

# Les TIC sans limite ?

**Prof. Jean-Pierre Raskin**

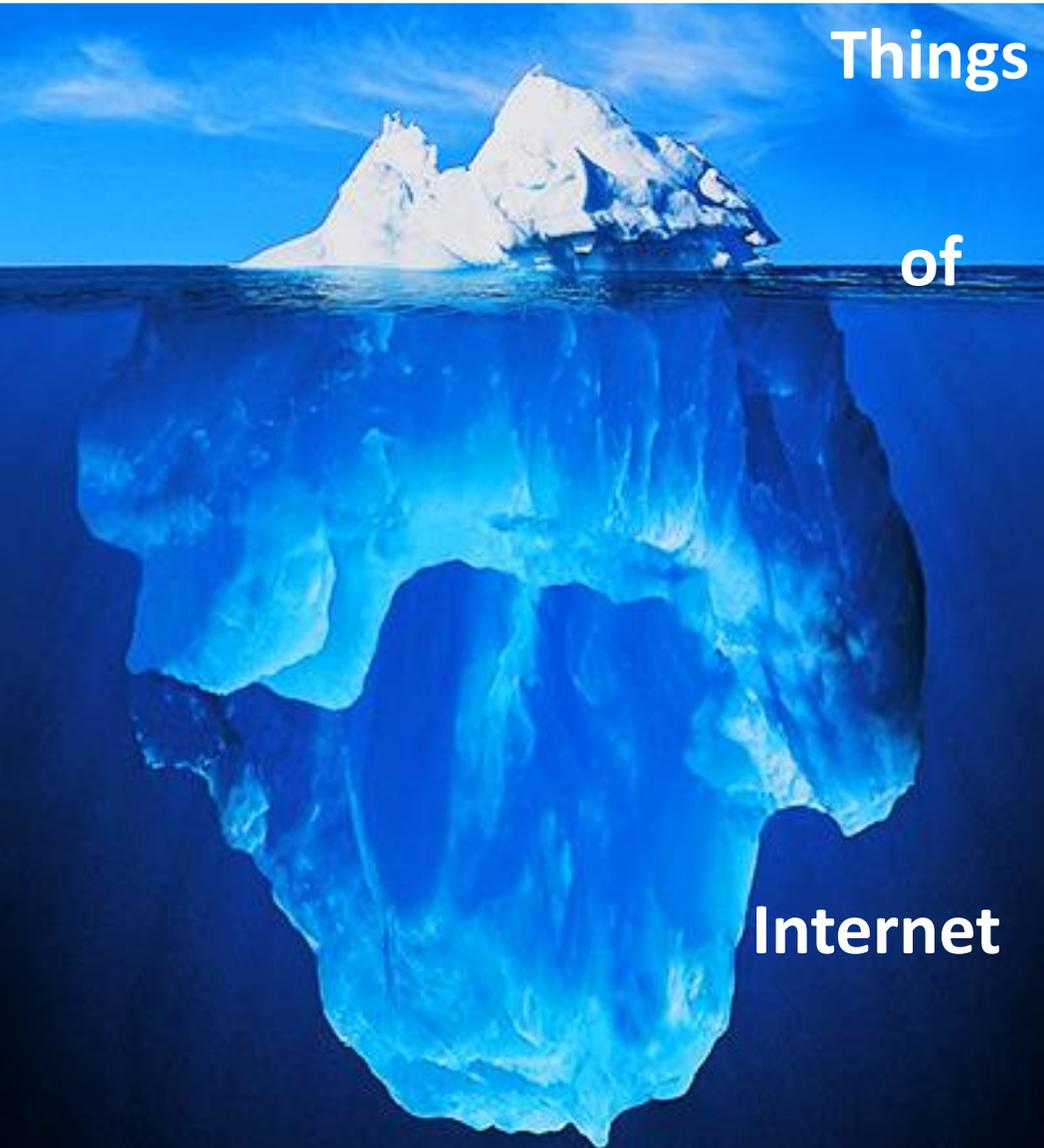
Institute of Information and Communication Technologies,  
Electronics and Applied Mathematics (ICTEAM)

**Université catholique de Louvain (UCL)**

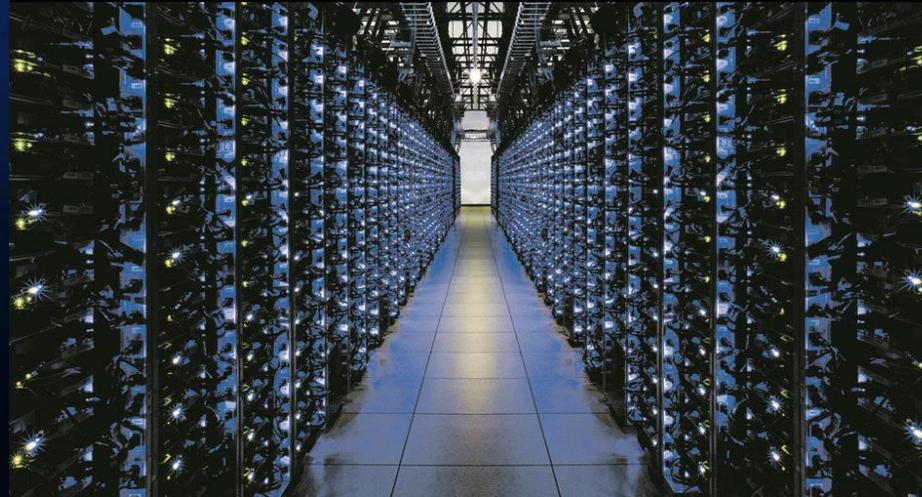
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# La partie immergée de l'iceberg : infrastructures

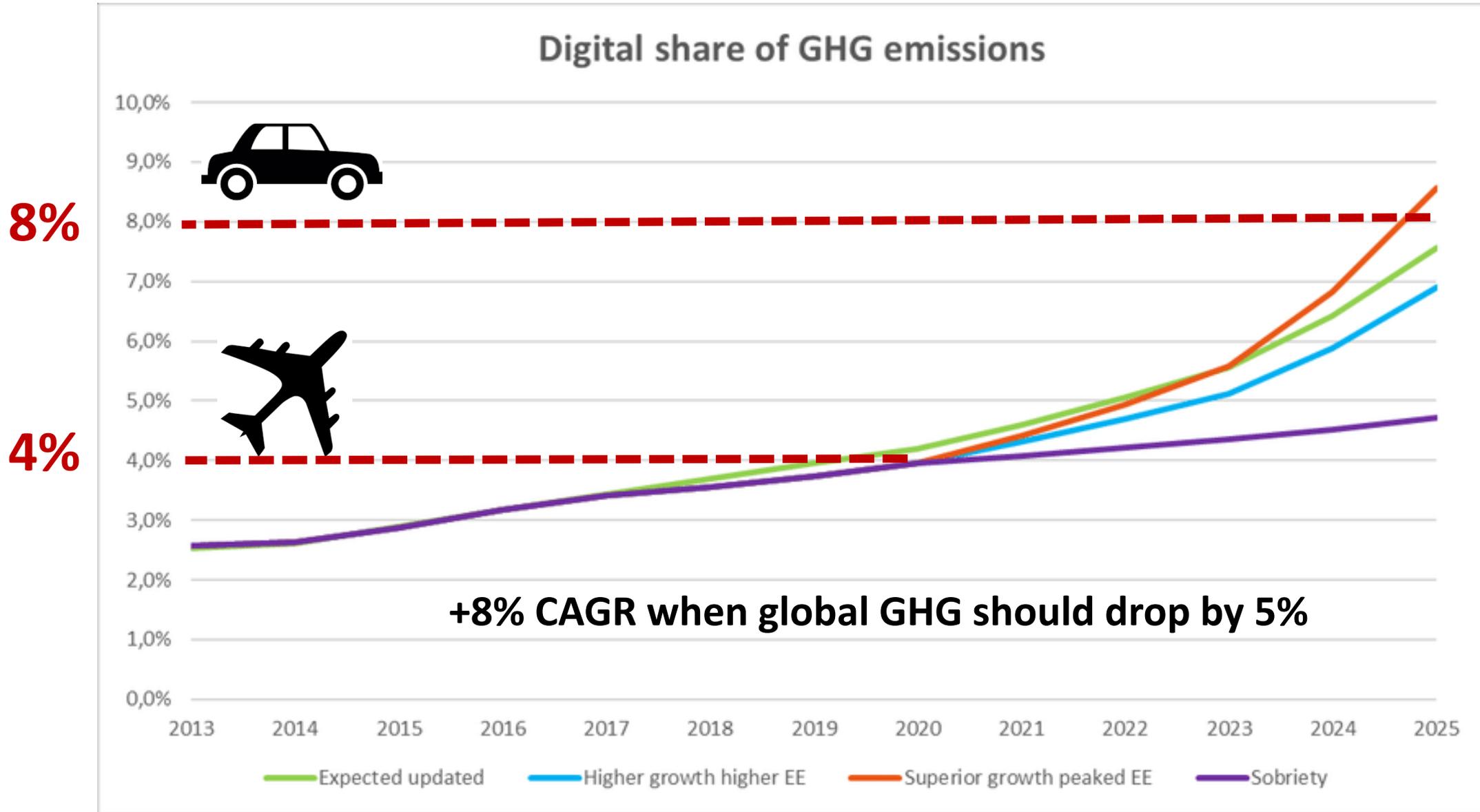


Access network

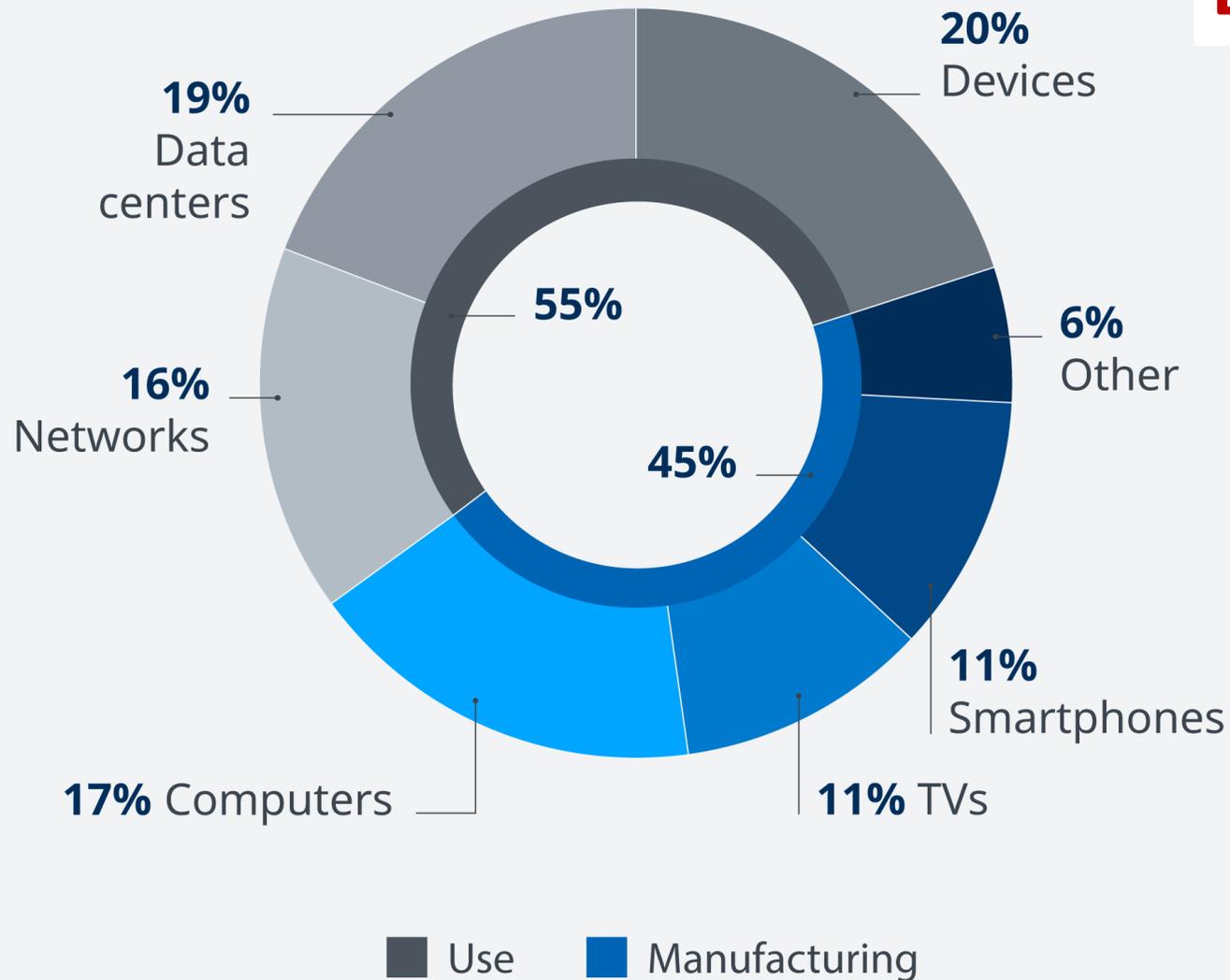


Data centers

# Plus de trafic = Plus de ressources = Plus de gaz à effet de serre



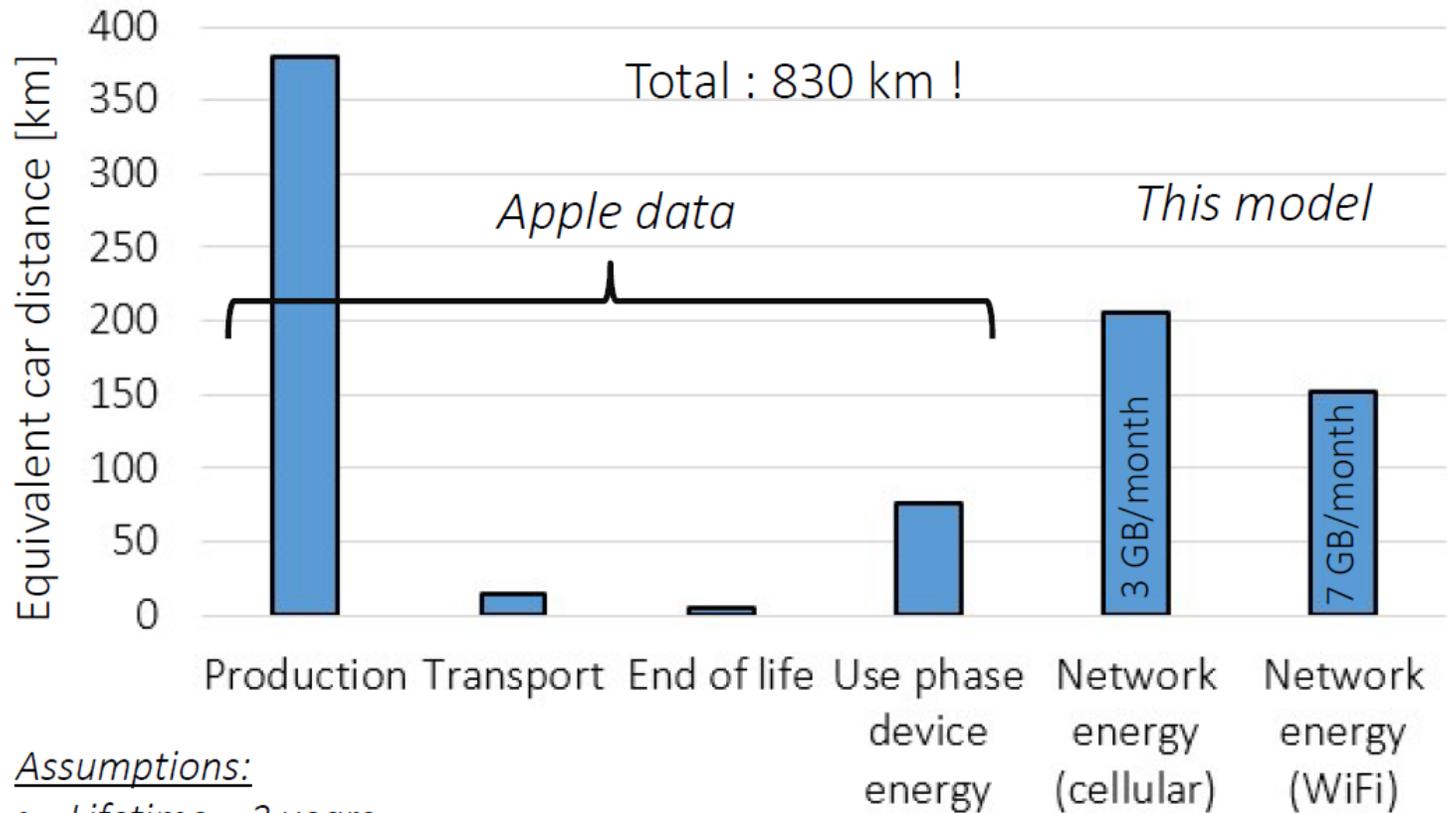
# Energie consommée par les TIC



~45% of consumed power for the **fabrication** of ICT equipment

# Energie consommée au niveau d'un Smartphone

## iPhone 8 life-cycle carbon footprint



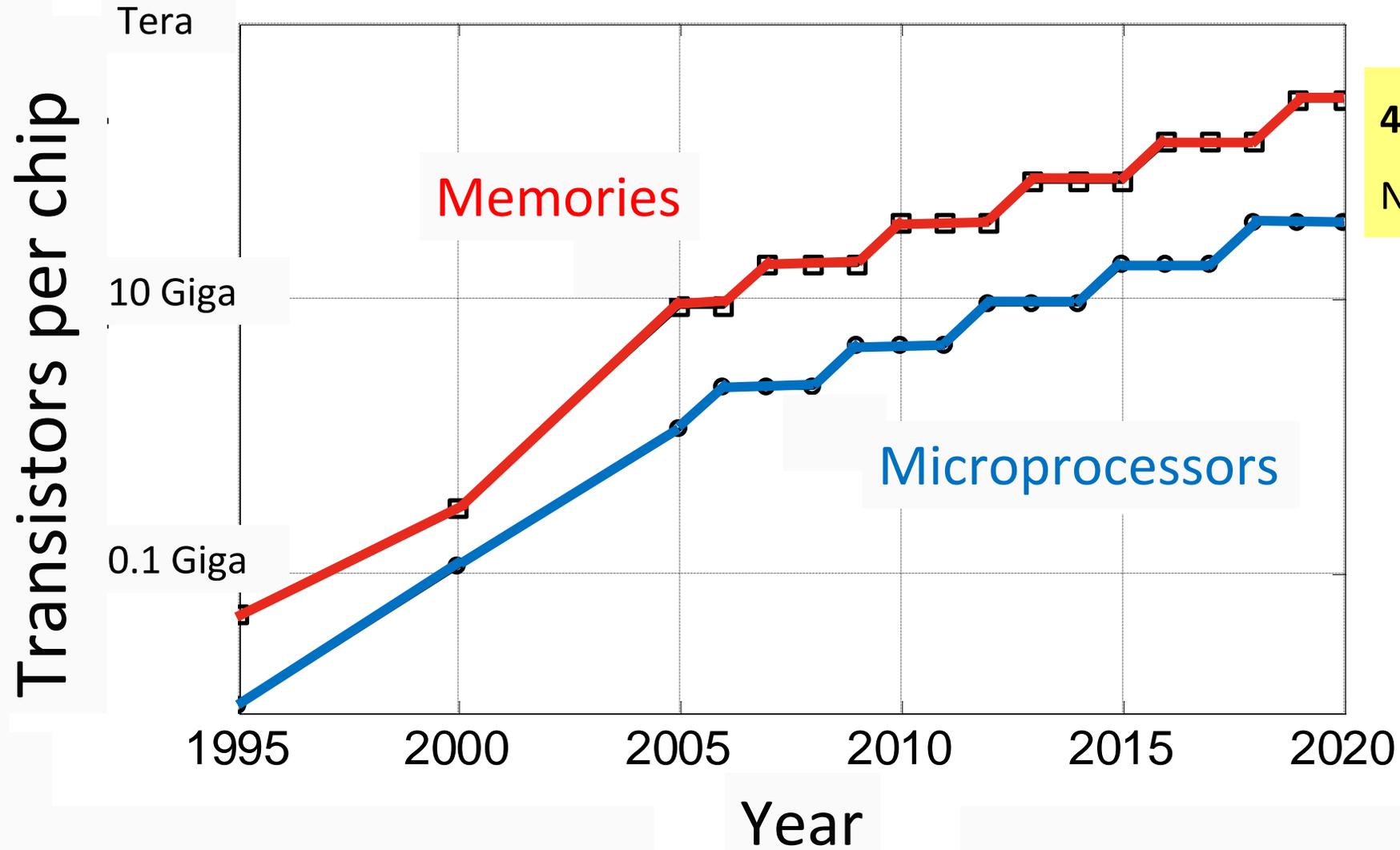
### Assumptions:

- Lifetime = 3 years
- Car driving GWP = 120 g CO<sub>2</sub>e / km
- Carbon footprint expressed in terms of Global Warming Potential (GWG)
- Electricity production GWP = 560 g CO<sub>2</sub>e / kWh = 160 g CO<sub>2</sub>e / MJ (World average)

> **80%** of consumed power for the **fabrication** of the Smartphone

**Lifetime = 18 months**

# La loi de Moore



400 billion

Number of stars in our galaxy

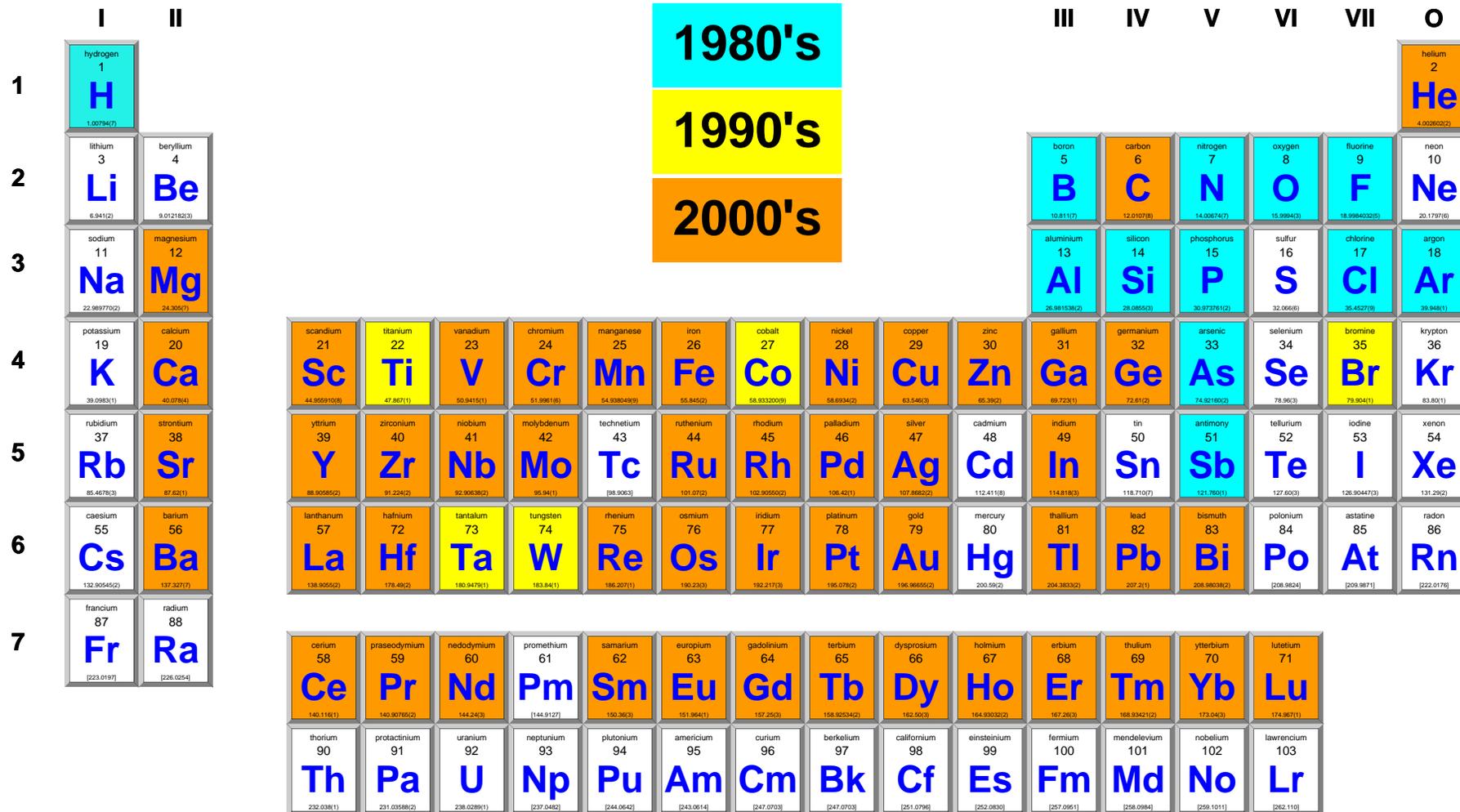
# Evolution de la microélectronique – Pression sur les matériaux

	I	II	1980's										III	IV	V	VI	VII	O												
1	hydrogen 1 <b>H</b> 1.00794(7)																		helium 2 <b>He</b> 4.002602(2)											
2	lithium 3 <b>Li</b> 6.941(2)	beryllium 4 <b>Be</b> 9.012182(3)											boron 5 <b>B</b> 10.811(7)	carbon 6 <b>C</b> 12.0107(8)	nitrogen 7 <b>N</b> 14.0064(7)	oxygen 8 <b>O</b> 15.9994(3)	fluorine 9 <b>F</b> 18.9984032(5)	neon 10 <b>Ne</b> 20.1797(6)												
3	sodium 11 <b>Na</b> 22.989770(2)	magnesium 12 <b>Mg</b> 24.305(7)											aluminium 13 <b>Al</b> 26.981538(2)	silicon 14 <b>Si</b> 28.085(3)	phosphorus 15 <b>P</b> 30.9737612(2)	sulfur 16 <b>S</b> 32.06(6)	chlorine 17 <b>Cl</b> 35.4527(9)	argon 18 <b>Ar</b> 39.948(1)												
4	potassium 19 <b>K</b> 39.0983(1)	calcium 20 <b>Ca</b> 40.078(4)	scandium 21 <b>Sc</b> 44.955910(8)	titanium 22 <b>Ti</b> 47.867(1)	vanadium 23 <b>V</b> 50.9415(1)	chromium 24 <b>Cr</b> 51.9961(6)	manganese 25 <b>Mn</b> 54.938049(9)	iron 26 <b>Fe</b> 55.845(2)	cobalt 27 <b>Co</b> 58.933200(9)	nickel 28 <b>Ni</b> 58.6934(2)	copper 29 <b>Cu</b> 63.546(3)	zinc 30 <b>Zn</b> 65.39(2)	gallium 31 <b>Ga</b> 69.723(1)	germanium 32 <b>Ge</b> 72.61(2)	arsenic 33 <b>As</b> 74.92160(2)	selenium 34 <b>Se</b> 78.96(3)	bromine 35 <b>Br</b> 79.904(1)	krypton 36 <b>Kr</b> 83.80(1)												
5	rubidium 37 <b>Rb</b> 85.4678(3)	strontium 38 <b>Sr</b> 87.62(1)	yttrium 39 <b>Y</b> 88.90585(2)	zirconium 40 <b>Zr</b> 91.224(2)	niobium 41 <b>Nb</b> 92.90638(2)	molybdenum 42 <b>Mo</b> 95.94(1)	technetium 43 <b>Tc</b> [98.9063]	ruthenium 44 <b>Ru</b> 101.07(2)	rhodium 45 <b>Rh</b> 102.90550(2)	palladium 46 <b>Pd</b> 106.42(1)	silver 47 <b>Ag</b> 107.8682(2)	cadmium 48 <b>Cd</b> 112.411(8)	indium 49 <b>In</b> 114.818(3)	tin 50 <b>Sn</b> 118.710(7)	antimony 51 <b>Sb</b> 121.760(1)	tellurium 52 <b>Te</b> 127.60(3)	iodine 53 <b>I</b> 126.90447(3)	xenon 54 <b>Xe</b> 131.29(2)												
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7	francium 87 <b>Fr</b> [223.0197]	radium 88 <b>Ra</b> [226.0254]	cerium 58 <b>Ce</b> 140.116(1)	praseodymium 59 <b>Pr</b> 140.90765(2)	neodymium 60 <b>Nd</b> 144.24(3)	promethium 61 <b>Pm</b> [144.9127]	samarium 62 <b>Sm</b> 150.36(3)	europium 63 <b>Eu</b> 151.964(1)	gadolinium 64 <b>Gd</b> 157.25(3)	terbium 65 <b>Tb</b> 158.92534(2)	dysprosium 66 <b>Dy</b> 162.50(3)	holmium 67 <b>Ho</b> 164.93032(2)	erbium 68 <b>Er</b> 167.26(3)	thulium 69 <b>Tm</b> 168.93421(2)	ytterbium 70 <b>Yb</b> 173.04(3)	lutetium 71 <b>Lu</b> 174.967(1)	thorium 90 <b>Th</b> 232.038(1)	protactinium 91 <b>Pa</b> 231.03688(2)	uranium 92 <b>U</b> 238.02891(1)	neptunium 93 <b>Np</b> [237.0442]	plutonium 94 <b>Pu</b> [244.0642]	americium 95 <b>Am</b> [243.0614]	curium 96 <b>Cm</b> [247.0703]	berkelium 97 <b>Bk</b> [247.0703]	californium 98 <b>Cf</b> [251.0796]	einsteinium 99 <b>Es</b> [252.0830]	fermium 100 <b>Fm</b> [257.0951]	mendelevium 101 <b>Md</b> [258.0984]	nobelium 102 <b>No</b> [259.1011]	lawrencium 103 <b>Lr</b> [262.110]

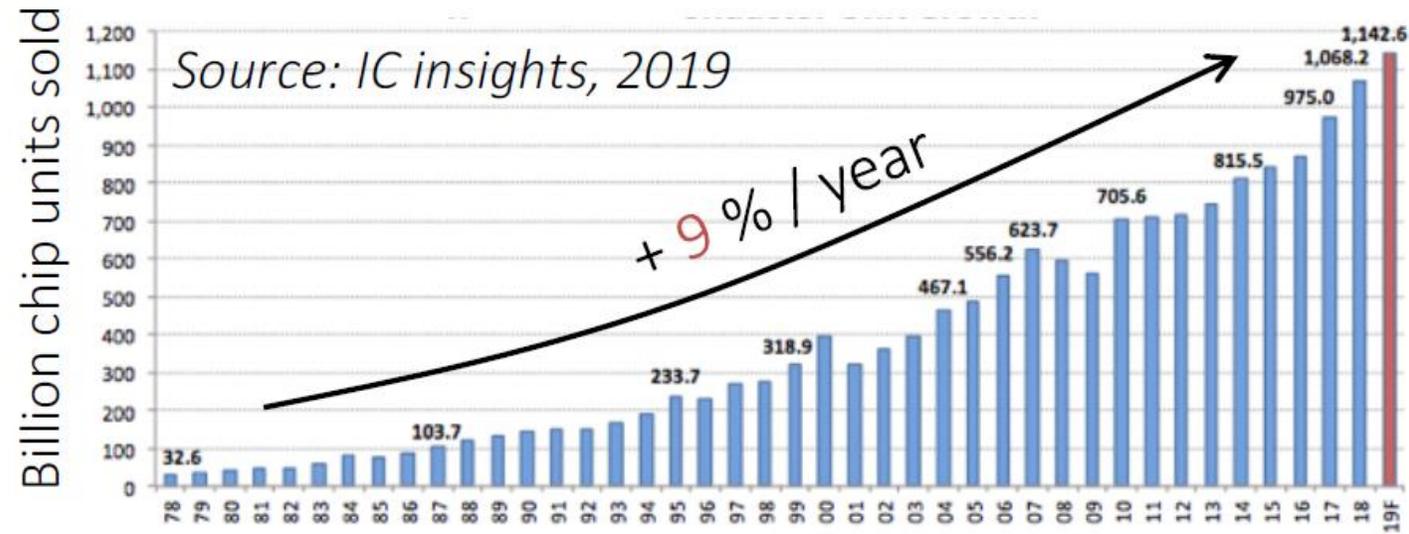
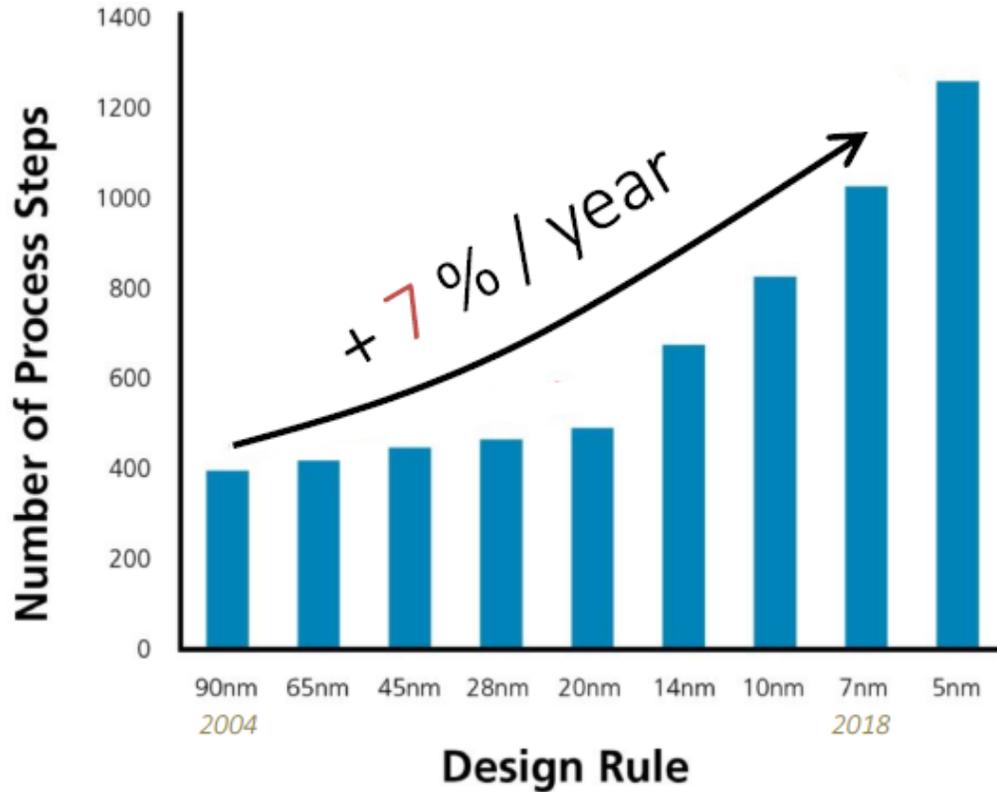
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# Evolution de la microélectronique – Pression sur les matériaux



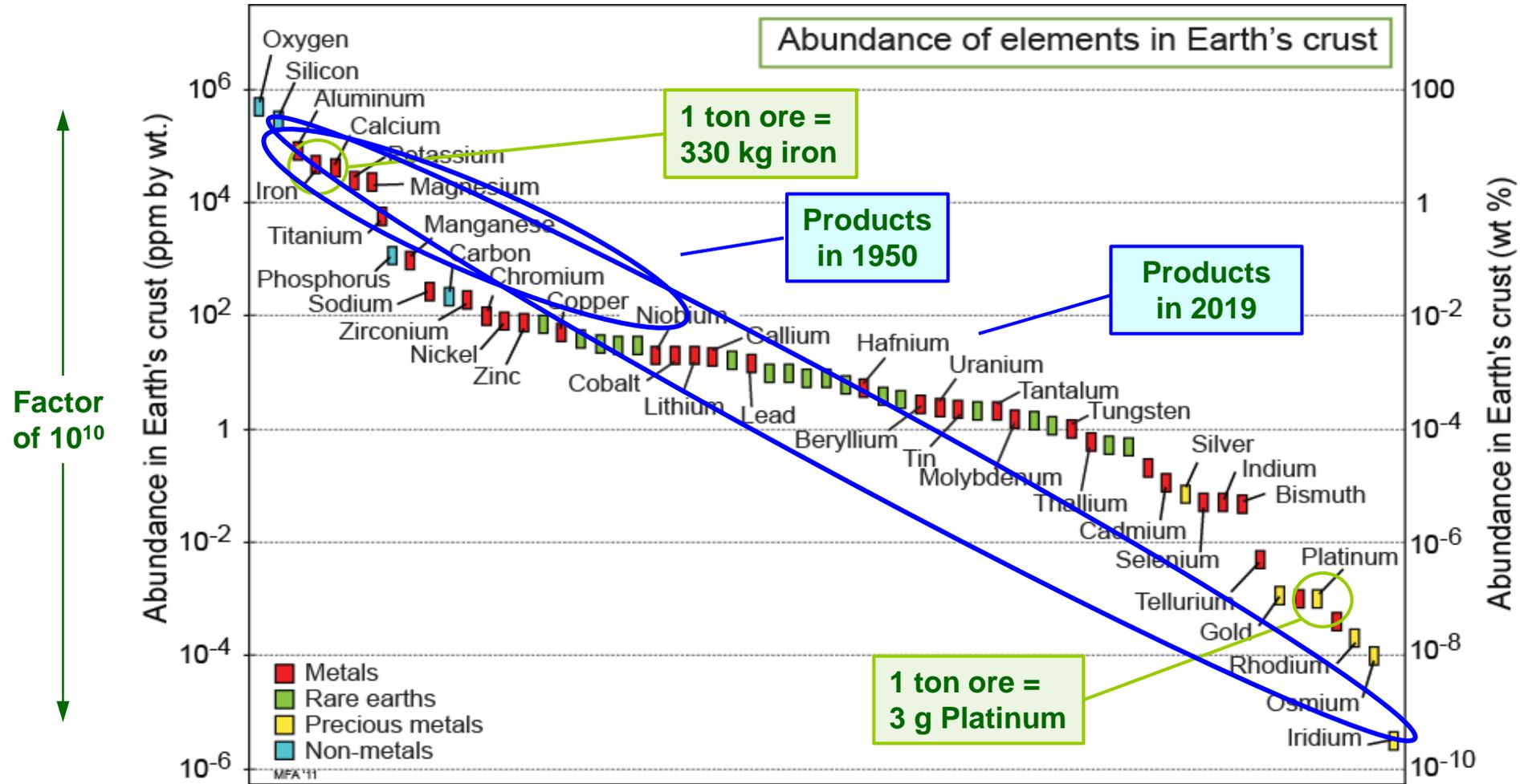
# Procédés plus complexes, plus de circuits intégrés vendus...



Chip unit **fab energy**: + 7% / year (techno scaling)  
+ Chip unit **sale**: + 9% / year (consumption, obsolescence)

Global chip fabrication  
**energy footprint**: + 16% / year

# Extraire toujours plus

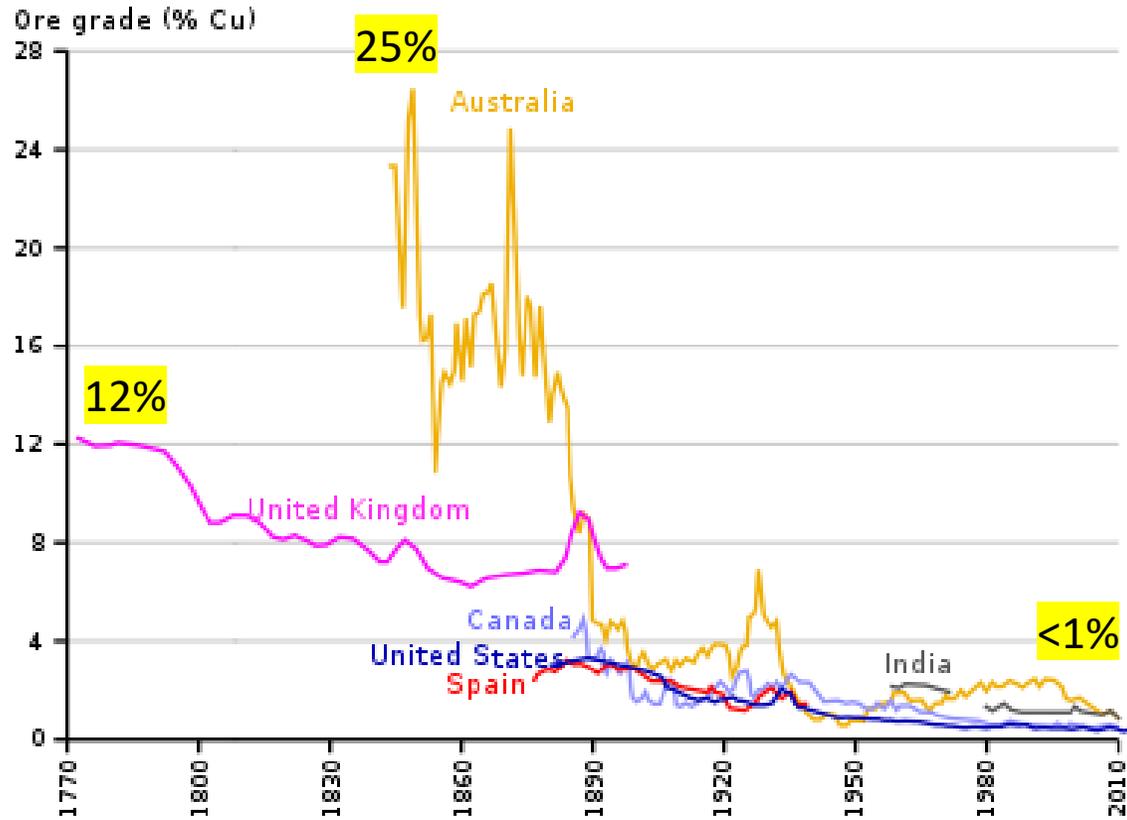


[Prof. M. Ashby, Cambridge Univ.]

Quantité d'énergie toujours plus importante par quantité de matière extraite

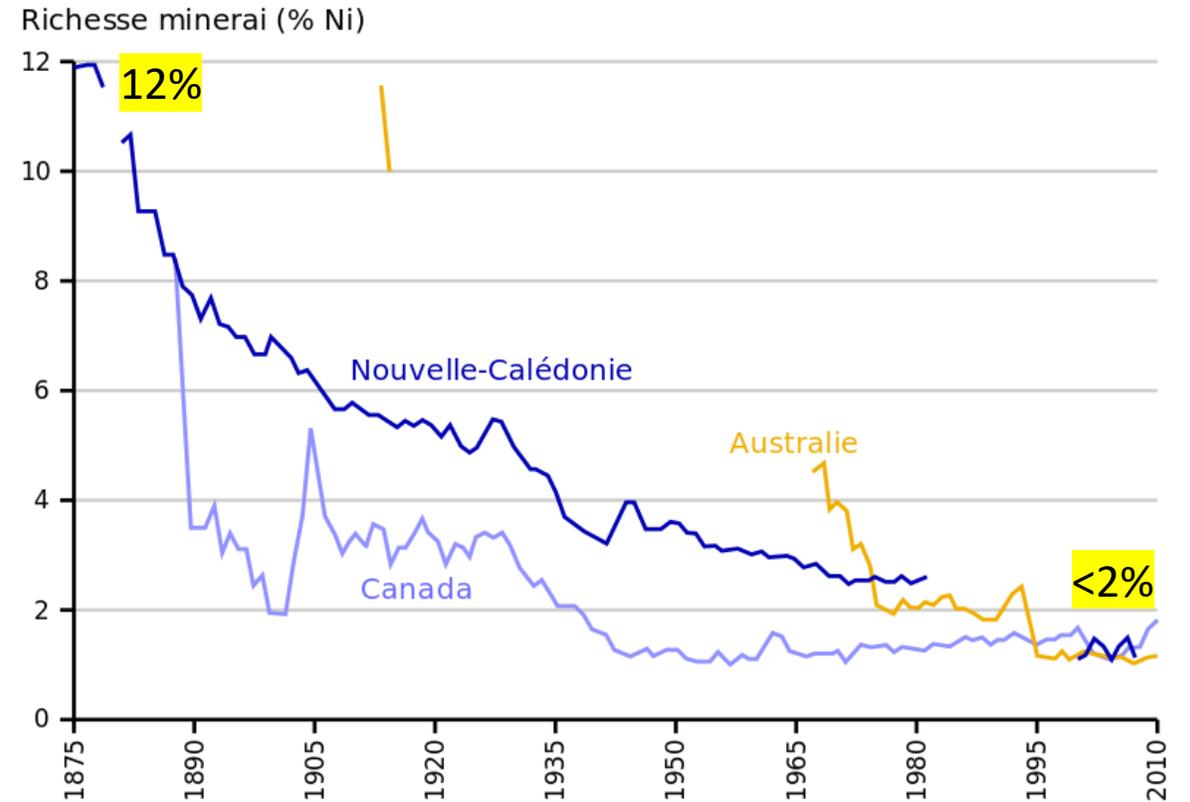
# Réduction de la concentration en minerai dans la roche

## Cuivre



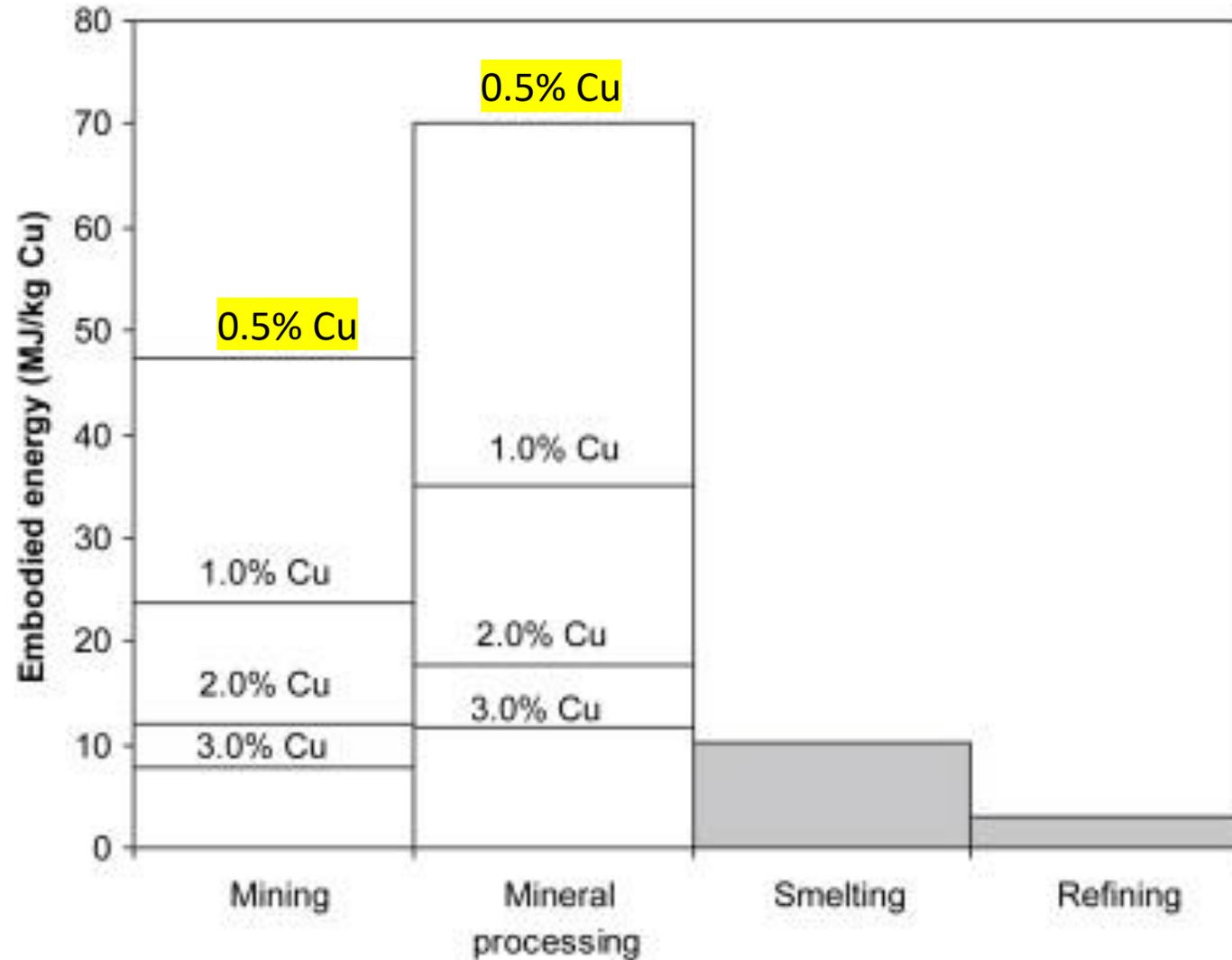
18<sup>ème</sup>

## Nickel



19<sup>ème</sup>

# Lien entre extraction de matière et énergie

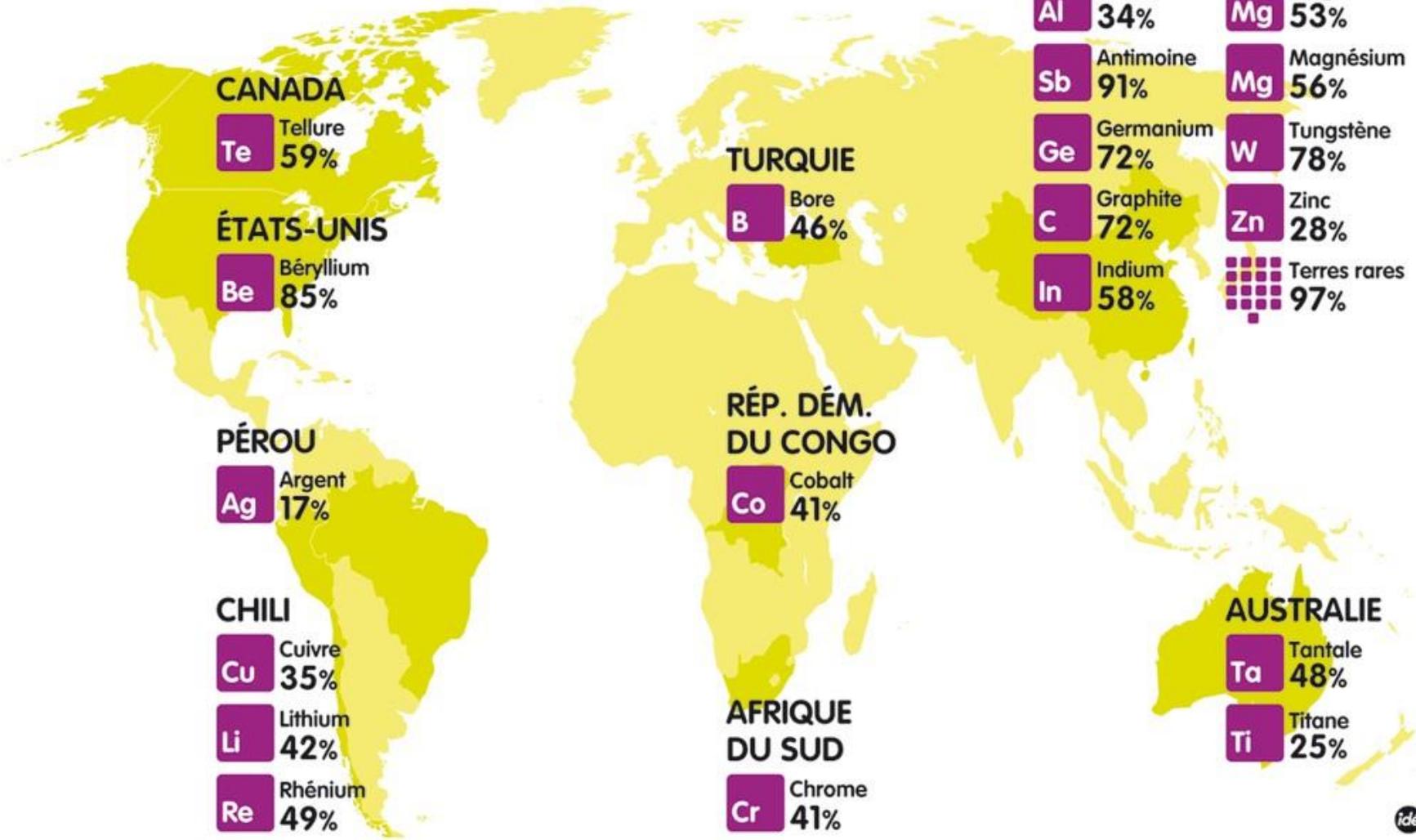


<https://doi.org/10.1016/j.jclepro.2009.09.020>

**Aujourd'hui, 90% = Extraction et traitement du minerai : dynamitage, concassage, flottation**

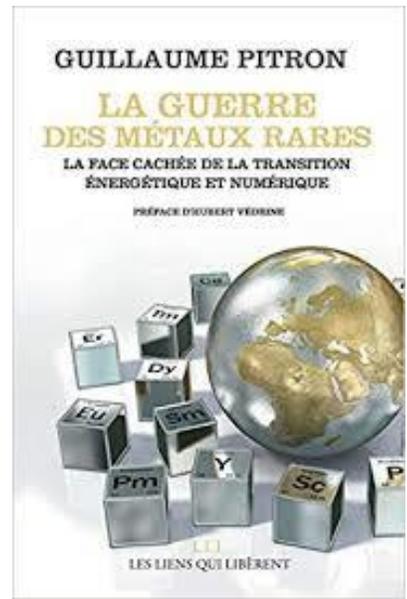
# Conflits géopolitiques

Part dans la production mondiale  
Source : Commission européenne



Rare earth,  
nearly only in China

Nearly nothing in Europe!



**Blood minerals:** Democratic Republic of Congo where army groups manage the mines. Since the 90's several hundreds thousand people have died due to mine conflicts.

# Dépendance Nord-Sud

## La technologie n'est pas neutre

Electronics waste



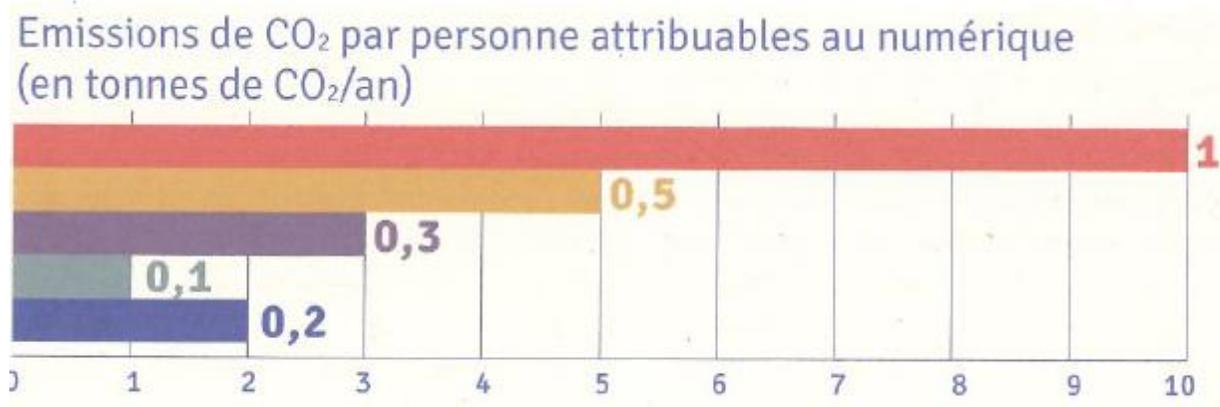
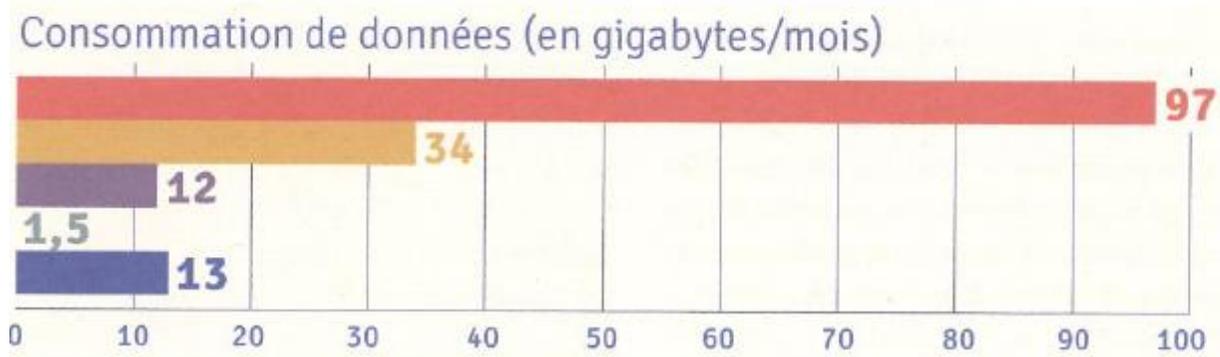
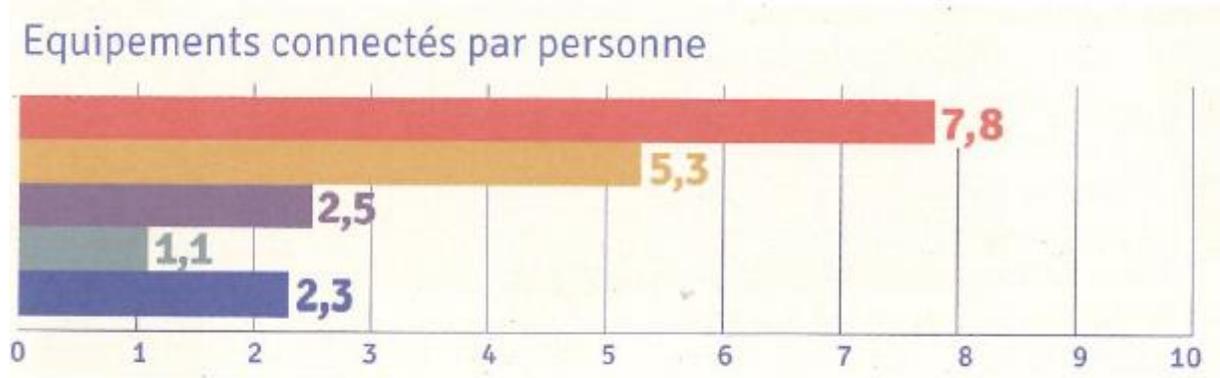
Poor recycling under extreme dangerous conditions



[Documentary: La tragédie électronique, ARTE 2014]

Environmental & human disaster

# La société digitale à deux vitesses



## Un monde globalisé

- Flux de la matière et des richesses
- Où sont les gagnants et les perdants
- Dominants-Dominés

# If business as usual...

In the absence of urgent and concerted action, rapid growth and inefficient use of natural resources will continue to create unsustainable pressures on the environment.

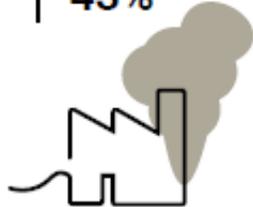
From 2015 to 2060, *Historical Trends*:

↑ more than  
doubles



Global material  
extraction

↑ increases by  
43%



Greenhouse gas  
emissions

↑ increases by  
more than 20%



Area of  
agricultural land

↑ increases by  
25%



Global  
pasture land

↓ reduces by  
over 10%



Forests

↓ reduces by  
around 20%



Other  
natural habitat

Groupe International d'Experts sur les Ressources (**GIER**)

[www.resourcepanel.org](http://www.resourcepanel.org)

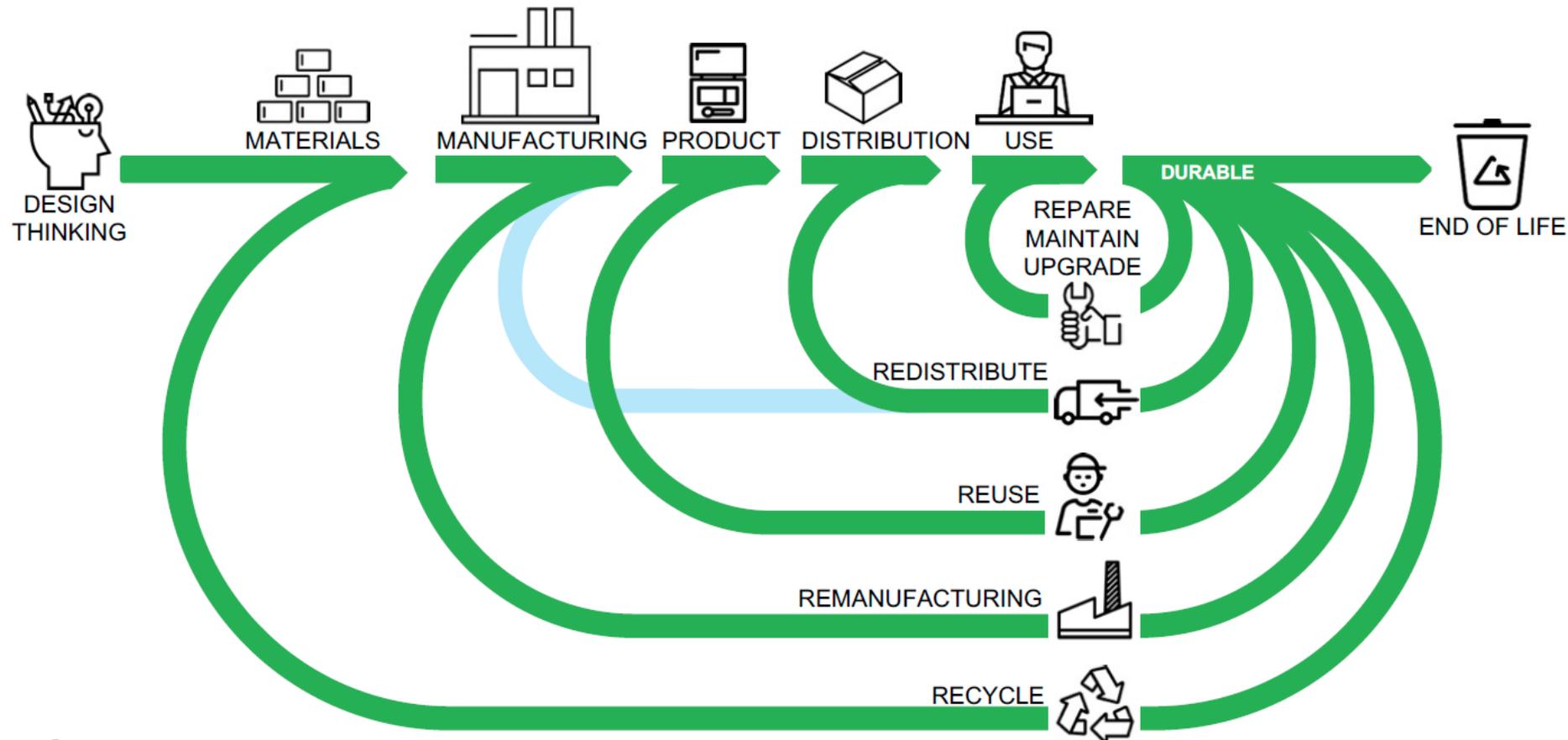


International  
Resource  
Panel

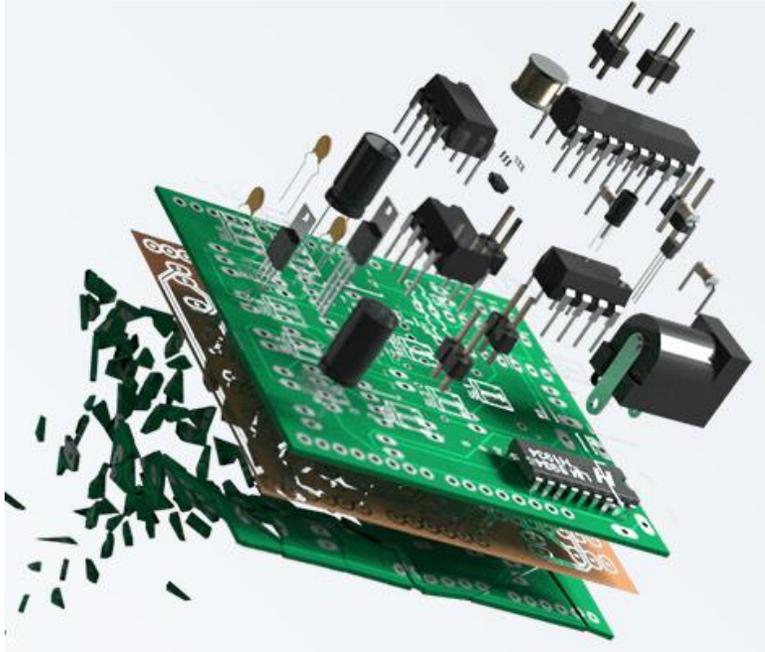
## System-wide Life-Cycle Thinking

PuzzlePhone •  
"Making More of Less"

The ecodesign approach is divided into seven steps, guiding us in the design and manufacture of sustainable products



# Le recyclage : une solution pour les déchets électroniques ?



[UMICORE]

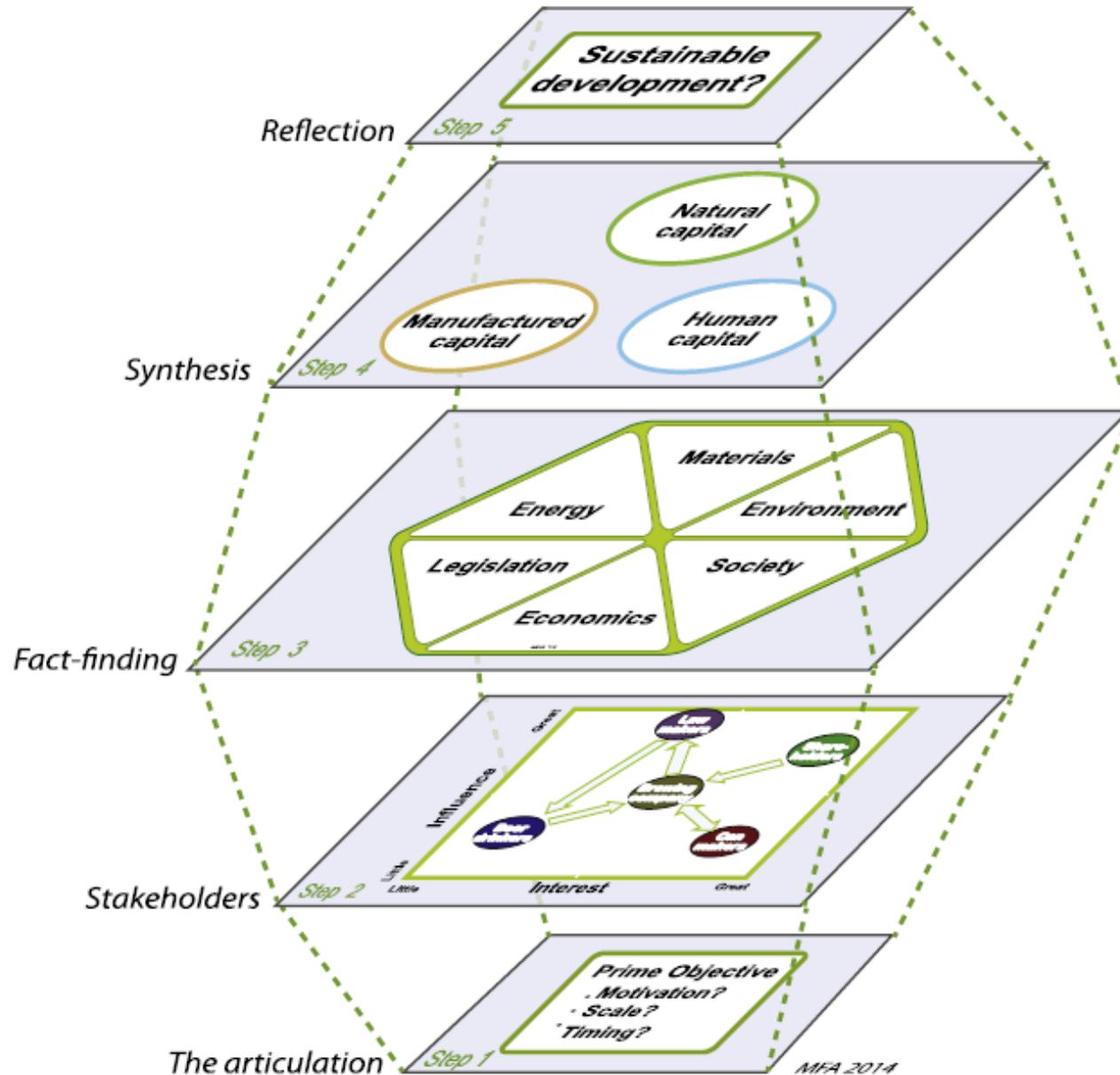
<b>Sn</b> Tin	<b>Te</b> Tellurium	<b>Ag</b> Silver
<b>Se</b> Selenium	<b>Ru</b> Ruthenium	<b>Rh</b> Rhodium
<b>Pt</b> Platinum	<b>Pd</b> Palladium	<b>Ni</b> Nickel
<b>Pb</b> Lead	<b>Ir</b> Iridium	<b>In</b> Indium
<b>Au</b> Gold	<b>Cu</b> Copper	<b>Bi</b> Bismuth
<b>As</b> Arsenic	<b>Sb</b> Antimony	

- Only **17** out of 60 elements
- Only **4-5** are profitable
- **Gold** pays for the others
- No more interesting if less than 20 grams of gold per ton of WEEE
- Not profitable because **raw materials** are really **too cheap**

**Think, design, innovate and act differently**

**Sustainable Development...**

**Innovate with limits!**



## 5. Débat de société, choix, vision,...

4. Synthèse, compris, contradictions, ...  
Impact sur les 3 P

3. Recherche des faits, impacts mesurés  
et mesurables de la technologie

## Niveaux indicateurs

2. Parties prenantes, leurs intérêts, leurs  
influences, les leviers, les contraintes, ...

1. Besoin, contexte, impact désiré, ...

#### 4. La synthèse, impact sur les 3 P

#### 5. Débat de société, choix, vision,...

	Human and social capital – People <i>Health? Wellbeing? Convenience? Culture? Tradition? Associations? Perceptions? Contributes to equality? Morality?</i>	Natural capital – Planet <i>Can prime objective be met? Are stakeholder concerns addressed? Are there unwanted consequences</i>	Manufactured capital – Prosperity <i>Cost – Benefit? (Cost facts vs. Eco facts) Legitimacy? (Conformity with law)</i>
<b>Materials</b>		(-) Some PV panels use critical elements for their manufacture: silver, indium, gallium, tellurium	
<b>Energy</b>	(+) There is an element of personal satisfaction in meeting energy needs locally	(+) Solar PV has great potential as a long-term source of renewable energy  (-) Rapid expansion can require more energy than existing PV installation can , at the time, produce	(-) Solar PV electricity is at present more expensive than that from national grids (+) Solar PV seen as a cushion against fluctuating energy prices and uncertain supply (-) Expanding PV generation beyond 20% of national need will require grid-scale energy storage
<b>Environment</b>	(+) Solar PV widely accepted as one path towards renewable energy.	(+/-) Solar PV power is carbon free but manufacture of the hardware is not. Rapid expansion can cause temporary increase in carbon emissions	
<b>Legislation</b>			(+) Subsidies and feed-in tariffs (FITs) have stimulated very rapid expansion of solar PV installation
<b>Economics</b>	(+/-) Solar PV is promoted as a good investment: "better than your pension". It is not clear that this is true.		(-) The reduction of the FIT means the pay-back time for solar PV is at present long (+) Cost parity of PV and commercial utility electricity is on the horizon
<b>Society</b>	(-) Solar farms require a large area and are found objectionable by some, on visual grounds		(+) The solar PV industry creates high technology employment
<b>Synthesis</b> (the most telling facts)	(+) Although there are objectors, solar PV attracts less opposition than other types of renewable energy generation.	(+/-) The environmental picture is one of short-term loss for longer-term gain.	(+) The financial picture, like the environmental one, is that of short-term loss for long-term gain

# Research differently

## European Nanoelectronics consortium on sustainability (ENCOS)

- Reduce the power consumption and industrial waste
- Substitute or decrease the use of toxic, hazardous, and critical raw materials
- Extend the lifetime of electronics devices by design
- Innovative recycling solutions
- Reduce power consumption of electronic
- Increase the transparency of the supply chain within the consumer electronics sector
- Develop new business models to overcome the planned obsolescence
- Advocacy - public authorities and governments to anticipate the new laws, labels, norms, regulations, etc.

PuzzlePhone

 **UCLouvain**

 **EPFL**

 **UNIVERSITY OF  
CAMBRIDGE**

ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

 **cea**  
FROM RESEARCH TO INDUSTRY

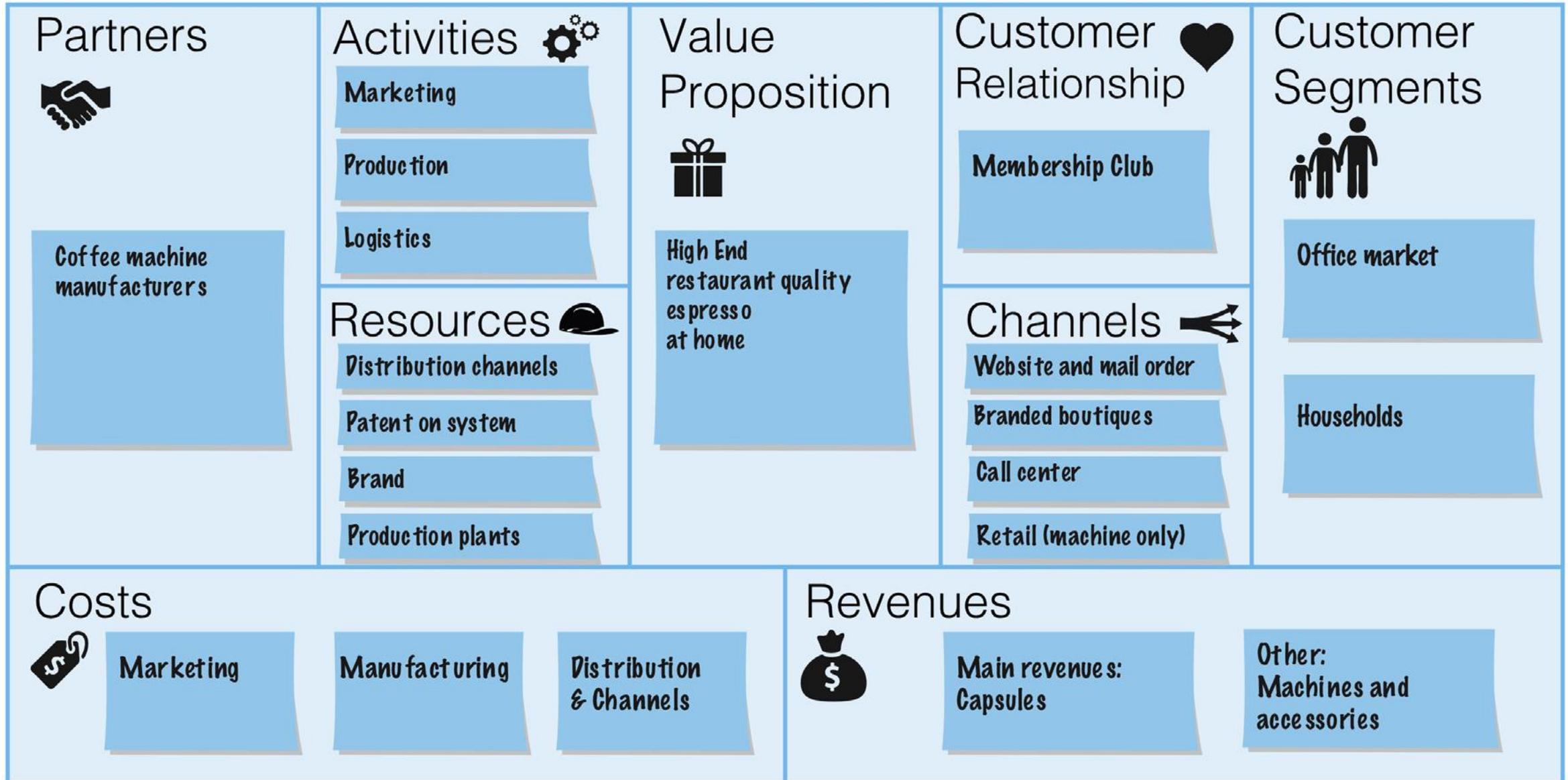
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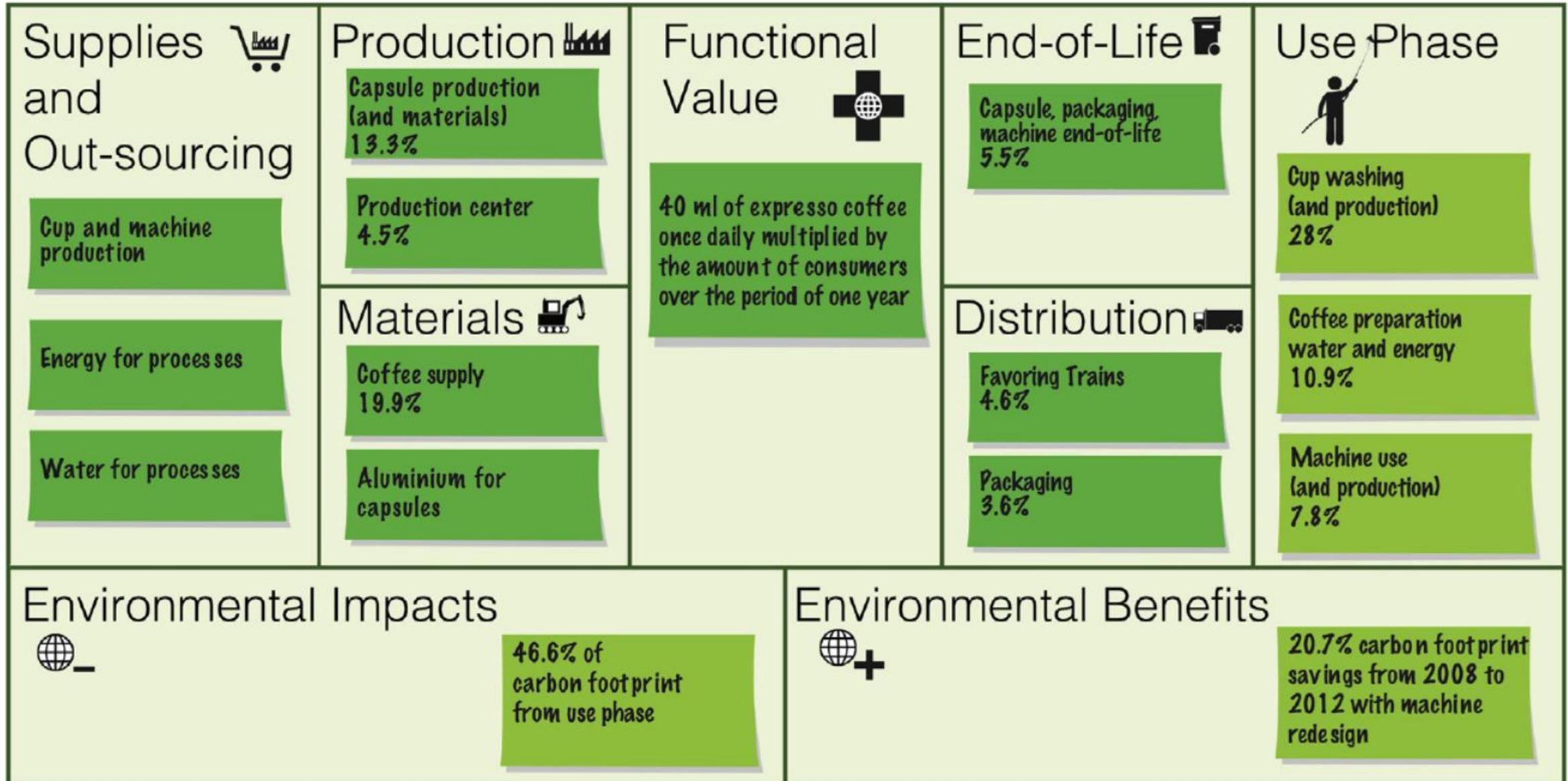
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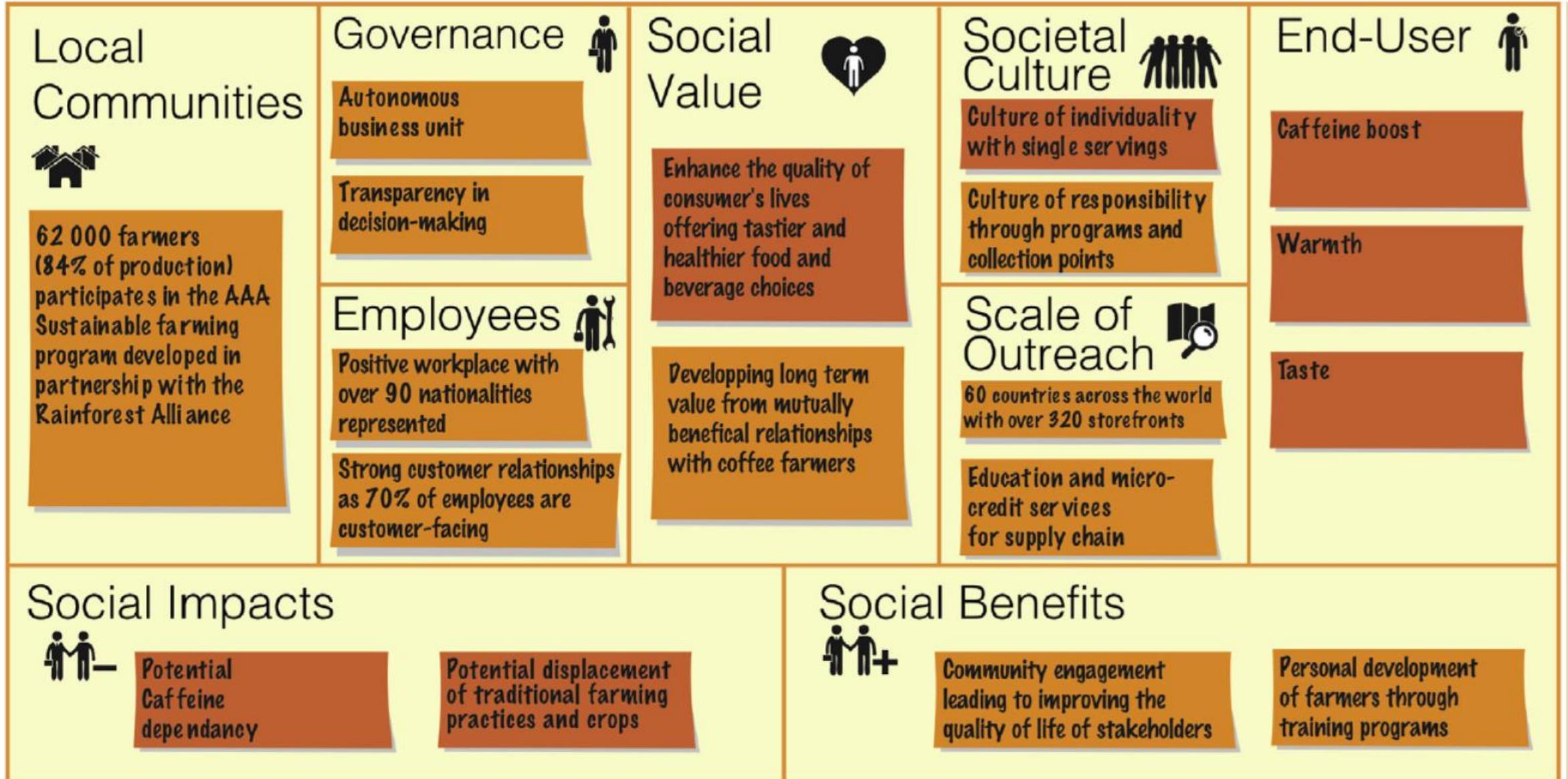
# Economic Business model canvas



# Environmental Life Cycle Business model canvas



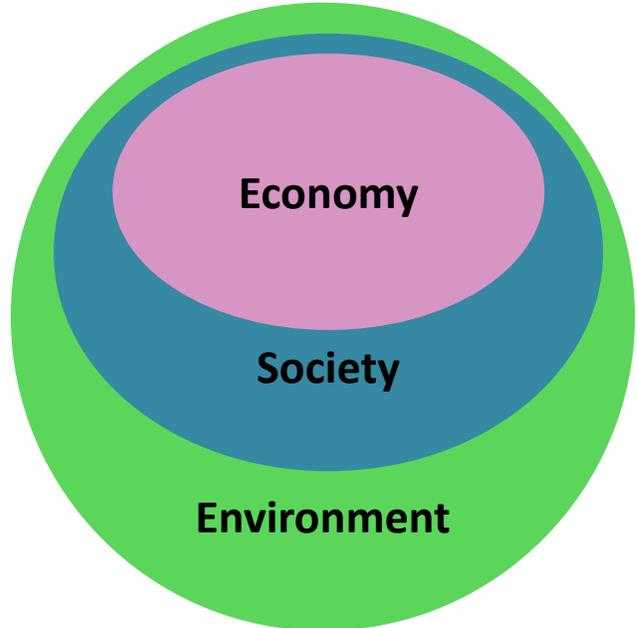
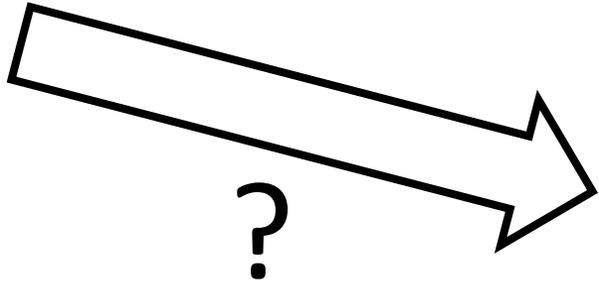
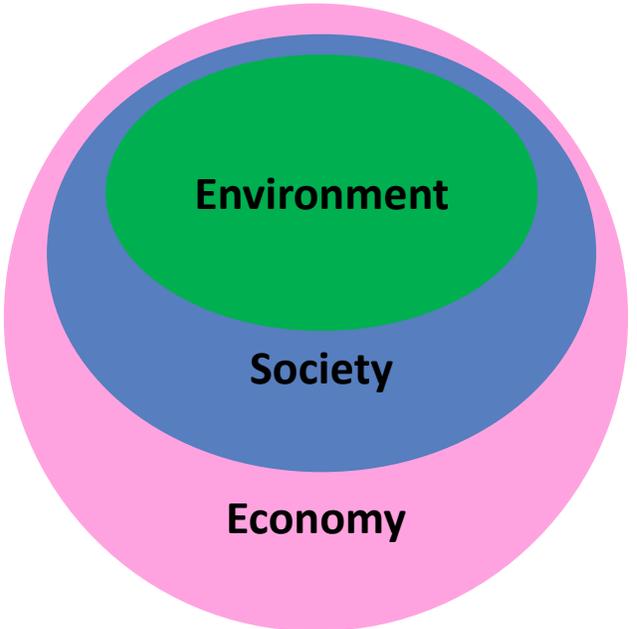
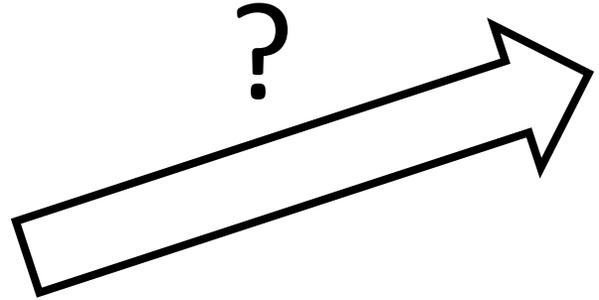
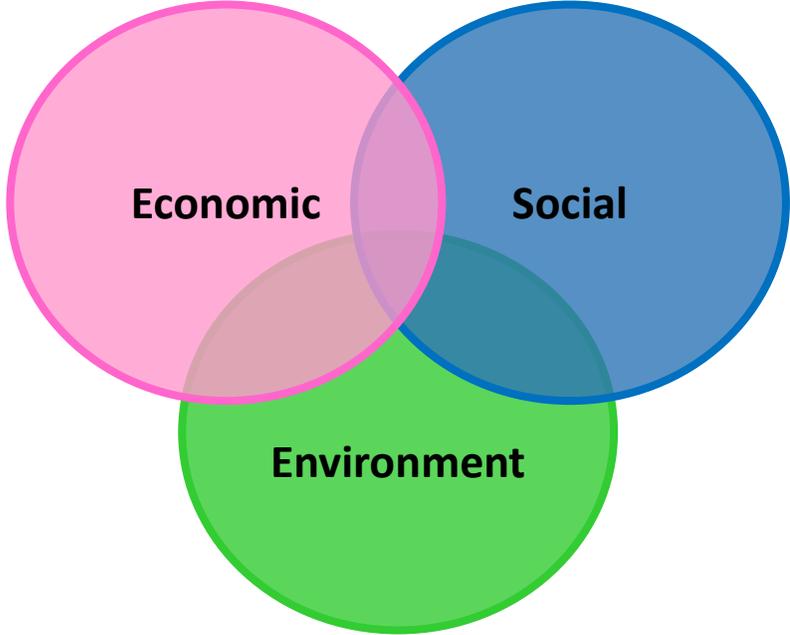
# Social Stakeholder Business model canvas



# Conclusions - Transition vers des technologies appropriées

- Les défis sont colossaux !
- Une optimisation du système techno-économique ne suffira pas (on déplace le problème), une **transformation profonde** des modes de vie des populations les plus riches est nécessaire
- Economie circulaire, design modulaire, économie de la fonctionnalité, ... une technologie centrée sur les besoins de base de l'humanité en respect avec son écosystème
- Nécessité d'outils d'aide à la décision – **Life Cycle Assessment (LCA)** + **continuous technology assessment** + **débats publics**
- Le **législatif** comme levier de changement. Les pouvoirs publics doivent défendre les biens communs et oeuvrer pour soutenir les plus fragiles ici et ailleurs.

Quels chemins ?  
Quelles visions ?  
Quelles valeurs ?



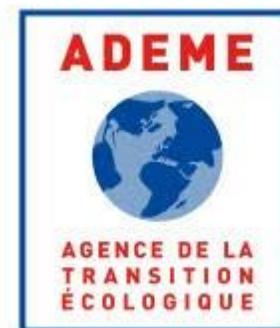
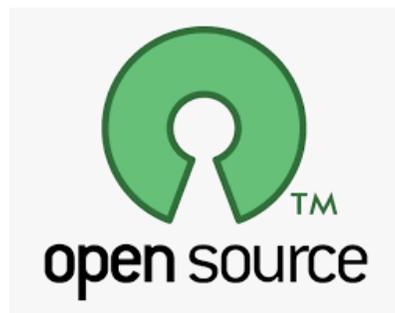


**Doctoral school on Sustainable ICT**

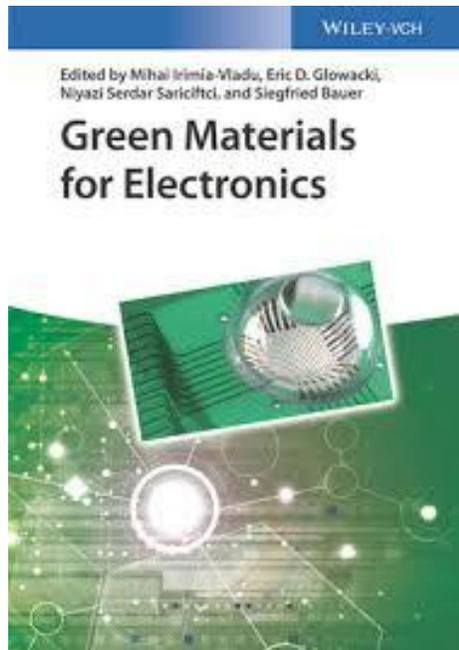
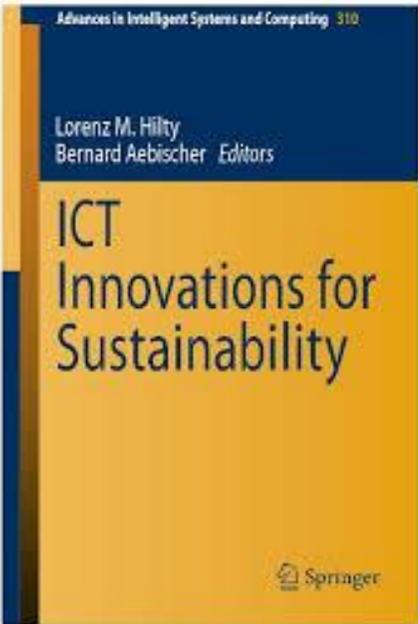
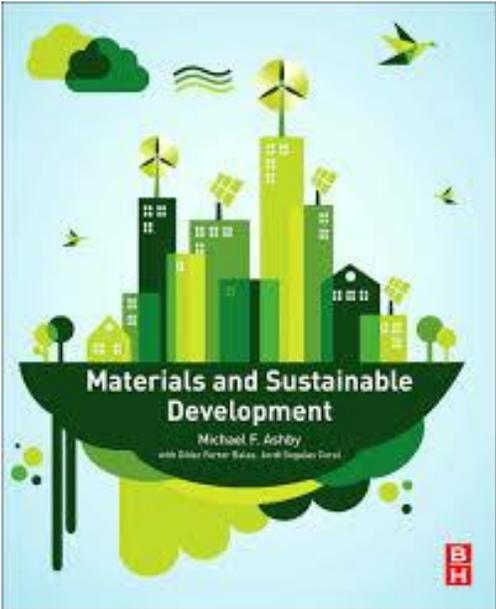
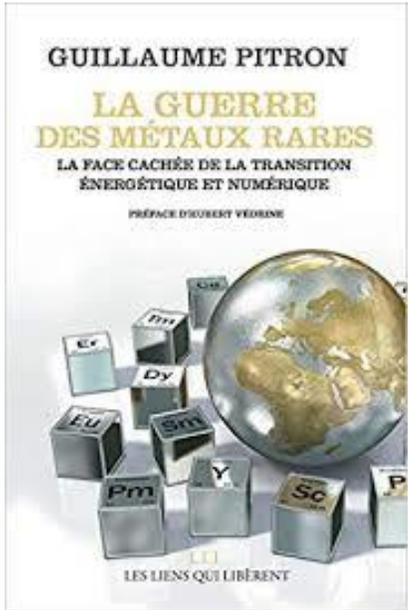
<https://sites.uclouvain.be/sict/>

**Université catholique de Louvain  
Louvain-la-Neuve**

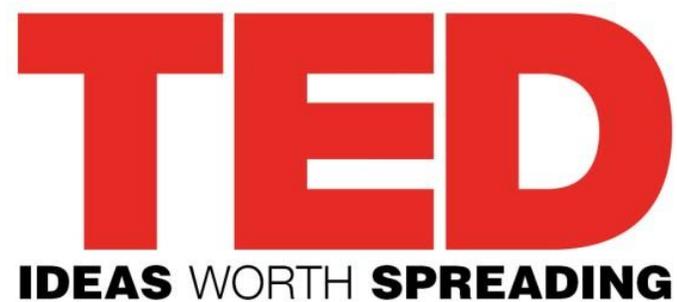
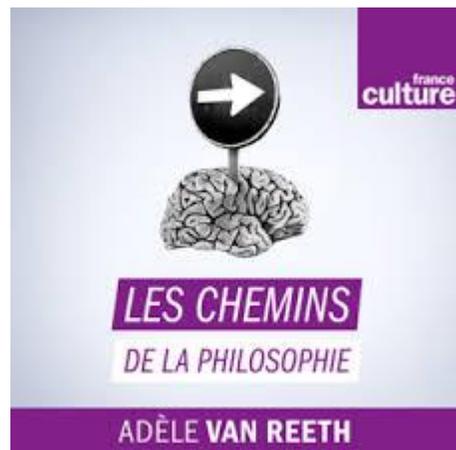
**September 7-11, 2020**



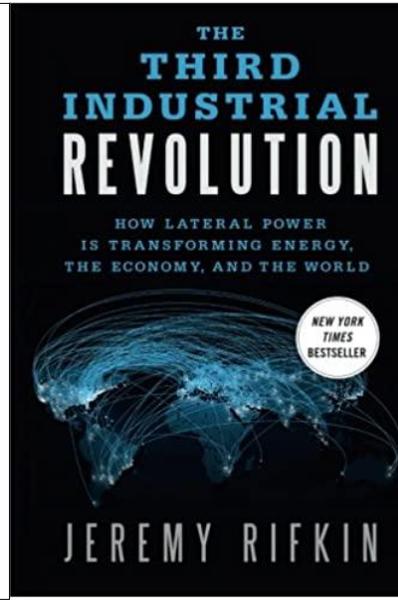
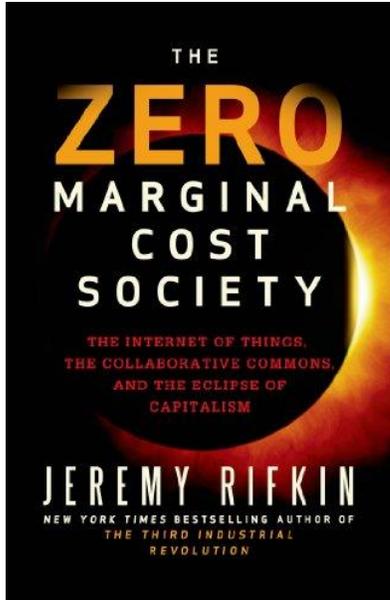
# Books



# Podcasts



# Courants de pensées : est-ce que la solution sera technologique ?

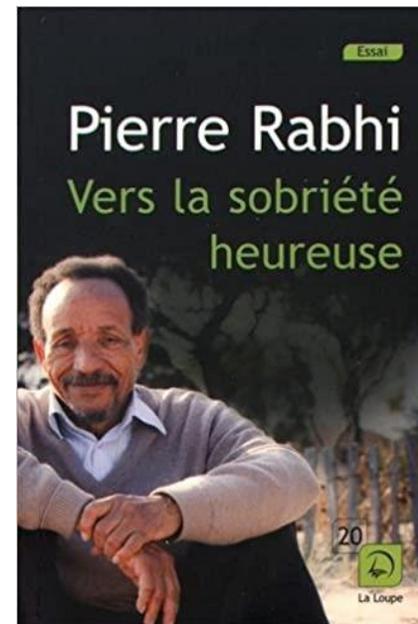


Est-ce que la technologie va nous sauver ?

“nous” de qui parle-t-on ?

Classes sociales, Nord-Sud, faune-flore,...

**Regards croisés !**



[Les couilles sur la table] Des ordis, des souris et des hommes

<https://podcastaddict.com/episode/100077123>

[AFROTOPIQUES] MALCOM FERDINAND // Penser une écologie décoloniale, une écologie-du-monde

<https://podcastaddict.com/episode/83329476>

TED talk - Chimanda Adichie : Le danger d'une histoire unique

Il y a différents centres de production du savoir, occident, Asie, Afrique, pas idéaliser, écouter les différents récits, prendre et construire son imaginaire

<https://www.youtube.com/watch?v=D9lhs241zeg&t=131s>

TED talk - Hans Rosling

New insight on poverty:

[https://www.ted.com/talks/hans\\_rosling\\_new\\_insights\\_on\\_poverty?referrer=playlist-the\\_best\\_hans\\_rosling\\_talks\\_yo](https://www.ted.com/talks/hans_rosling_new_insights_on_poverty?referrer=playlist-the_best_hans_rosling_talks_yo)

Global population growth, box by box:

[https://www.ted.com/talks/hans\\_rosling\\_global\\_population\\_growth\\_box\\_by\\_box?referrer=playlist-the\\_best\\_hans\\_rosling\\_talks\\_yo](https://www.ted.com/talks/hans_rosling_global_population_growth_box_by_box?referrer=playlist-the_best_hans_rosling_talks_yo)

The magic of washing machine:

[https://www.ted.com/talks/hans\\_rosling\\_the\\_magic\\_washing\\_machine?referrer=playlist-the\\_best\\_hans\\_rosling\\_talks\\_yo](https://www.ted.com/talks/hans_rosling_the_magic_washing_machine?referrer=playlist-the_best_hans_rosling_talks_yo)

#SMARTer2030 – ICT Solutions for 21st Century Challenges

[http://smarter2030.gesi.org/downloads/Full\\_report.pdf](http://smarter2030.gesi.org/downloads/Full_report.pdf)



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GLOBAL e-SUSTAINABILITY  
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