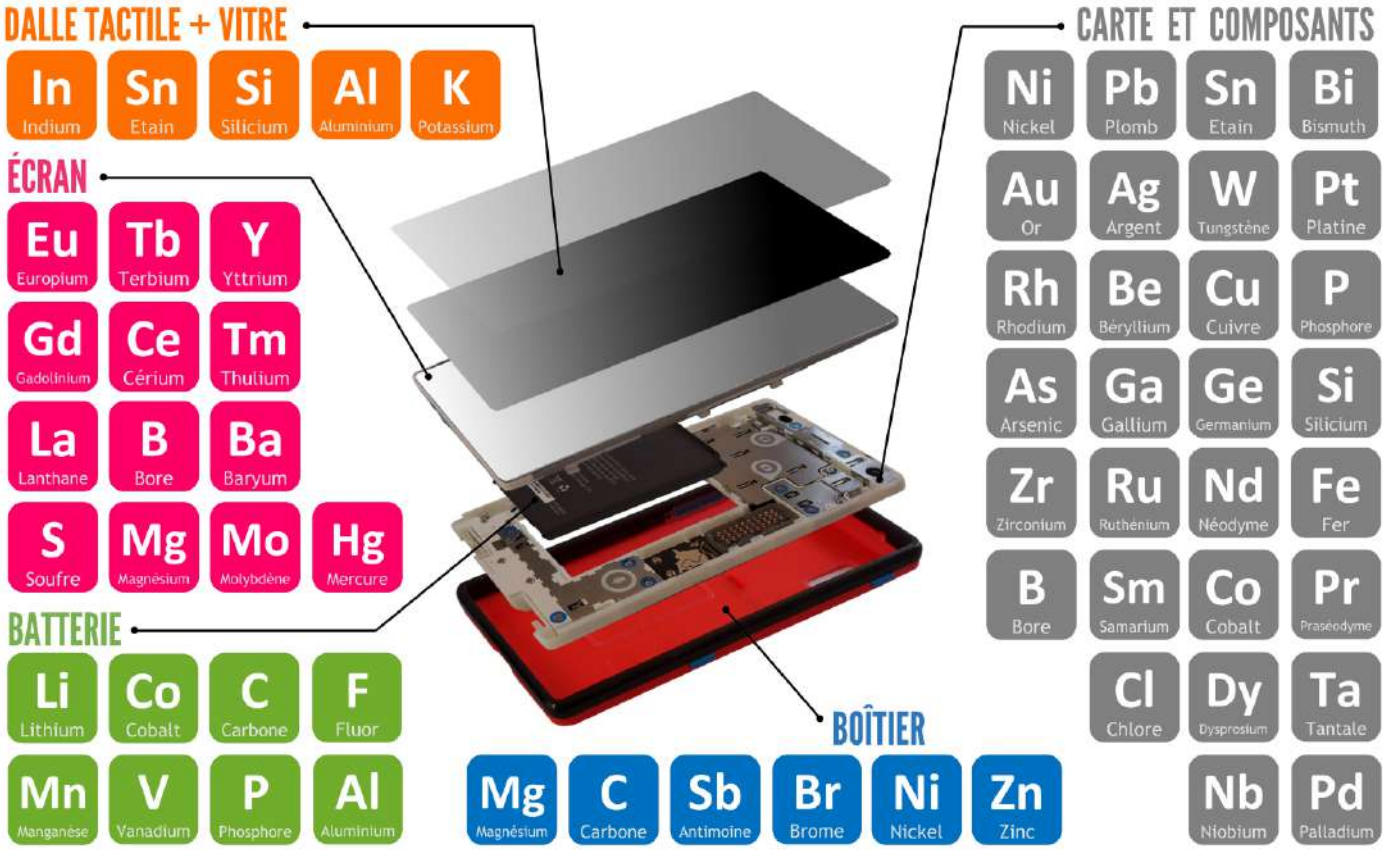
We live in a material world.

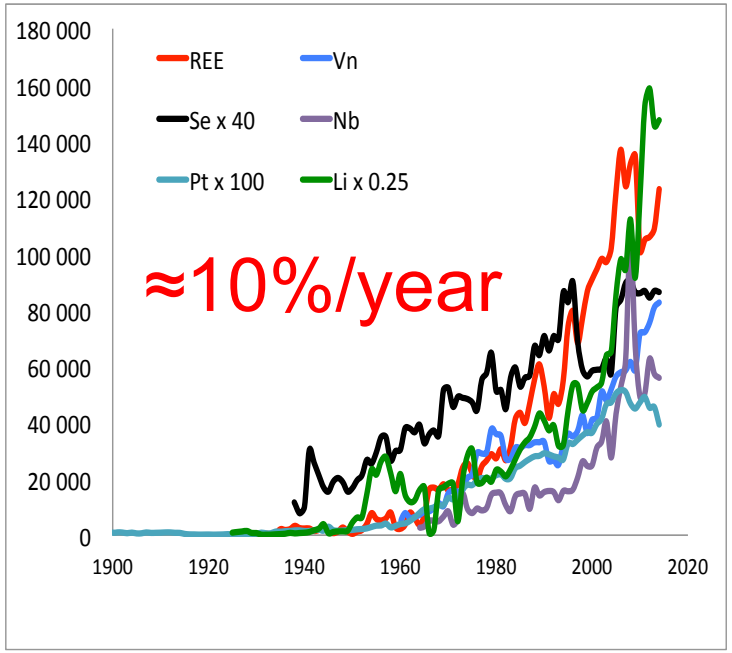
Structural raw materials – concrete, steel, Al, Cu

$(1.07)^{10\text{years}} = 2$



High Tech metals





Source: SystExt Outil | Des métaux, pas que dans les smartphones

Quelle place pour la transition énergétique ?

À boire, à boire !

[…] « Historique », c'est ainsi qu'avait été saluée la découverte de pétrole au large de la Guyane […] Selon les dernières données de Shell, le bassin pétrolier guyanais comporterait 700 millions de barils

Libération, 28/06/2012

En combien de temps l'humanité consomme-t-elle cette quantité de pétrole actuellement ?

- **A : 10 ans**
- **B : 1 an**
- **C : 1 mois**
- **D : 1 semaine**

Infographie:
Avenir Climatique

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Infographie:
Avenir Climatique

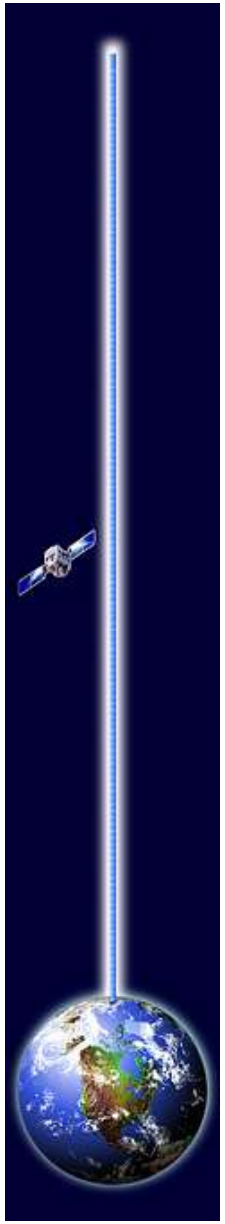
Notre dépendance aux énergies fossiles

159 litres
50 par 80 cm

100 millions
barils/jour

80 000 km de
haut

Terre-Lune en 5
jours :
384 400 km



Source: **P. Adams Schwertransporte, LinkedIn** “Finishing the year with a set of 67m rotor blades on a challenging route”

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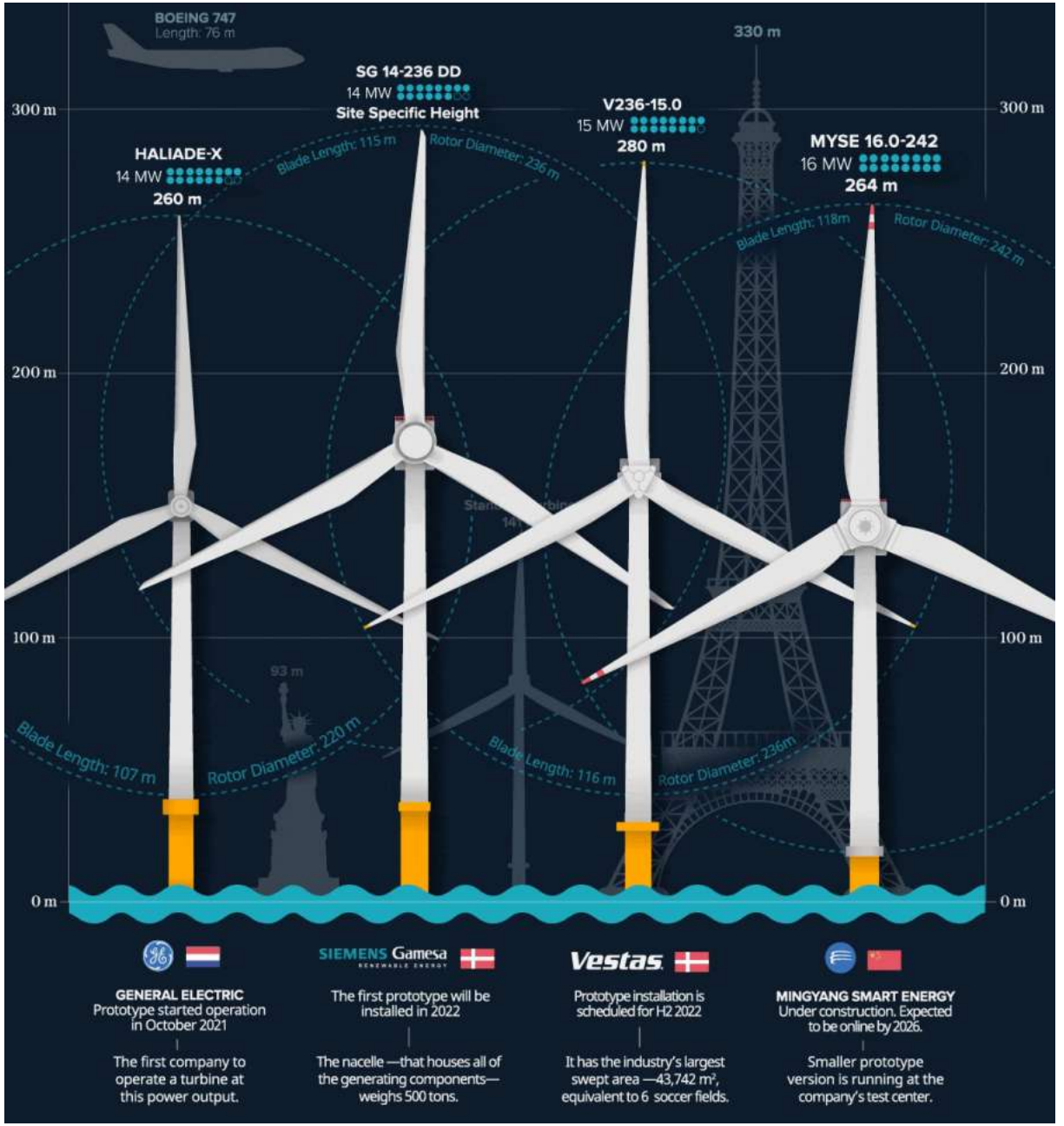
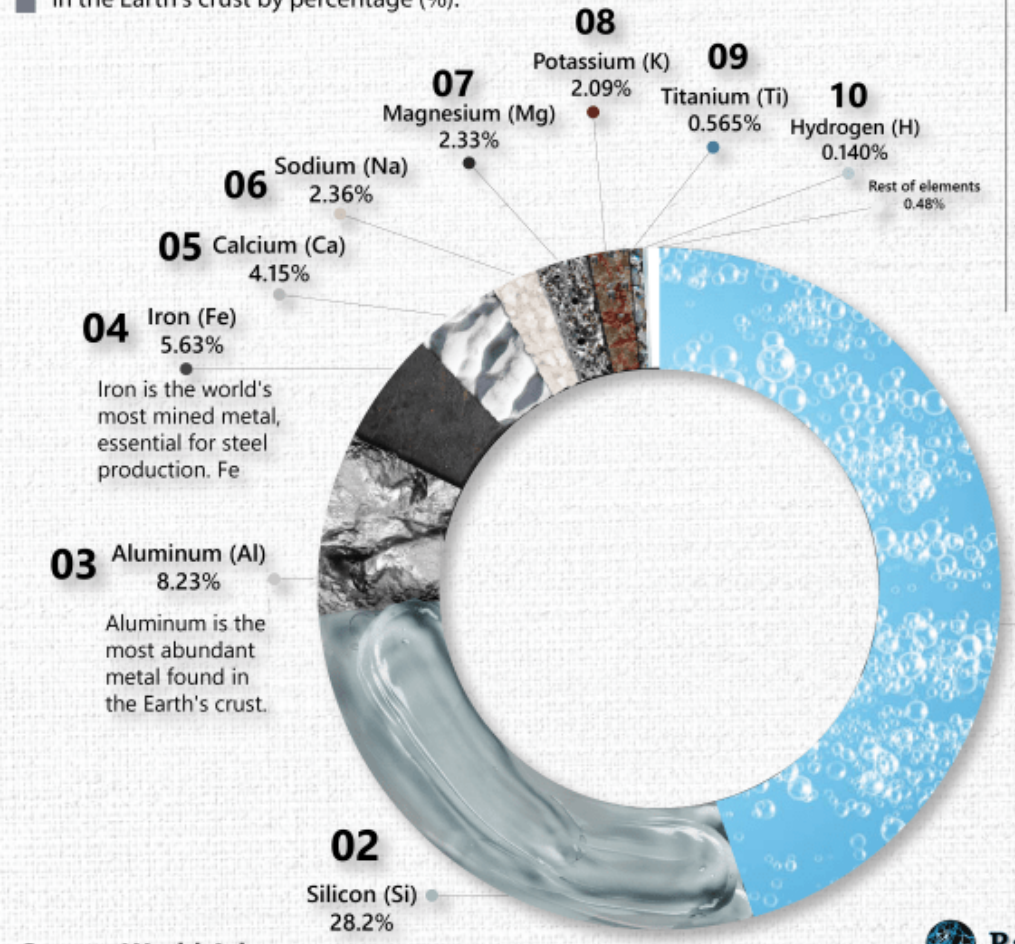


Infographie:
Visual capitalist

Vers une pénurie de métaux?

Most Common Elements in Earth's crust

The Earth's crust is only 1% of the planet's volume but it contains the materials we use everyday. Here is the abundance of elements in the Earth's crust by percentage (%).



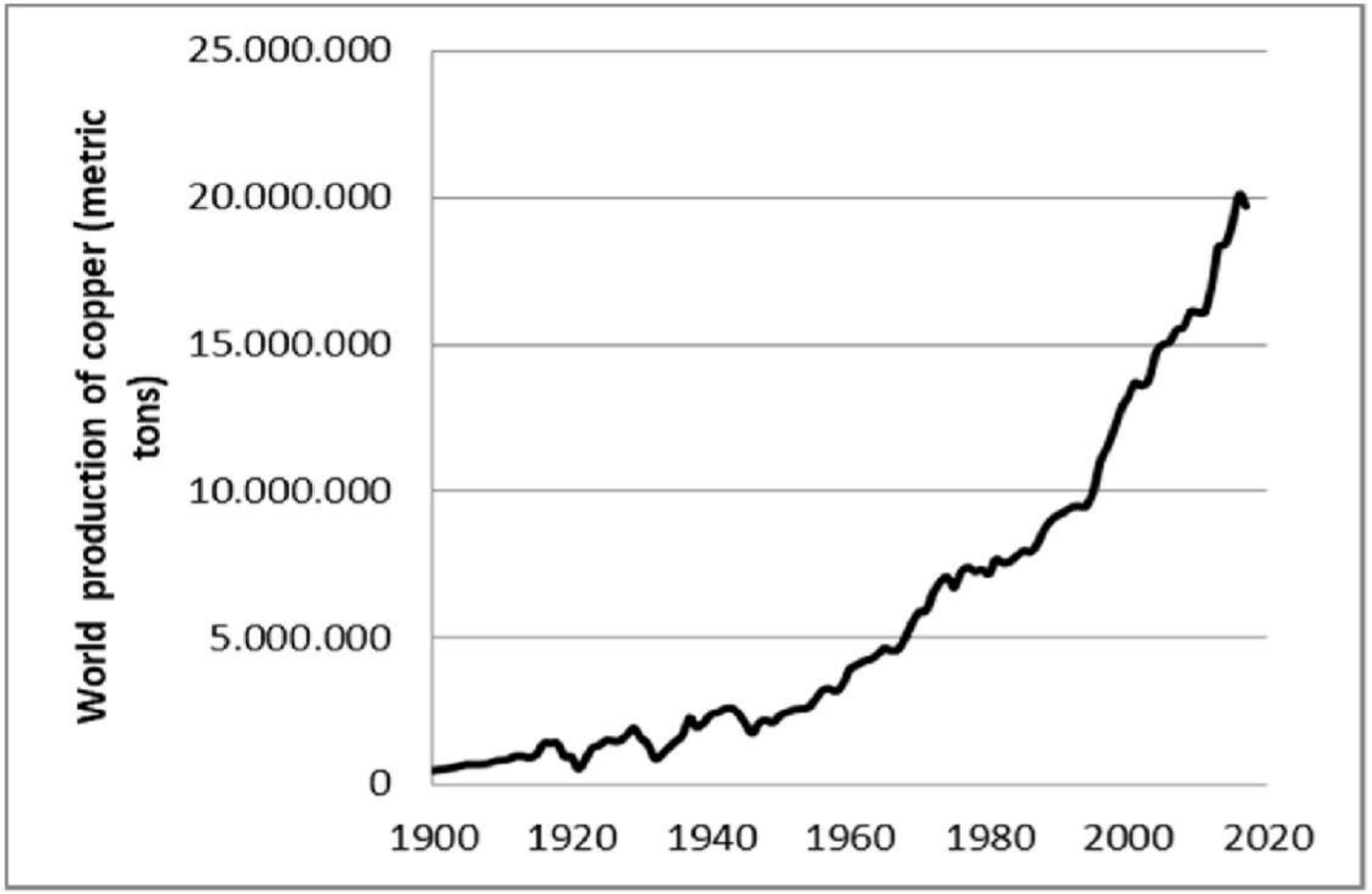
While gold, silver, copper and other base and precious metals are among the most sought after elements, together they make up less than 0.03% of the Earth's crust.

Copper: 0.006%
Zinc: 0.007%
Nickel: 0.0084%
Gold: 0.000004%
Silver: 0.0000075%
Platinum: 0.0000005%
Palladium: 0.0000015%

Source: World Atlas

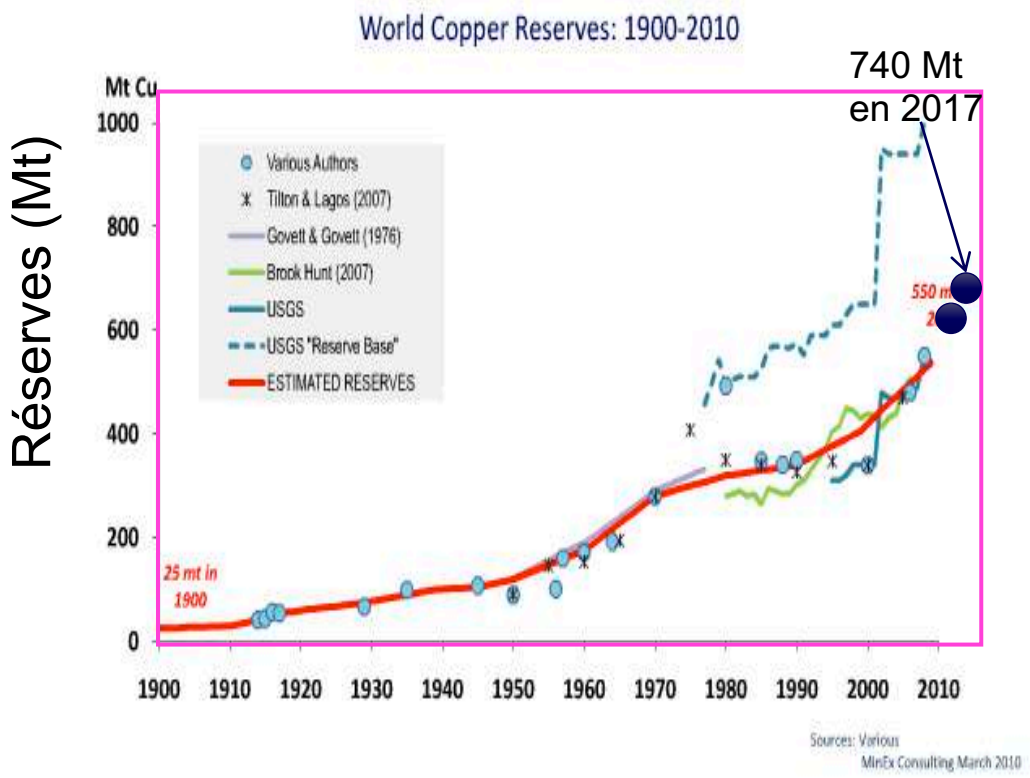
RankingRoyals

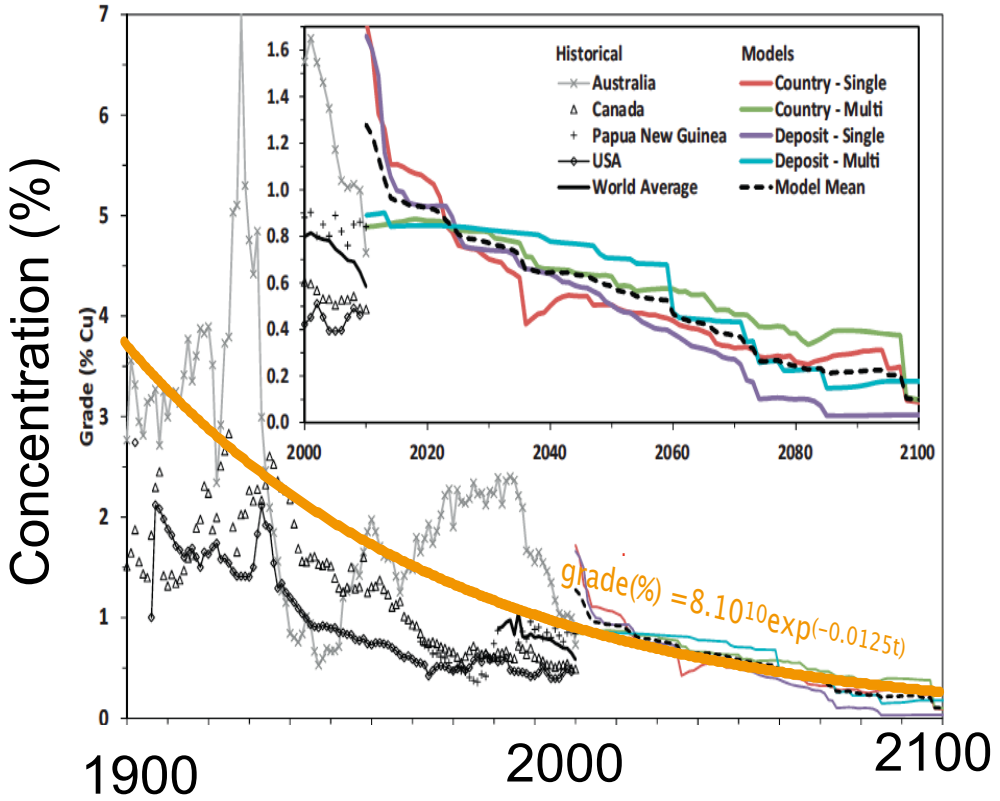
Exemple du Cuivre

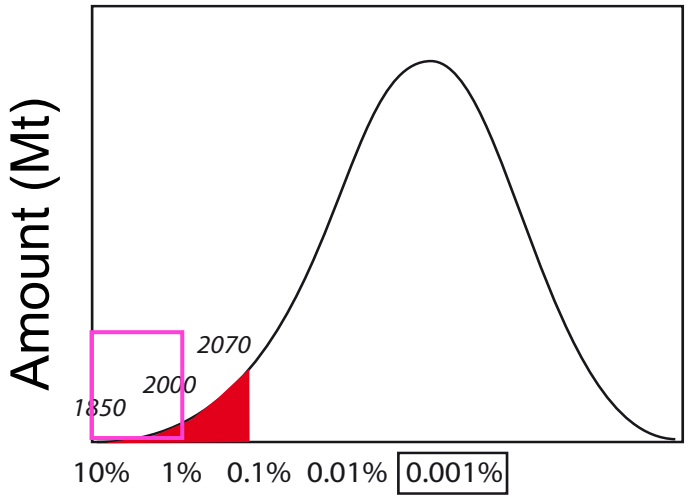


Source: Henckens et al. 2020

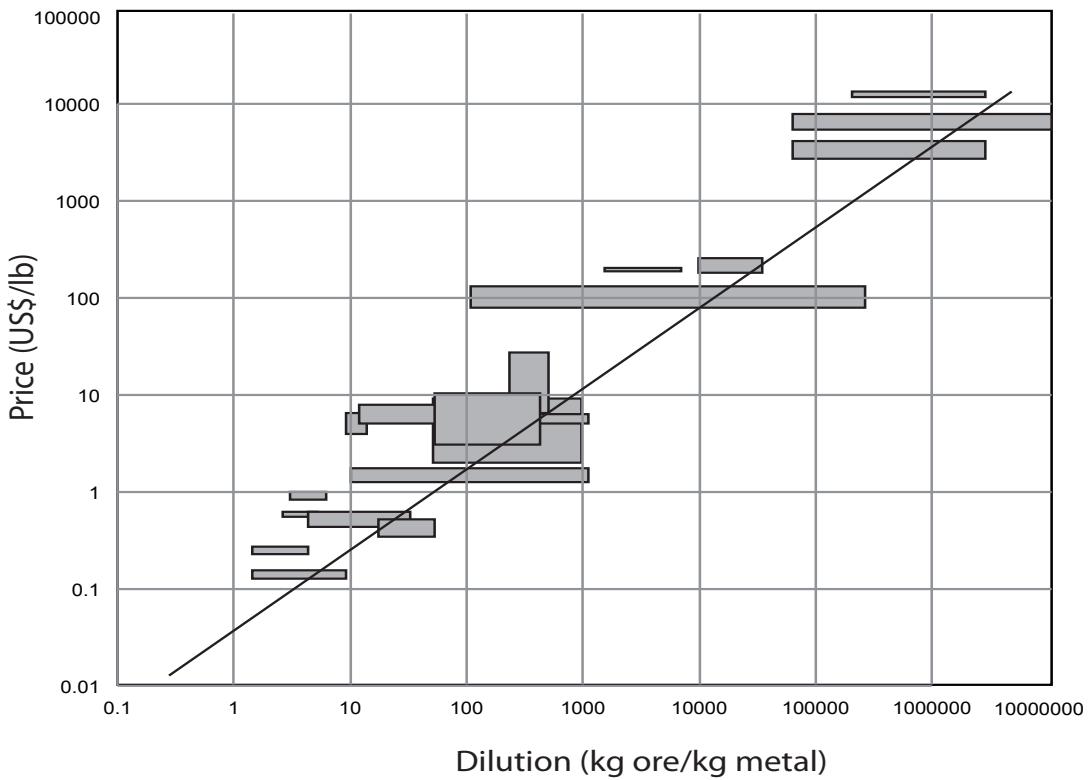
Cu reserves have been growing because the average ore grade of exploited deposits has been decreasing

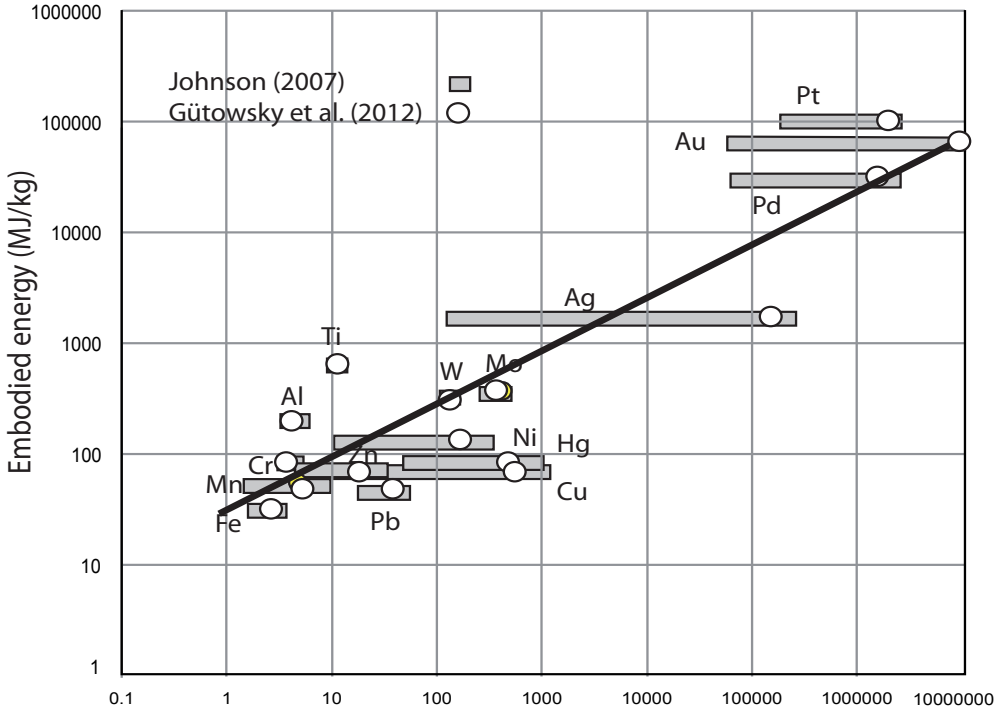




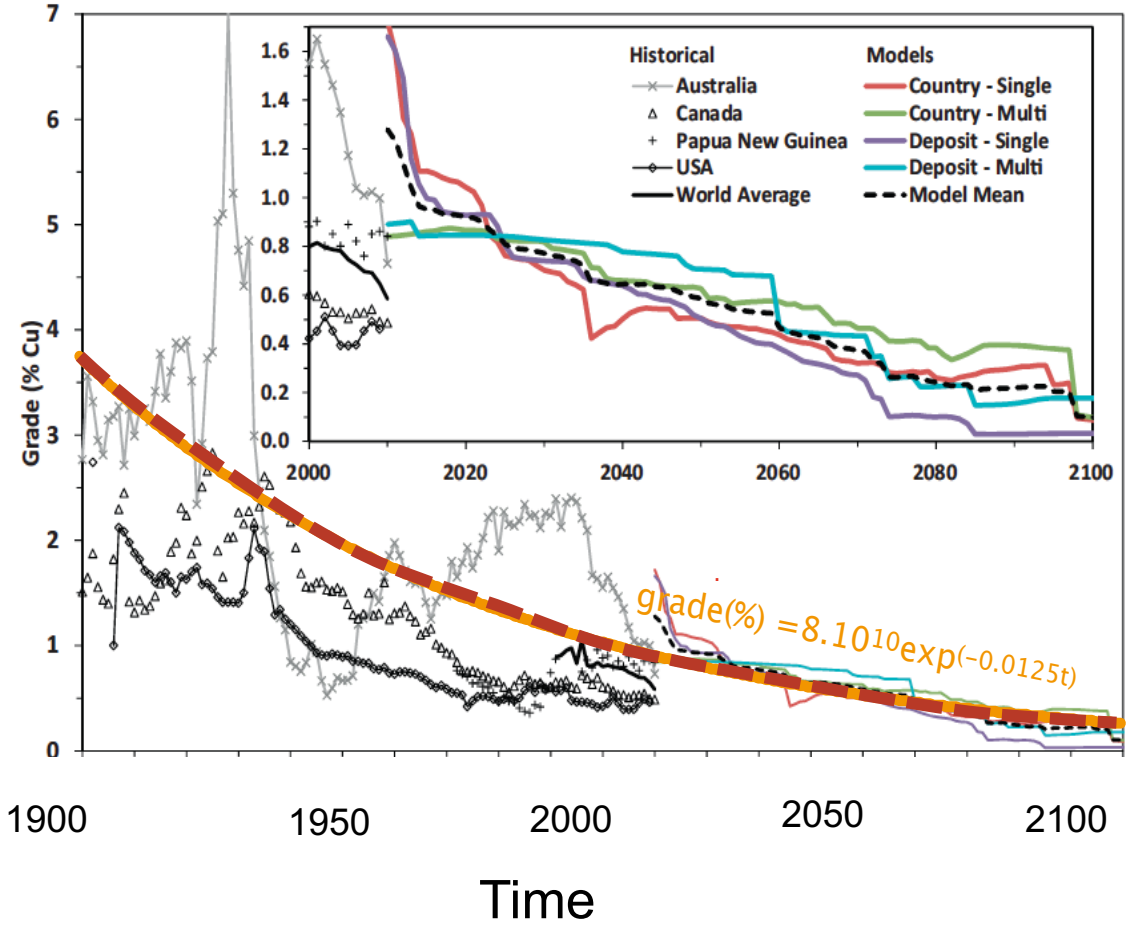


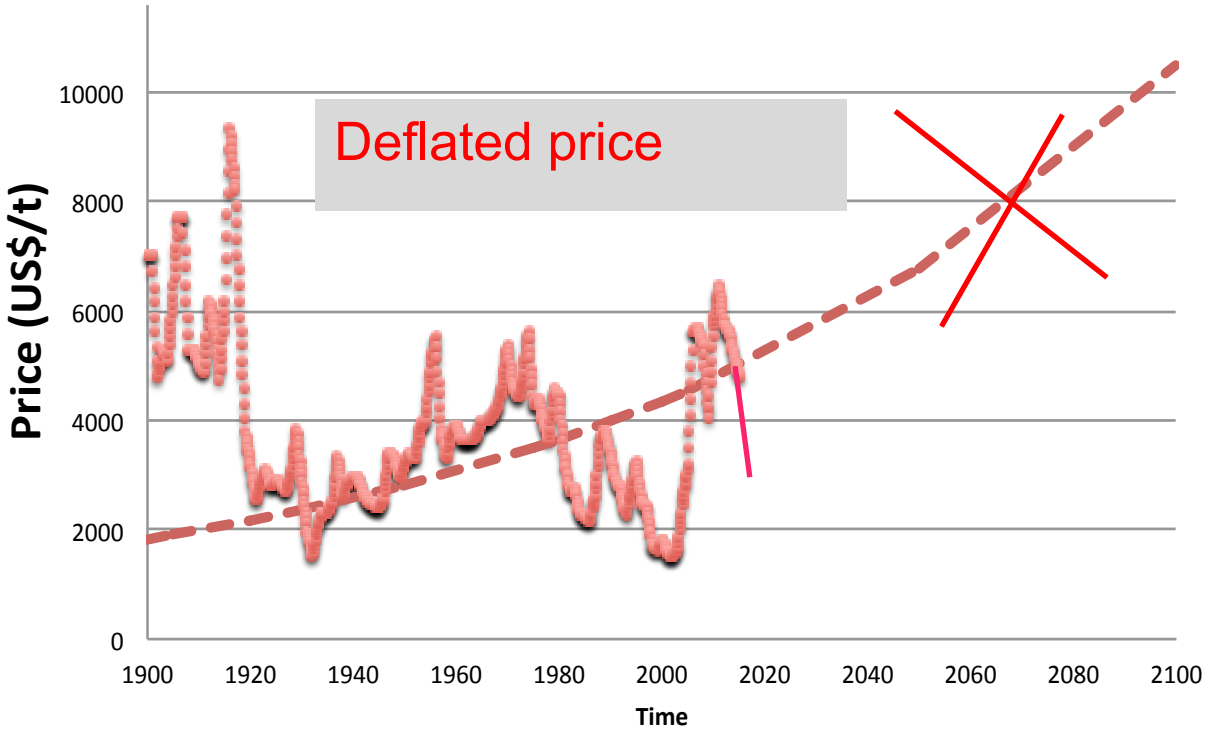
Price = a.(1/Cmetal)^u





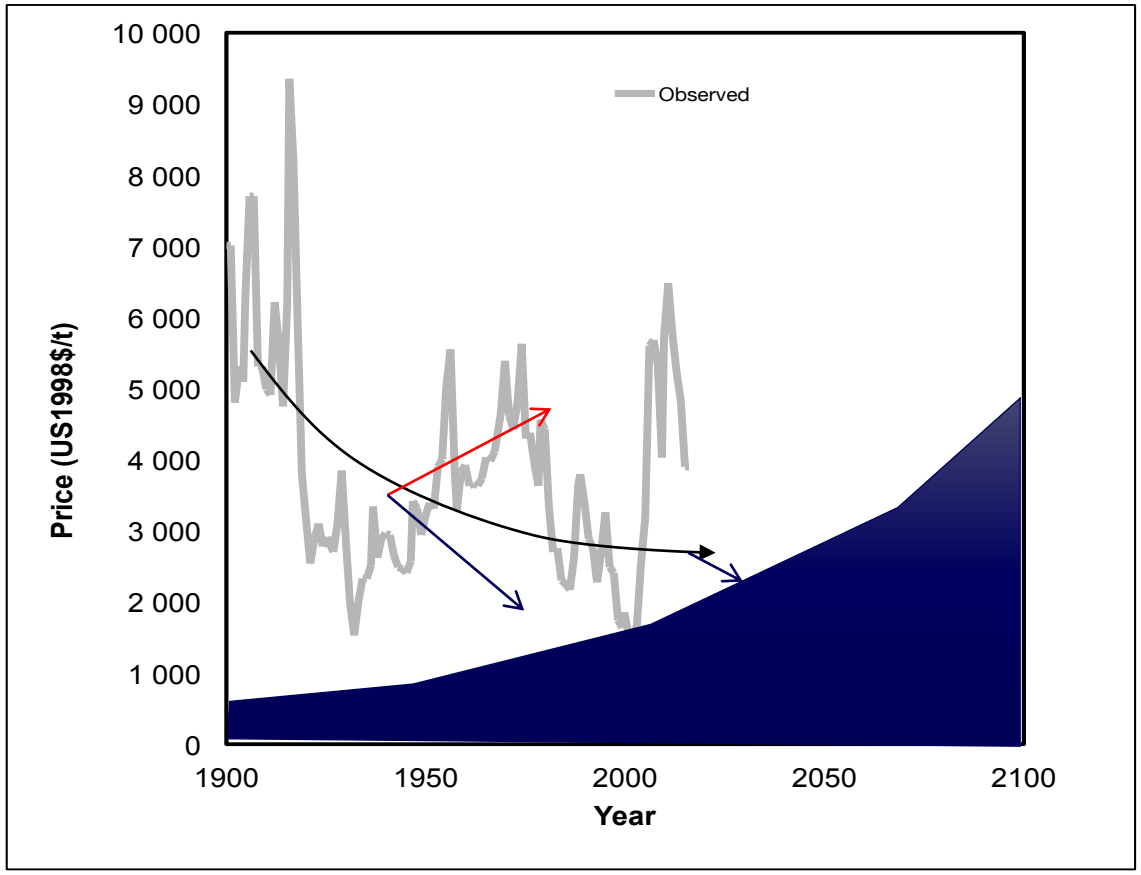
Progrès technologique





Il y a-t-il assez de matières premières pour la transition ?

Ca dépend, vous payez combien ?



Comminution

$$\bar{E}_{TL} = \Delta G_f^{\circ} i + Esi + \left(\frac{0.2}{C}\right)$$

Metallurgy (Gibb's free energy of formation)

Separation (mixing entropy)

Au prix de quels impacts ?

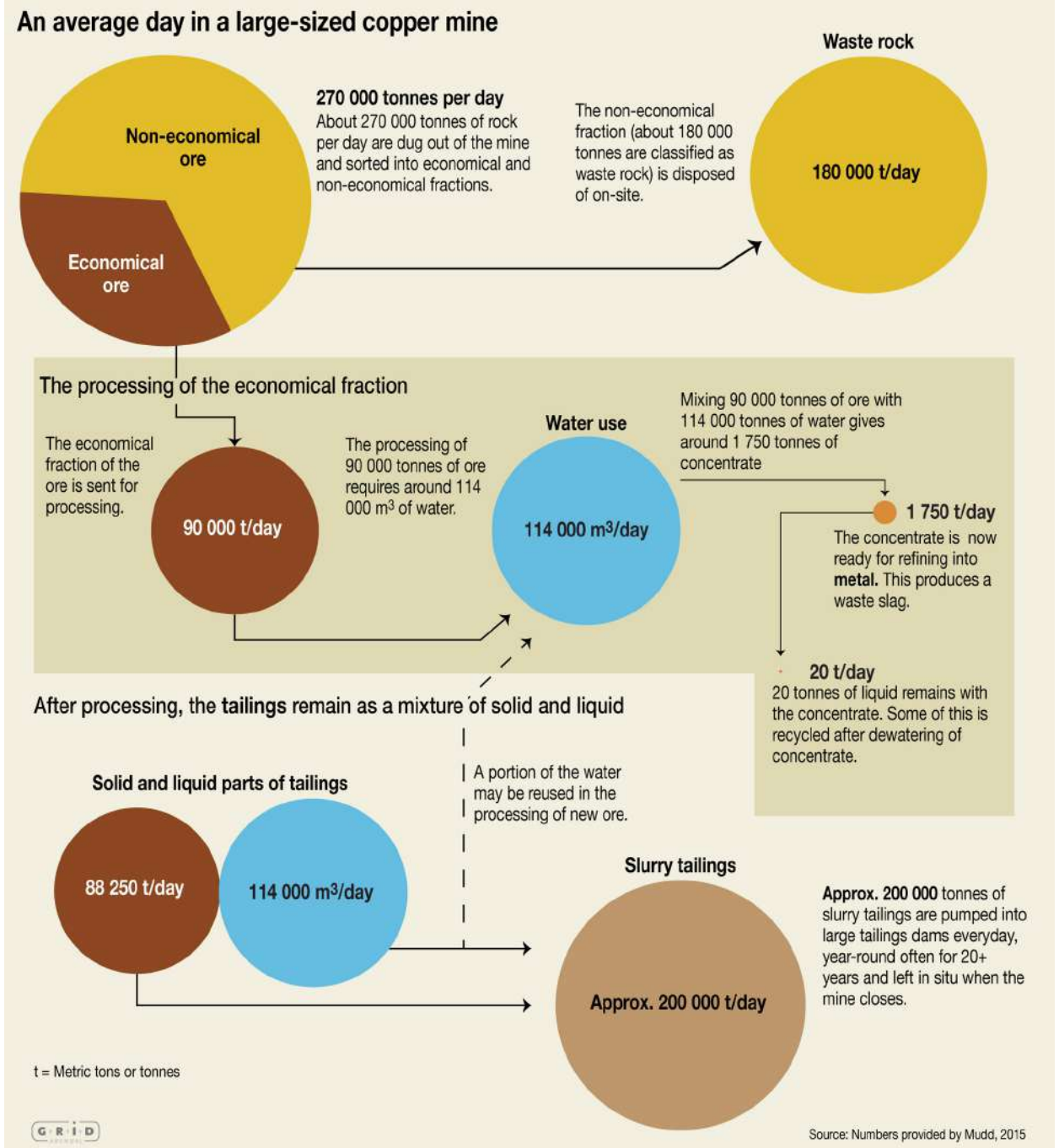

7978
115
7978

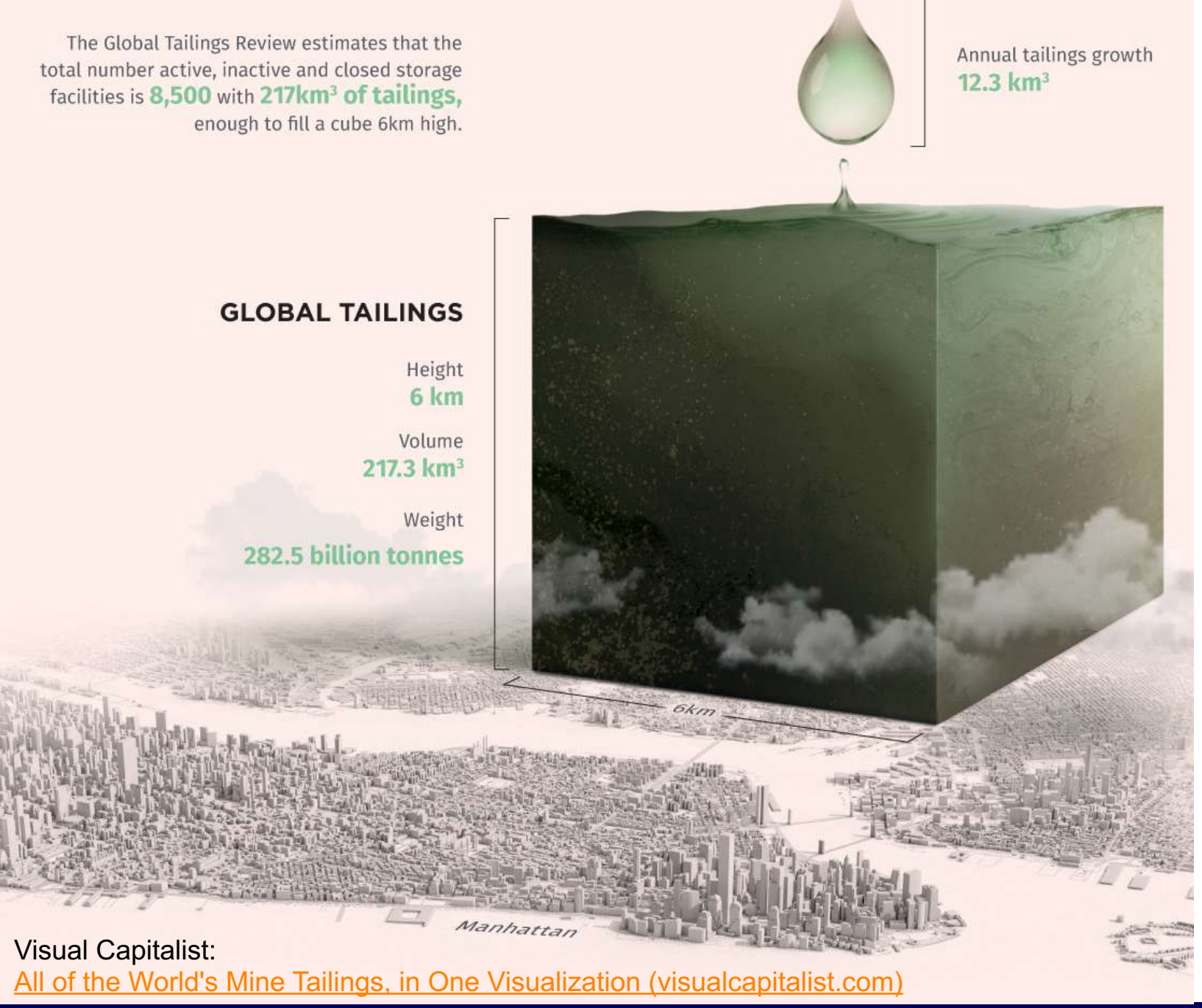
Systext 2021 – Controverses minières Volet 1

100Mt Cu/year in 2050

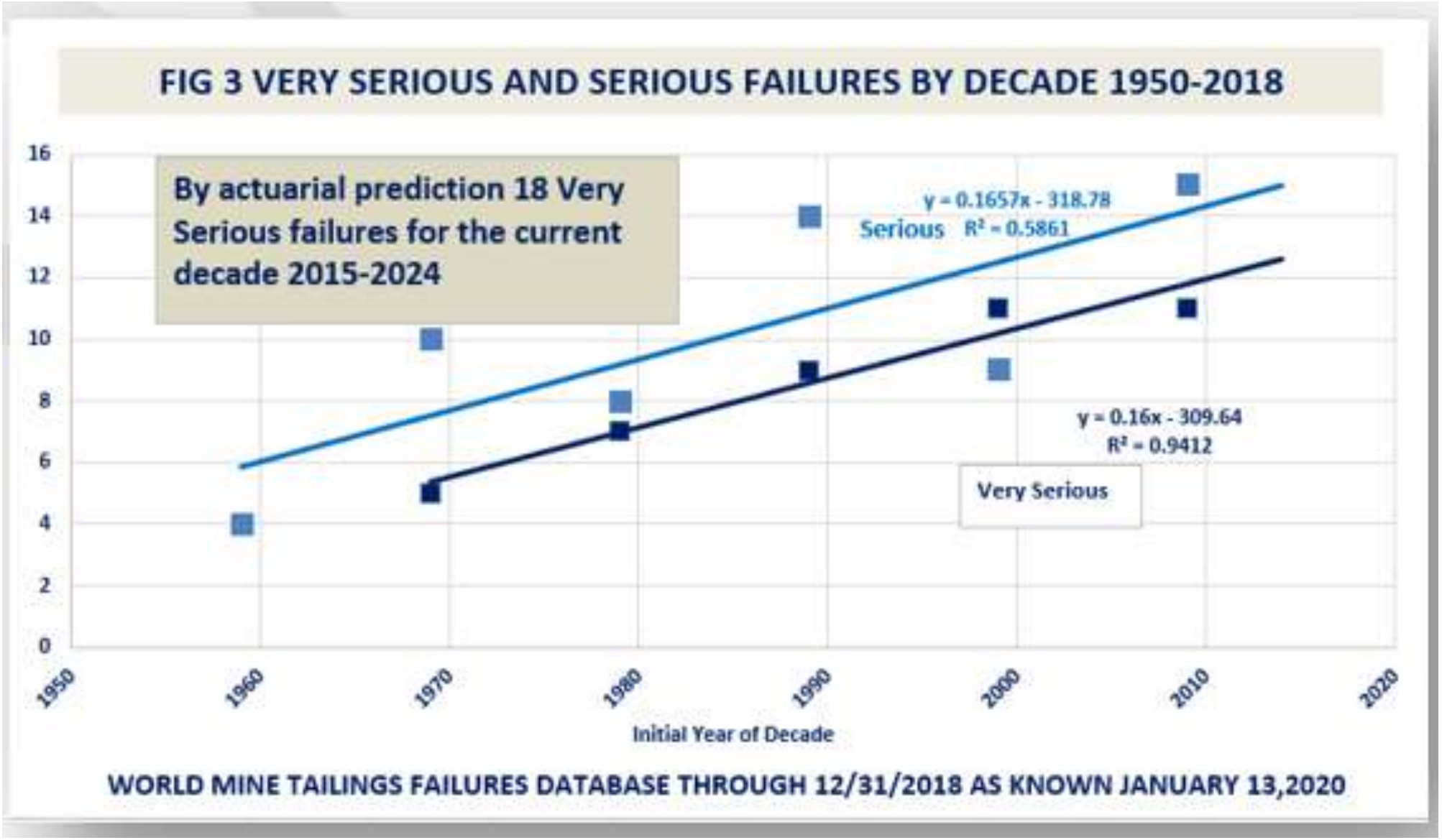
Palabora X 25

Systext 2021 – Controverses minières Volet 1


An average day in a large-sized copper mine
Non-economical ore
Economical ore
270 000 tonnes per day
About 270 000 tonnes of rock per day are dug out of the mine and sorted into economical and non-economical fractions.
The non-economical fraction (about 180 000 tonnes are classified as waste rock) is disposed of on-site.
Waste rock
180 000 t/day
The processing of the economical fraction
The economical fraction of the ore is sent for processing.
90 000 t/day
The processing of 90 000 tonnes of ore requires around 114 000 m3 of water.
Water use
114 000 m3/day
Mixing 90 000 tonnes of ore with 114 000 tonnes of water gives around 1 750 tonnes of concentrate
1 750 t/day
The concentrate is now ready for refining into metal. This produces a waste slag.
20 t/day
20 tonnes of liquid remains with the concentrate. Some of this is recycled after dewatering of concentrate.
After processing, the tailings remain as a mixture of solid and liquid
Solid and liquid parts of tailings
88 250 t/day
114 000 m3/day
A portion of the water may be reused in the processing of new ore.
Slurry tailings
Approx. 200 000 t/day
Approx. 200 000 tonnes of slurry tailings are pumped into large tailings dams everyday, year-round often for 20+ years and left in situ when the mine closes.
t = Metric tons or tonnes
GRID
Source: Numbers provided by Mudd, 2015

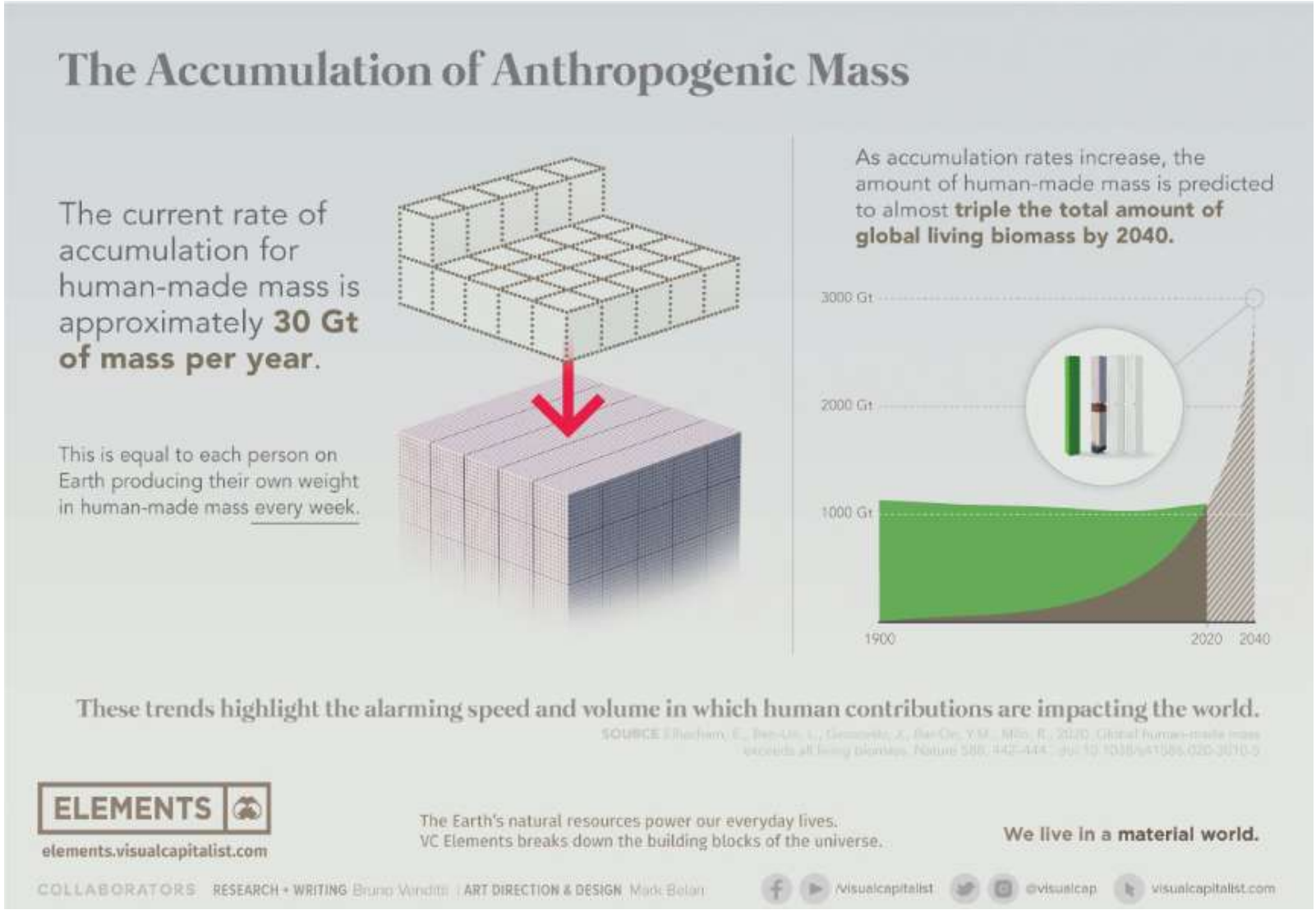


Visual Capitalist:
[All of the World's Mine Tailings, in One Visualization (visualcapitalist.com)]



Source: World Mine Tailings Failures—from 1915 – supporting global research in tailings failure root cause, loss prevention and trend analysis


DYNAMINE
La mine, prédatrice et dangereuse
SystExt
Dommages paysagers
Mouvements de terrain
Travail des enfants
Accident ou catastrophe minière
Conditions de travail dangereuses
Pollution de l'air
Maladies professionnelles
Mise en péril des eaux domestiques
Trafics et délinquance
Atteinte à la biodiversité
Contamination du milieu de vie
Artificialisation des territoires
Répression et actes de violence
Mise en danger des pop. autochtones
Pollution des sols
Pollution des eaux
Raréfaction des eaux
Protestations et mobilisations
Désinformation et corruption
Changement de l'organisation sociale
Paupérisation et déclin économique
Afflux massif de travailleurs
Mise en péril des ress. de subsistance
ISF SystExt Janvier 2017 - Illustration X.Aliot
Association SystExt · Septembre 2020 · CC BY-NC-SA 3.0 FR



La question ne devrait pas être « va-t-on en manquer ? »
mais « En a-t-on besoin ? »

Un exemple:

Rue de Rivoli – de l'absurdité de la voiture individuelle (en ville)

Carlos Moreno

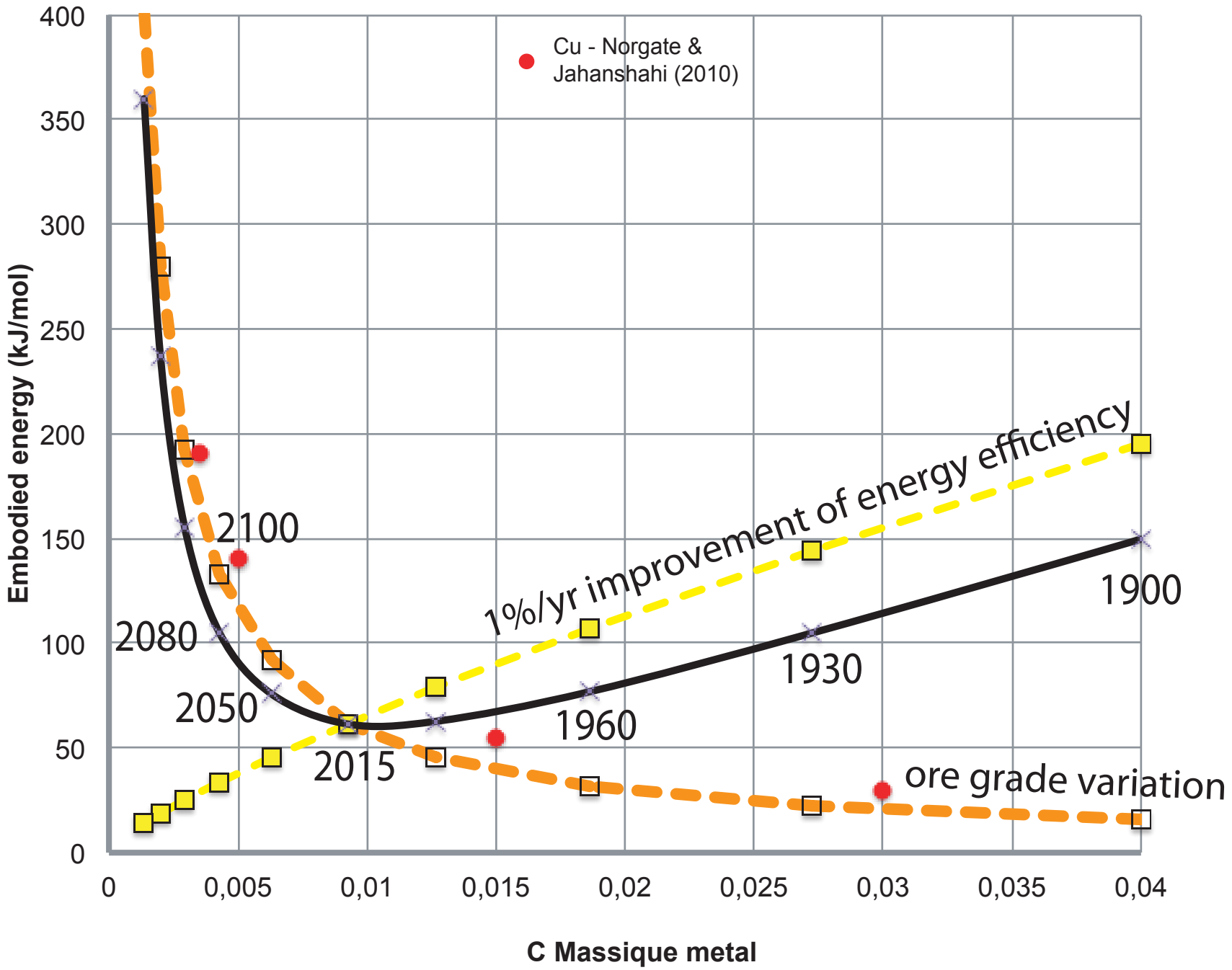
Romuald Meeigneux

« Avec
un bulldozer qui
fonctionne à
l'énergie solaire, on
peut raser
l'Amazonie. »

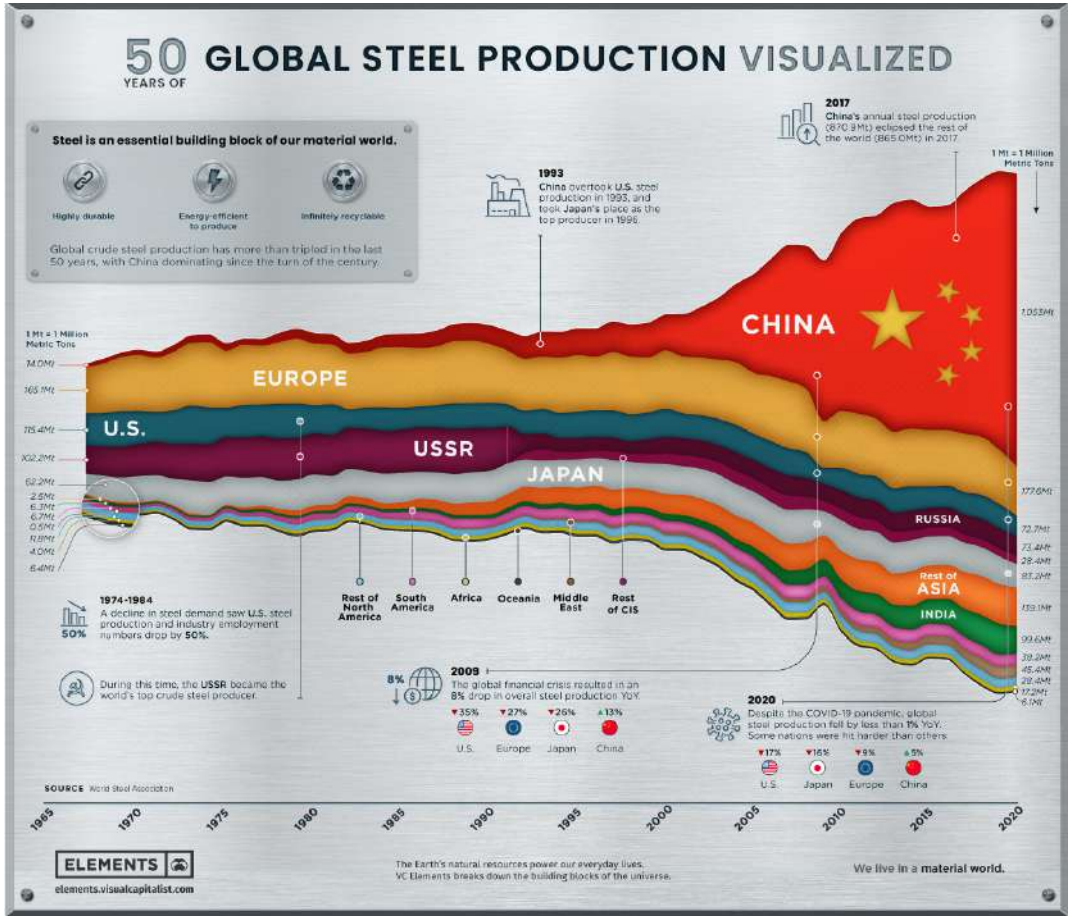
Aurélien Barrau

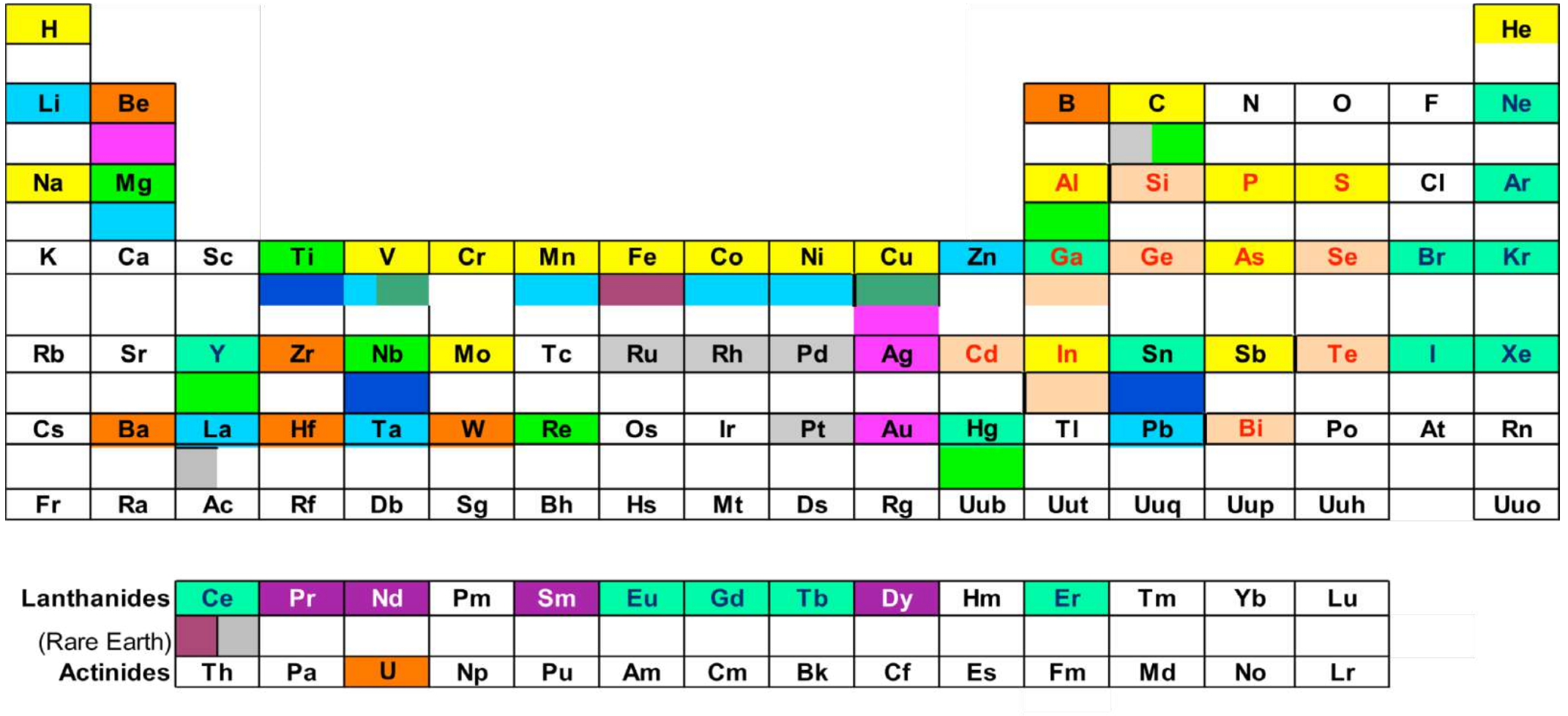
Questions

THE SHIFT PROJECT


Cu - Norgate & Jahanshahi (2010)
Embodied energy (kJ/mol)
400
350
300
250
200
150
100
50
0
0
0,005
0,01
0,015
0,02
0,025
0,03
0,035
0,04
C Massique metal
2100
2080
2050
2015
1960
1930
1900
1%/yr improvement of energy efficiency
ore grade variation

Structural raw materials – concrete, steel, Al, Cu





Les symboles chimiques des éléments semi-conducteurs sont indiqués en lettres rouges