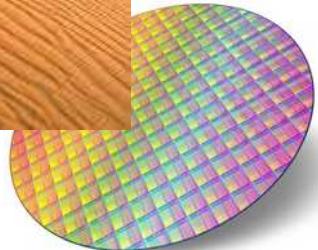


# Digital Technology, gas pedal of the Anthropocene



<https://creativecommons.org/licenses/by-nc/4.0/>



Didier Mallarino

# Who am I ?

Didier Mallarino - CNRS Research Engineer (since 2002)

- **Location**: University of Toulon (since 2007 au LSEET/MIO/OSU Pytheas)
- **Education** : DUT GEII Toulon, Supelec engineer
- **Activities** :
  - Open Science & Data Management for Scientific projects, IT Support, Sustainable part of the Exa-AToW-Numpex PEPR project
  - Course & Intervention (engineer school & university)
- **Management** of the SIST & EcolInfo professional networks
- And forgive me in advance, but English is not my strongest skill :-)

- Founded in **2006** & « **Groupement De Service** » (**GDS**) in **2012**.
  - Supported by the **CNRS** through two of its institutes : **I'INS2I** (Computer Science) and **I'INSEE** (Ecology & Environnement).
- Around **60 engineers, teachers, professors and researchers** from different sectors of ESR in France who work around a **common goal** :

**Act to reduce negative environmental & societal impacts of ICT**

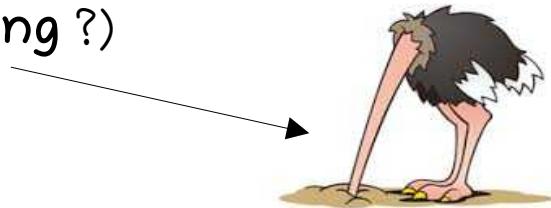
Act



# Sommaire



- The general context and environmental issues : **why we must act now ?**
- Digital impacts, **tools** to understand them : direct, indirect and rebound effect, LCA and first level of actions.
- How to act at the individual and, more importantly, collective level ?
- Barriers to action (or **why the hell don't we do something ?**)
- Conclusion

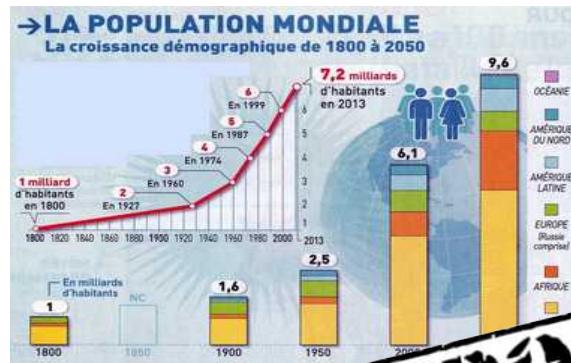


# Context : the Anthropocene era

- **Anthropocene Era** : current geological age, viewed as the period during which human activity has been the dominant influence on climate and the environment.
- **Global changes** have been accelerating for the last hundred years and the **causes** of these changes are **largely human** and especially **systemic**:
  - **Modes of consumption and production**: intensive agriculture, soil artificialization, chemical inputs, excessive meat-based diet, combustion of fossil fuels for domestic comfort, transportation, agriculture, and energy production (**JM Jancovici**).
  - Population growth (+2,64 people every second, source : <https://www.ined.fr/>),



[https://fr.wikipedia.org/wiki/%C3%89levage\\_en\\_batterie](https://fr.wikipedia.org/wiki/%C3%89levage_en_batterie)



<http://ecohumanite.canalblog.com/archives/2019/11/10/37779007.html>

<https://www.ined.fr/>

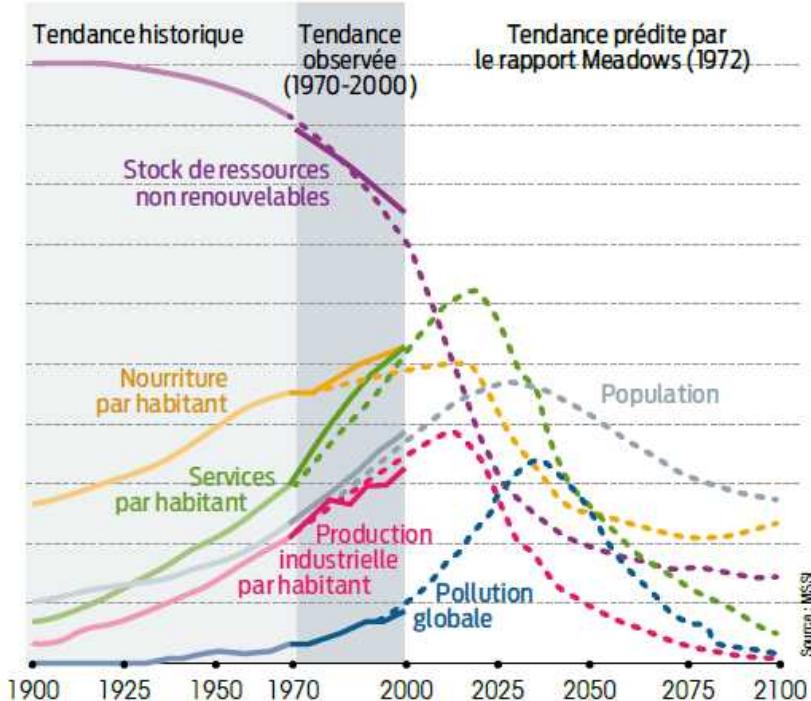
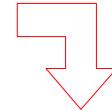
<http://www.musee delhomme.fr/fr/aller-plus-loin/dossiers/77-milliards-dhumains-20-19-sommes-nous-trop-nombreux-terre-4058>

# ■ Already in 1972...

- In 1972, the Club of Rome, a think tank that originated at MIT, published "**The Limits to Growth**" also known as "**Meadows Report**" :
  - *if nothing is done to stabilize population and industrial growth, the planetary system will collapse.* This projection gave the global economic system **sixty years (until 2030)** before its collapse, due to the decline of resources and environmental degradation
- On March 1, 2012, **40 years later**, the Smithsonian Institution released an updated version and **confirmed** the 1972 findings :
  - *A radical overhaul is essential if we hope to extend this deadline*

# ... we knew the root cause

« Anyone who believes in infinite exponential growth in a finite world is either a fool or an economist »



But even back then, and still today, the prevailing notion has been, "To save the economy, one must buy, buy anything."

Dwight D. Eisenhower (1890-1969), 34th president of the USA



<http://jeanzin.fr/2012/09/11/la-societe-de-consommation-avant-le-capitalisme/>

# Context & indicators

Indicators are largely in the red part.

A catastrophic and detrimental situation for our species.

Indicateur global: Earth Overshoot Day (Jour du dépassement, 5 mai 2022 pour la France)

## Country Overshoot Days 2021

When would Earth Overshoot Day land if the world's population lived like...



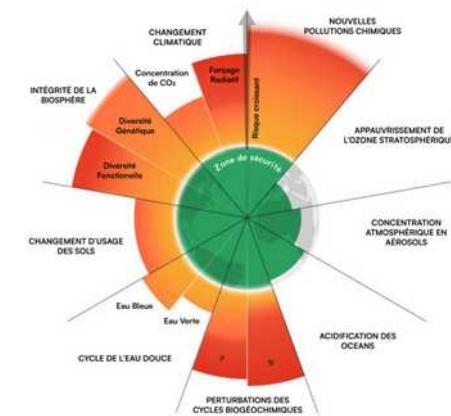
## 6 planetary boundaries already crossed

- Climate change
- Biodiversity Sixth mass extinction
- January 2022 : chemical pollutions  
(water, soils, atmosphere)
- Soil and ecosystems/biomes  
Destruction
- Changes in geochemical cycles
- April 2022 : Changes in freshwater cycle

Indicateur sectoriel : Limite Planétaires (Planetary Boundaries) - Rockström & al (2009) et Steffen & al (2015)

## LES LIMITES PLANÉTAIRES

2023 : 6 Limites dépassées

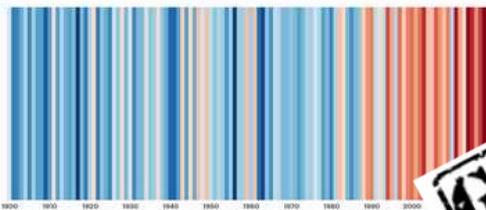


# Climate, some elements



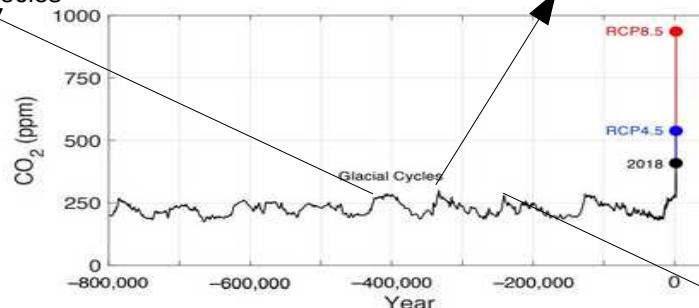
Ce graphique représente l'évolution de la température moyenne par an en France métropolitaine sur une période de 120 ans, de 1900 à 2020. Il indique également l'écart aux normales (soit 11,8 °C, calculé à partir de la moyenne des températures de 1981 à 2010).

10,8°C 14°C



**GIEC 2025**

-445,000 : L'ordovician  
70 % of species



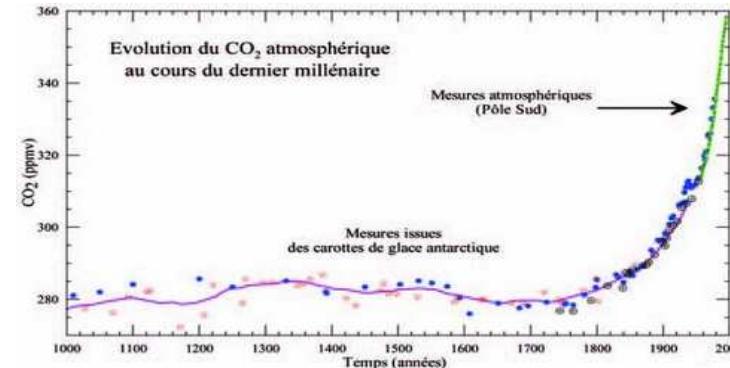
-360,000 : L'ordovician  
75 % os species



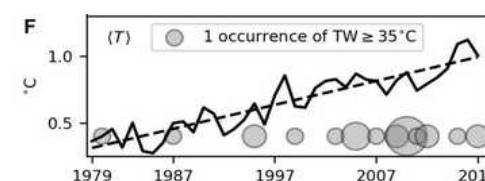
-252,000: Permian  
95 % of species



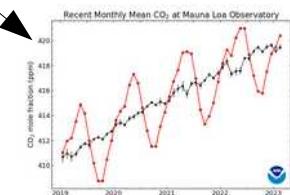
« Among the ten hottest years since 1900, seven belong to the decade 2010-2020 »



February 2023 : **420ppm**, Mauna Lao observatory



Global trends of humid heat: curve shows global annual average temperature (relative to 1850-1879) ; circles indicate TW occurrences above 35 °C.



**CO<sub>2</sub>>400ppm ~ Pliocene**  
(3 million years) : Trees in Antarctica, sea level 15 to 20 mètres higher & average temperature 3 to 5 degrés above

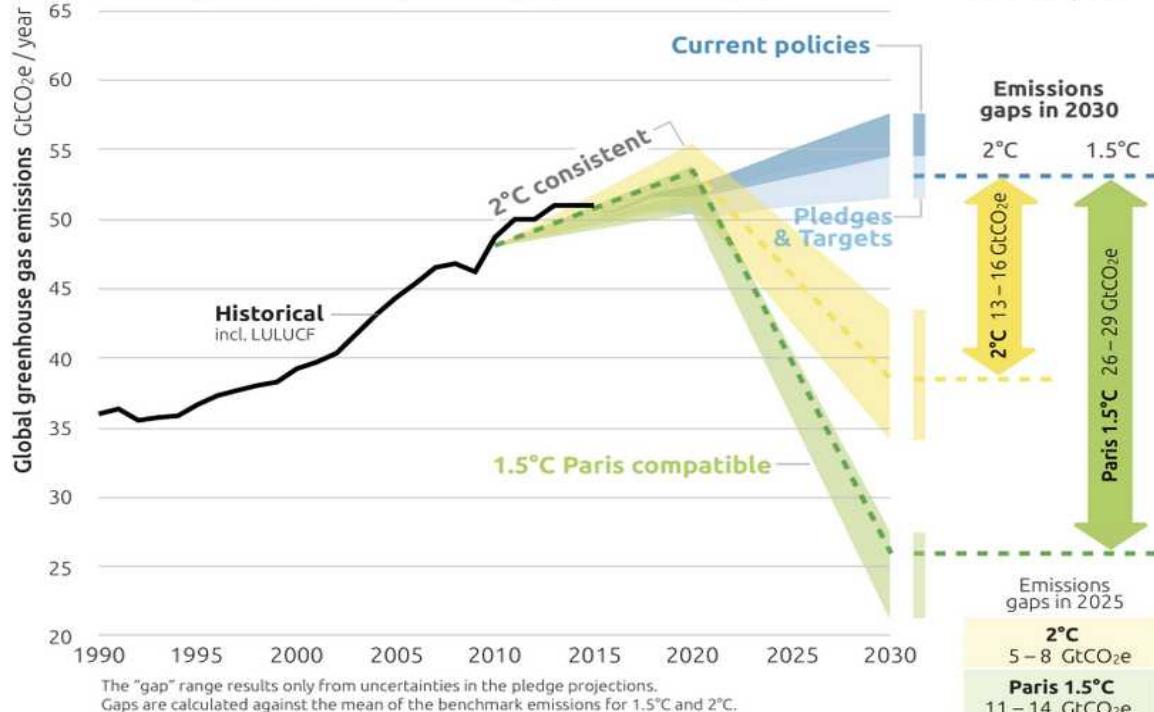
# Our CO<sub>2</sub> emissions

## 2030 EMISSIONS GAPS

CAT projections and resulting emissions gaps in meeting the 1.5°C Paris Agreement goal vs 2°C Cancún goal

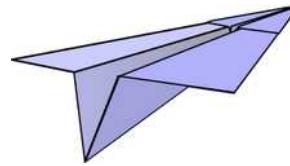


Dec 2019 update



And digital part ?

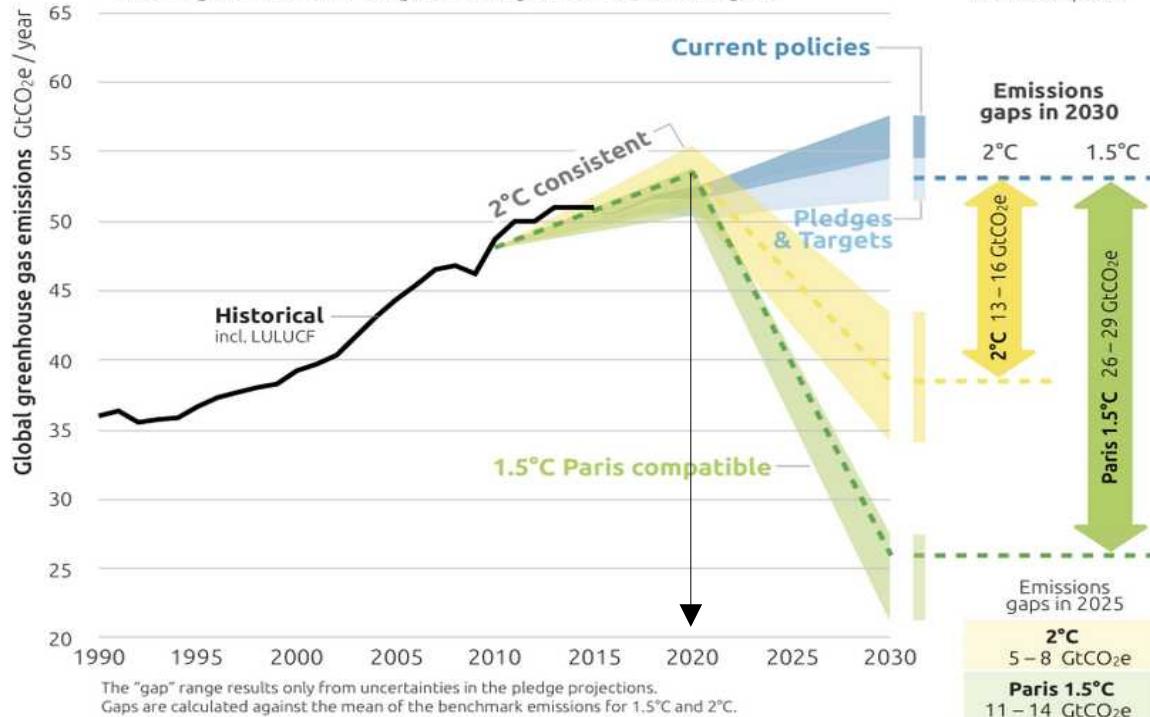
# Our CO<sub>2</sub> emissions



**TIC** ~ 4 % but,  
+6 %/year (i.e x2 /  
12 years)

## 2030 EMISSIONS GAPS

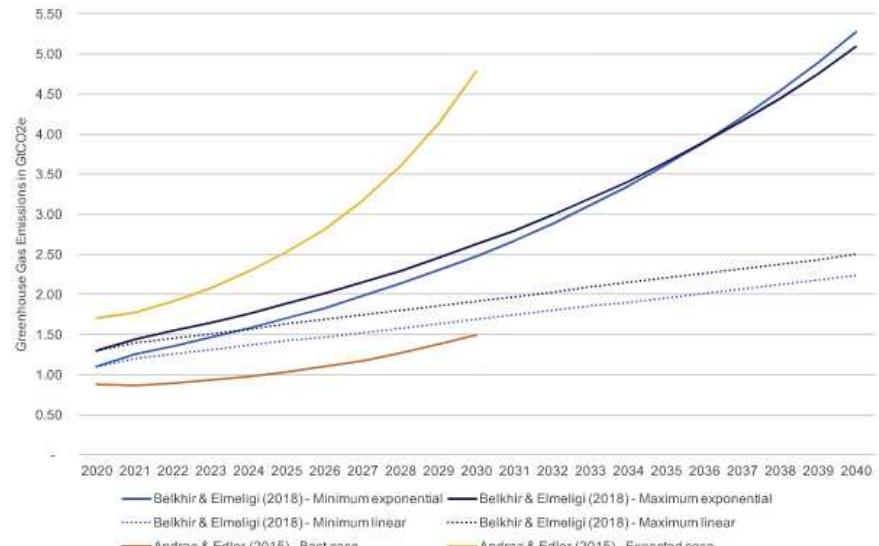
CAT projections and resulting emissions gaps in meeting the 1.5°C Paris Agreement goal vs 2°C Cancún goal



Dec 2019 update

Aviation Industry

Digital growth projection (GHG impacts)

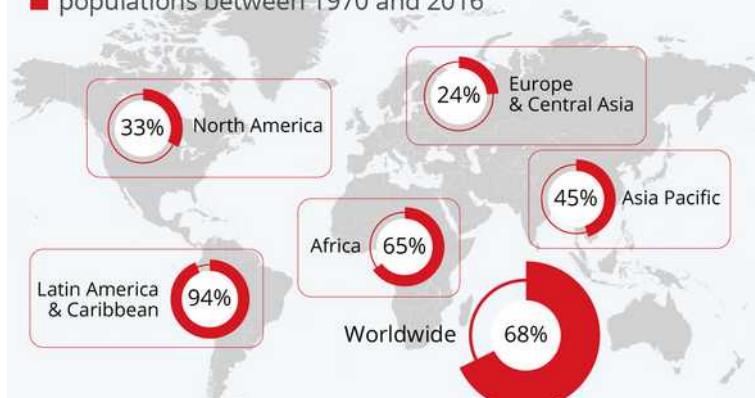


# Biodiversity



## Global Wildlife Populations Suffer Catastrophic Collapse

Decline in monitored vertebrate species populations between 1970 and 2016\*

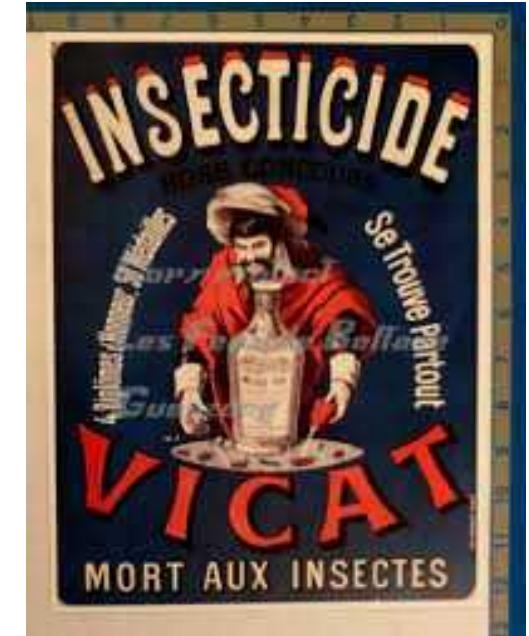
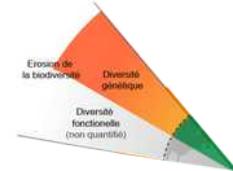


\* Based on 20,811 populations of 4,392 species (mammals, birds, amphibians, reptiles and fish).

Source: 2020 Global Living Planet Index



statista



# Biodiversity

Biodiversity : one species out of eight animal and plant is at risk of disappearing in the near future : we are facing a **sixth mass extinction**

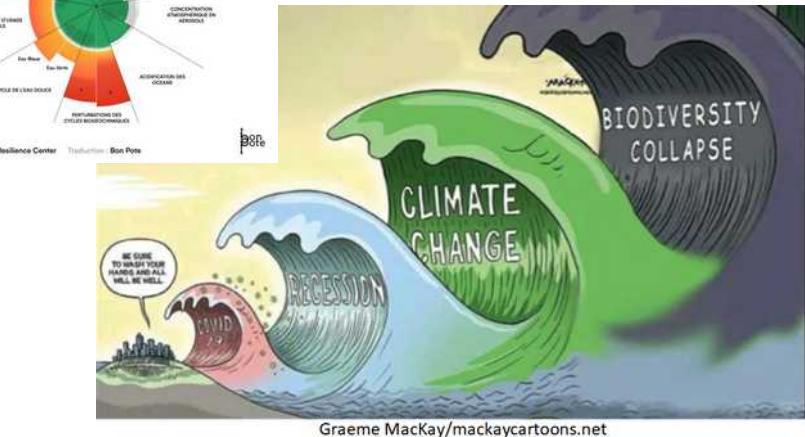
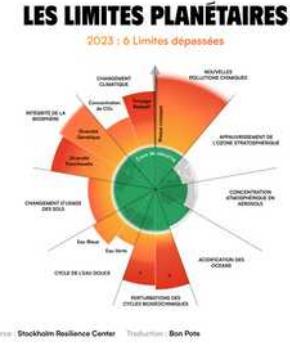
Source : IPBES  
(Intergovernmental Platform on Biodiversity and Ecosystem Services) - 2019



- **A German study spread over 30 years has shown a decrease in Europe of 75 to 82% of the global biomass of insects**
- 68% of vertebrate animals have disappeared since 1970, according to **WWF living planet report** (France Info), **PDF Report**
- 38 % of bats disappeared from metropolitan France between 2006 and 2016 and 23 % of common specialist birds between 1989 and 2018.
- In term of **biomass, humans and livestock** represent **96 % of mammals, 18 % of vertebrates**, and **humans** represent **0.01 %** of the total biomass.
- We **kill 300 billion fish and 80 billion farmed animals** each year : **1,1 billion/day**.

# Deep changes already here

- Deep changes in water cycles
  - minimal human needs : 20 liters by days
- Significant increase of heatwaves anomalies (> 35 °C Tw)
- Deep ecosystems disruptions
  - 6th extinction, plants and animals,
  - Desertified lands
  - Pandemics
- Giants fires
- Significant increase of extremes events.



*And numerous consequences on our societies : Famines, struggle for water ressources, migrations, wars. "We cannot seriously contemplate the future in light of the present and its temporary stability."*

# The Digital



<https://www.piqsels.com/fr/public-domain-photo-sbzrt>

Digital is **virtual** and **immaterial**,  
isn't it ? Digitizing the world,  
that's **the** solution, right ?



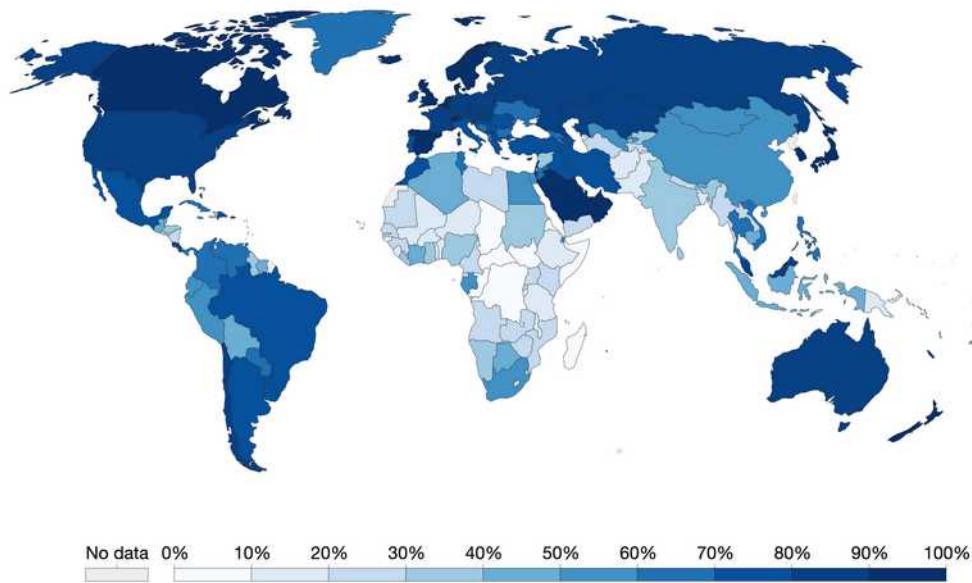
<http://www.pressenza.com/fr/2016/05/revenu-de-base-sauver-planete/>

# Who is using digital technologies ?

## Share of the population using the internet, 2019

All individuals who have used the Internet in the last 3 months are counted as Internet users. The Internet can be used via a computer, mobile phone, personal digital assistant, gaming device, digital TV etc.

Our World  
in Data

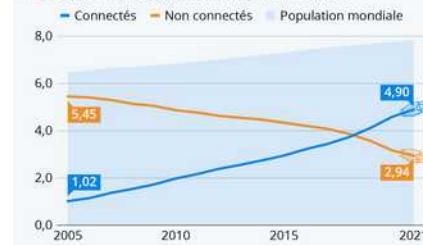


Source: International Telecommunication Union (via World Bank)

[OurWorldInData.org/technology-adoption/](https://OurWorldInData.org/technology-adoption/) • CC BY

## Plus du tiers de l'humanité n'a pas accès à Internet

Estimation du nombre de personnes ayant accès ou pas à Internet dans le monde (en milliards)



Source : Union internationale des télécommunications

statista

# Three approaches to consider

⇒ 3 analysis axes, and therefore, of first level  
possible actions



Software



Hardware



Data

# Hardware

Cables, antennas, boxes, billion of terminals plus connected objects

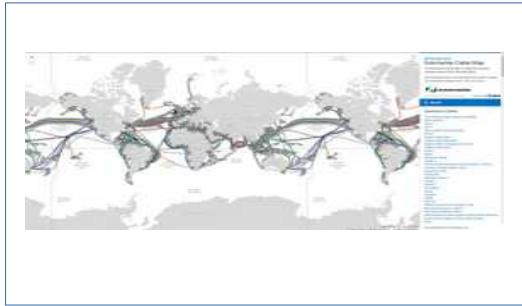
Phone sales : 2 billion/year, 80/s



2 billion Pcs in service in 2020, 500 million pro in 1980 ; sales about 10/s



**99 % of intercontinental traffic through submarine cables** ; 250 cables in 2013, 448 cables in 2018 for 1,2 million kilometers ; ~ 100.000 km of cables / year deployed

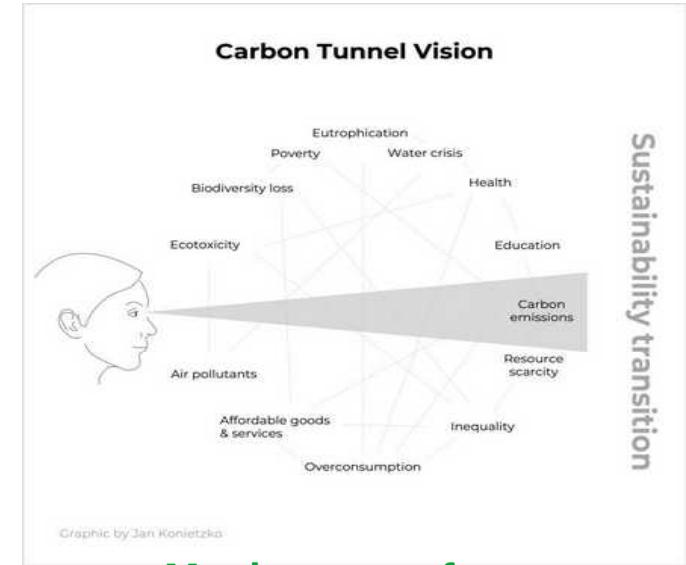


In 2021, more than **8000 major data centers** (Just in France, in 2016, 157 data centers = 8% of the electricity consumption)

# Life Cycle Assessment

**Standardized evaluation method (ISO 14040 et 14044)**

- **Applications :**
  - **Identification** of environmental issues,
  - **eco-design** of products,
  - products **comparison...**
- **« Life cycle » approach** : all stages of the life cycle of a product, process or service are taken into account for the inventory of incoming (energy, materials) and outgoing (waste, gaseous and liquid polluting emissions) flows
- **Multi-criteria approach**: Quantification at each stage of incoming and outgoing flows with their impacts ⇒ order of magnitude, because of many uncertainties due to the complexity of the analysed situation

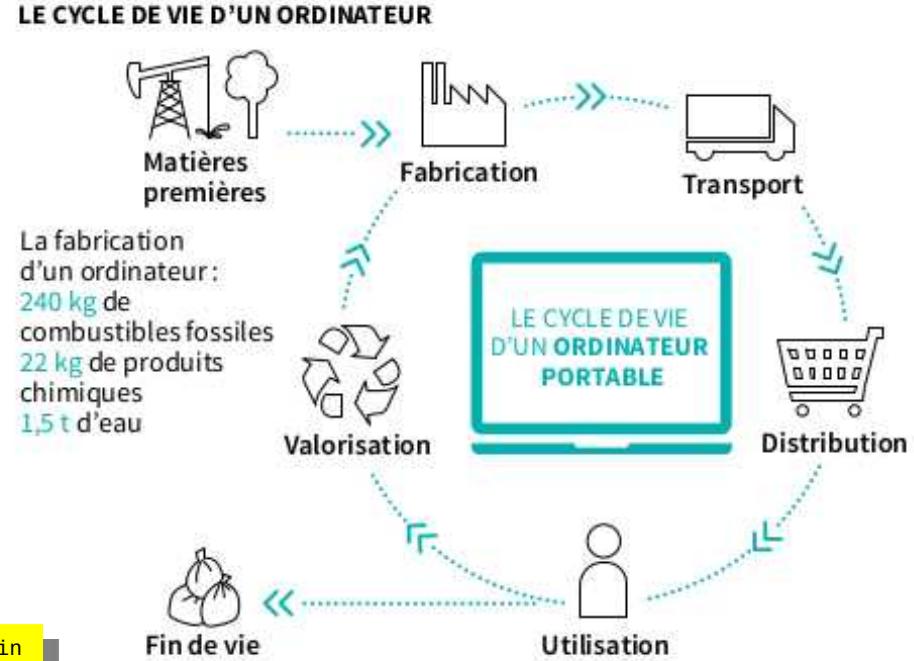


**Moving away for a  
carbon centric vision**

# Life Cycle Assessment

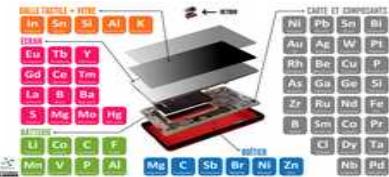
- **Perimeter** : Objective and functional unit  
(example: light bulb that illuminates 1000 hours with a luminosity of 40W, pen that has a writing length of 20km)
- **Describe** life cycle
- **Study limits**, required **Data quality** and **audience** of the study.
- **Inventory** of in and outgoing of each elementary process
- **Assessment** of impacts and problems : raw results of analyse.
- **Interpretation of results**

Lenovo LCA (in 2015)  
indicates 6 t d'eau :

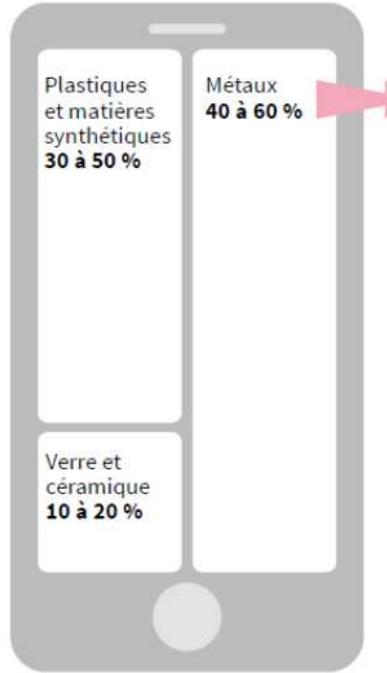


Étude de « Kuehr et Willians », 2003

# Life Cycle Assessment



RÉPARTITION DU POIDS DES MATERIAUX  
DANS LA COMPOSITION D'UN SMARTPHONE



Materials ~ 240 kg ; Water ~ 85.000 l

## PROPORTION DES MÉTAUX

80 à 85 % de métaux ferreux et non ferreux: cuivre, aluminium, zinc, étain, chrome, nickel...

0,5 % de métaux précieux : or, argent, platine, palladium...

0,1 % de terres rares et métaux spéciaux : europium, yttrium, terbium, gallium, tungstène, indium, tantalum...

15 à 20 % d'autres substances : magnésium, carbone, cobalt, lithium...

Ils sont indispensables.  
Plus de 70 matériaux différents pour fabriquer un smartphone (ADEME; Guide « Achats : Les impacts du smartphone; 2019»)

**Dozens of « essential » materials**

- ✓ Glass, ceramics,
- ✓ Synthetic materials
- ✓ Metals
  - ✓ Precious
  - ✓ Rare earth minerals
  - ✓ Ferrous or non-ferrous
  - ✓ Other

# Directs impacts : Extraction



Une mine d'extraction de métaux rares dans la région de Baotou dans le nord de la Chine. Photo prise le 6 juillet 2010. —AP/SIPA



La lac toxique de Baotou (Chine)  
David Gray / Reuters



Une femme et un enfant cassent de la roche extraite d'une mine de cobalt à Lubumbashi, dans la province du Katanga, en RDC, le 23 mai 2016. (JUNIOR KANNAH / AFP)



Mine de chrome, Kazakhstan, crédit photo : businessmir.kz.



- Extraction of raw materials

- Sands
- Minerals,
- Oil

- Pollutions

- Extractions : chemical reactions
- dissolutions, water, acids
- Grinding, heating,



- Water

- Desalinisation

- Children oppression and exploitation



- Armed conflicts

<https://ecoinfo.cnrs.fr/2010/08/06/les-terres-rares-la-separation-des-terres-rares/>

La guerre des métaux rares, Guillaume Pitron

<https://corpus.ulaval.ca/jspui/bitstream/20.500.11794/28326/1/34069.pdf>

<https://www.planetoscope.com/sols/1048-production-mondiale-de-terres-rares.html>

<https://www.cieau.com/le-metier-de-leau/ressource-en-eau-eau-potable-eaux-usees/quels-sont-les-usages-domestiques-de-leau>

<https://www.jforum.fr/découvrir-une-usine-de-désalémentation-de-l'eau-de-mer-video.html>

# Direct Impacts : Extraction

## Le poids des TIC dans la demande mondiale

Métal	Production minière mondiale 2013 (*)	Consommation totale du secteur électronique % de la demande (**)	Commentaires
Cuivre	18,7 millions t	~ 6 %	3% équipements, 3% infrastructure télécom
Etain	296.000 t	<b>- 35%</b>	
Antimoine	160.000 t	< 20 %	Total retardateur de flammes ~ 35%
Argent	26.000 t	~ 20 %	
Or	2.860 t	~ 10 %	
Platine	160 t	~ 2 %	
Palladium	190 t	~ 12 %	
Ruthénium	~ 30 t	<b>- 55%</b>	
Tantale	~ 1400 t	<b>- 60 %</b>	
Indium	~ 800 t	<b>- 80 %</b>	
Gallium	~ 440 t	<b>- 90 %</b>	
Germanium	~ 160 t	<b>30 – 50%</b>	
Bismuth	8.500 t	~ 15 %	
Sélénium	~ 2.300 t (hors USA)	~ 10%	Inclus photovoltaïque
Tellure	~ 450 t (?)	< 10 %	Principalement photovoltaïque
Lithium	36.000 t	~ 20 %	
Cobalt	112.000 t	<b>- 35%</b>	

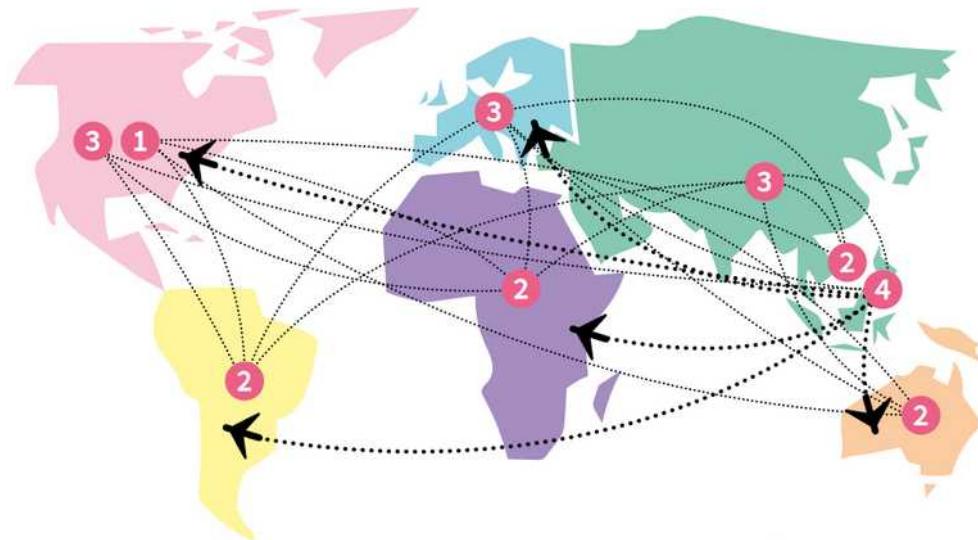
Source : (\*) USGS 2015, (\*\*) Demande totale = Production minière + Recyclage + Déstockage

Global demand for raw materials is expected to double by 2060

4

# Direct Impacts: Transport

QUATRE TOURS DU MONDE POUR FABRIQUER UN SMARTPHONE



**1. Conception** le plus souvent aux États-Unis

**2. Extraction et transformation des matières premières** en Asie du Sud-Est, en Australie, en Afrique centrale et en Amérique du Sud

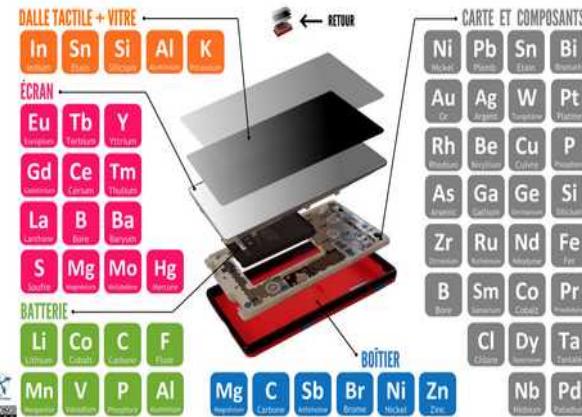
**3. Fabrication des principaux composants** en Asie, aux États-Unis et en Europe

**4. Assemblage** en Asie du Sud-Est

**Distribution** vers le reste du monde, souvent en avion.

- Trucking
- Maritime Transport:
  - Heavy fuel oil
  - Noise from boats disrupt marine mammals
  - mass displacement of water and invasive species
- Aviation:
  - Various Pollutions

# Direct Impacts: Manufacturing



Source : Ingénieurs  
Sans Frontières

- A wafer of 300 mm / 20 g about 8330 liters of water, 70 % ultra pure
- Produce one kilo of silicon wafer:
  - 2933 kWh of electricity
  - 280 kg of chemicals products



<https://www.novethic.fr> - Article



The smaller you try to make it, the more the consumption of primary resources required to do so increases.  
wafers technology node :  
10nm, 7nm, 5nm, 3nm  
(2022)  
Virus Size : 30 times larger... VIH: 90 nm -  
SARS-CoV-2 : 50-140 nm

# Direct impacts : usage

According to the Shift Project, in 2018

- One american : **10 connected digital devices ; data : 140 Go/month**
- An indian : only **1 connected digital device ; data : 2Go/month.**



LMA & Master WAVES

T1 2016	
Nombre moyen d'écrans total par foyer	6,4
Télévision	1,6
Ordinateur	1,4
Console TV	0,5
Console portable	0,3
Baladeur fonction vidéo	0,1
Téléphone mobile (dont smartphone : 1,3)	1,9
Tablette tactile	0,6

Chiffres : CSA, 2016



# Direct Impacts : usage order of magnitude

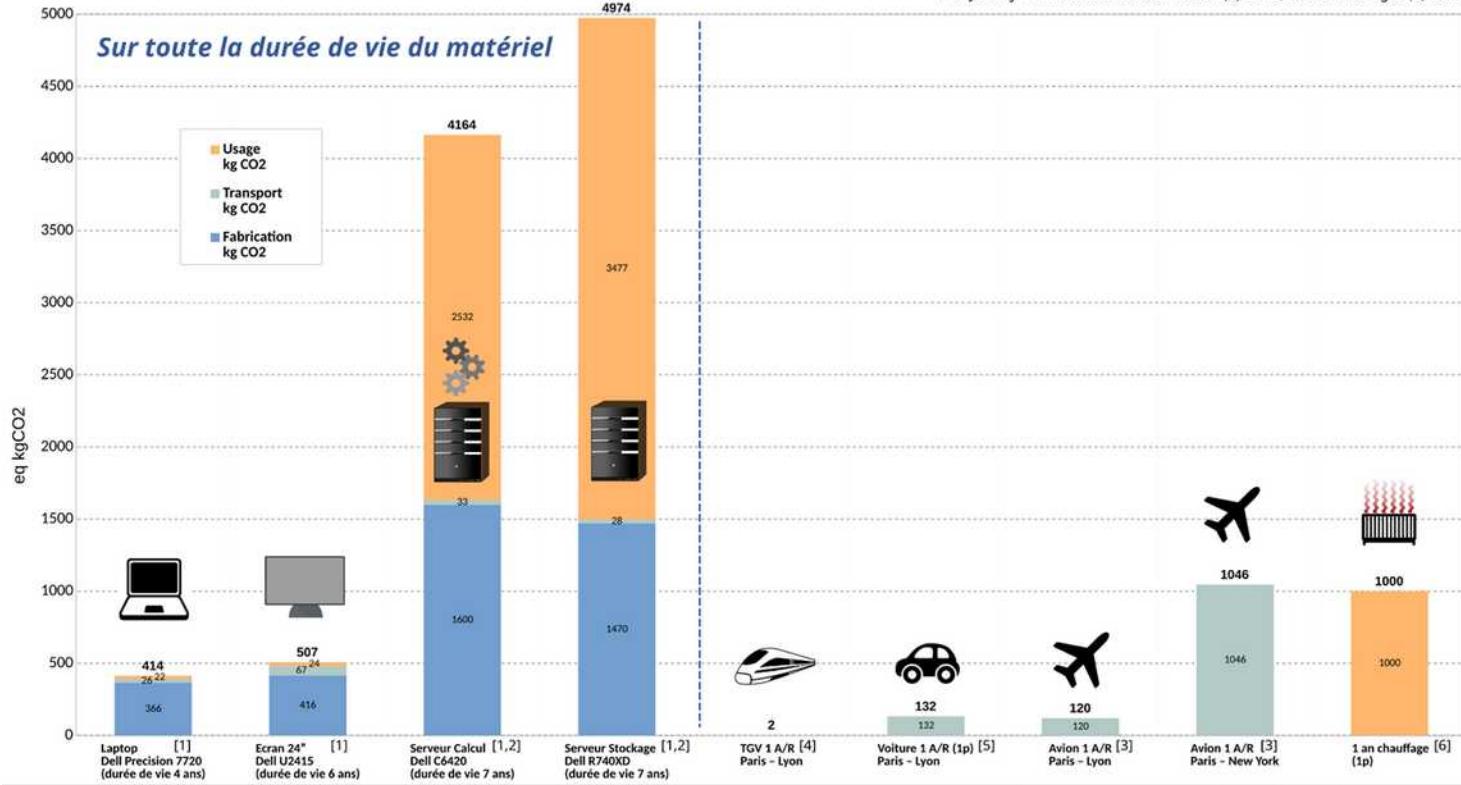
Quoi	Qu'est ce que cela inclut ? (périmètre)	combien ? (en g eq CO2)
<b>une heure.cœur de calcul</b>	Les serveurs, les équipements de refroidissement et d'alimentation électrique (fabrication, transport et usage)	de l'ordre de 2,5 à 5 g (résultat préliminaire) <a href="https://hal.science/hal-02549565v5/document">https://hal.science/hal-02549565v5/document</a> GENCI : moyenne de ~4tCO2e par projet/an (50tCO2e et plus pour les plus gros) <a href="https://www.genci.fr/fr/content/bilan-des-campagnes">https://www.genci.fr/fr/content/bilan-des-campagnes</a>
<b>1 Go stocké pendant 1 an</b>	les serveurs de stockage et les équipements de refroidissement et d'alimentation électrique (fabrication, usage)	de l'ordre de 10 à 30 g <a href="https://hal-cnrs.archives-ouvertes.fr/hal-03573790v1">https://hal-cnrs.archives-ouvertes.fr/hal-03573790v1</a>
<b>fabrication et transport d'un écran d'un serveur d'un ordinateur portable</b>	Extraction des métaux et des ressources abiotiques, fabrication des composants, assemblage, transport vers le site de vente.	selon la méthodologie : de l'ordre de 150 à 500 kg de l'ordre de 800 à 1800 kg de l'ordre de 140 à 450 kg <a href="https://ecoinfo.cnrs.fr/ecoddiag-calcul/">https://ecoinfo.cnrs.fr/ecoddiag-calcul/</a>
<b>1h de visio par personne</b>	Les équipements terminaux des utilisateurs (usage) et tous les équipements intermédiaires : serveurs, réseaux (fabrication, transport et usage).	7 g à 70 g eCO2/h <a href="https://labos1point5.org/les-infographies/poster-ecoinfo-method">https://labos1point5.org/les-infographies/poster-ecoinfo-method</a>
<b>Consommation électrique pendant 1 an d'un serveur qui tourne presque à vide (calcul ou stockage)</b>	Uniquement la consommation électrique du serveur	Entre 30 et 50% de la consommation maximale du matériel (pleine charge)

Source : Françoise Berthoud, Emmanuelle Frenoux et Gaël Gennebaud pour Labos 1point5

<b>What</b>	<b>Perimeter</b>	<b>Cost (g eq CO2)</b>
Processing Data (1 hour/core)	Servers, Cooling and power supply equipement - Manufacturing, usage and transport	Around 2 to 5g
1 Go storage / year	Servers, Cooling and power supply equipement - Manufacturing, usage	Around 10 to 30g
Manufacturing and transport for : - a screen - a server - a laptop	Raw extraction, manufacturing phases and transport	Following methodologies : - 150 → 500 kg - 800 → 1800 kg - 140 → 450 kg
One hour visioconference	Manufacturing transport and usage of all involved materials	Around 7 to 70g
One year electric consumption of a server (processing or storage)	Only electric consumption	Around 30 to 50 % of the maximal consumption

# Distribution of direct Impacts

Par Jérémie Wambecke & Carole Plasson (C) 2019, Laurent Bourgès (C) 2020



[1] Données Fiches Dell (usage corrigé pour usage FR) :  
[https://www.dell.com/learn/us/en/upsrcc1/corp-comm/environment\\_carbon\\_footprint\\_products](https://www.dell.com/learn/us/en/upsrcc1/corp-comm/environment_carbon_footprint_products)

[2] Usage à partir de la consommation moyenne (Berthoud et al. 2020) d'un noeud = 275W (C6420), 375W (R740XD) (<https://hal.archives-ouvertes.fr/hal-02549565>)

[3] <https://eco-calculateur.dta.aviation-civile.gouv.fr/>

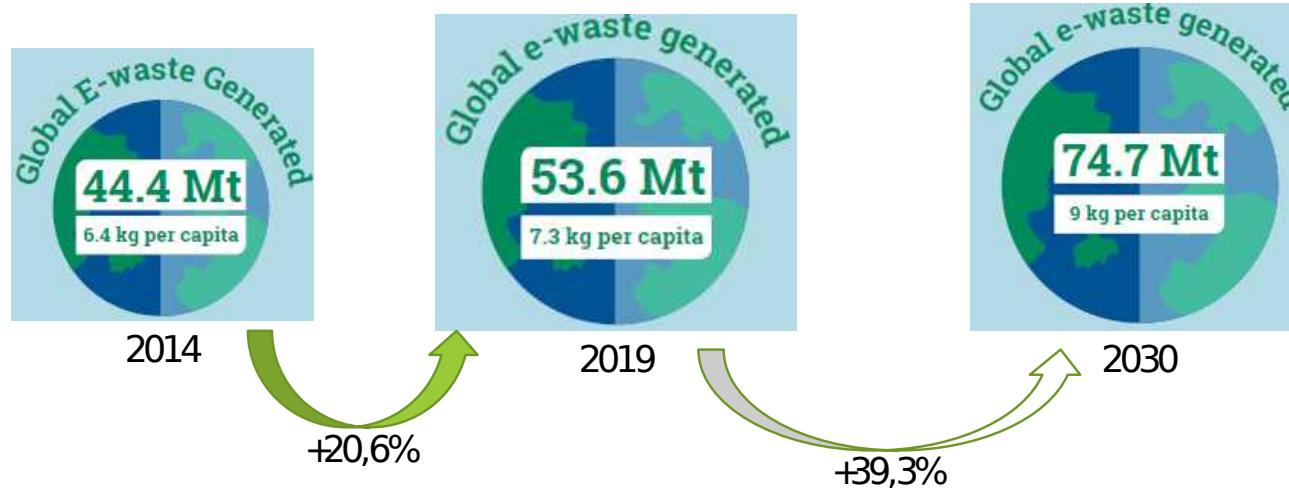
[4] <https://ressources.data.sncf.com/explore/dataset/emission-co2-tgv/table/>

[5] Trajet de 473km, pour une voiture émettant 140g CO2/km

[6] <https://www.insee.fr/fr/statistiques/fichier/1281320/ip1445.pdf>

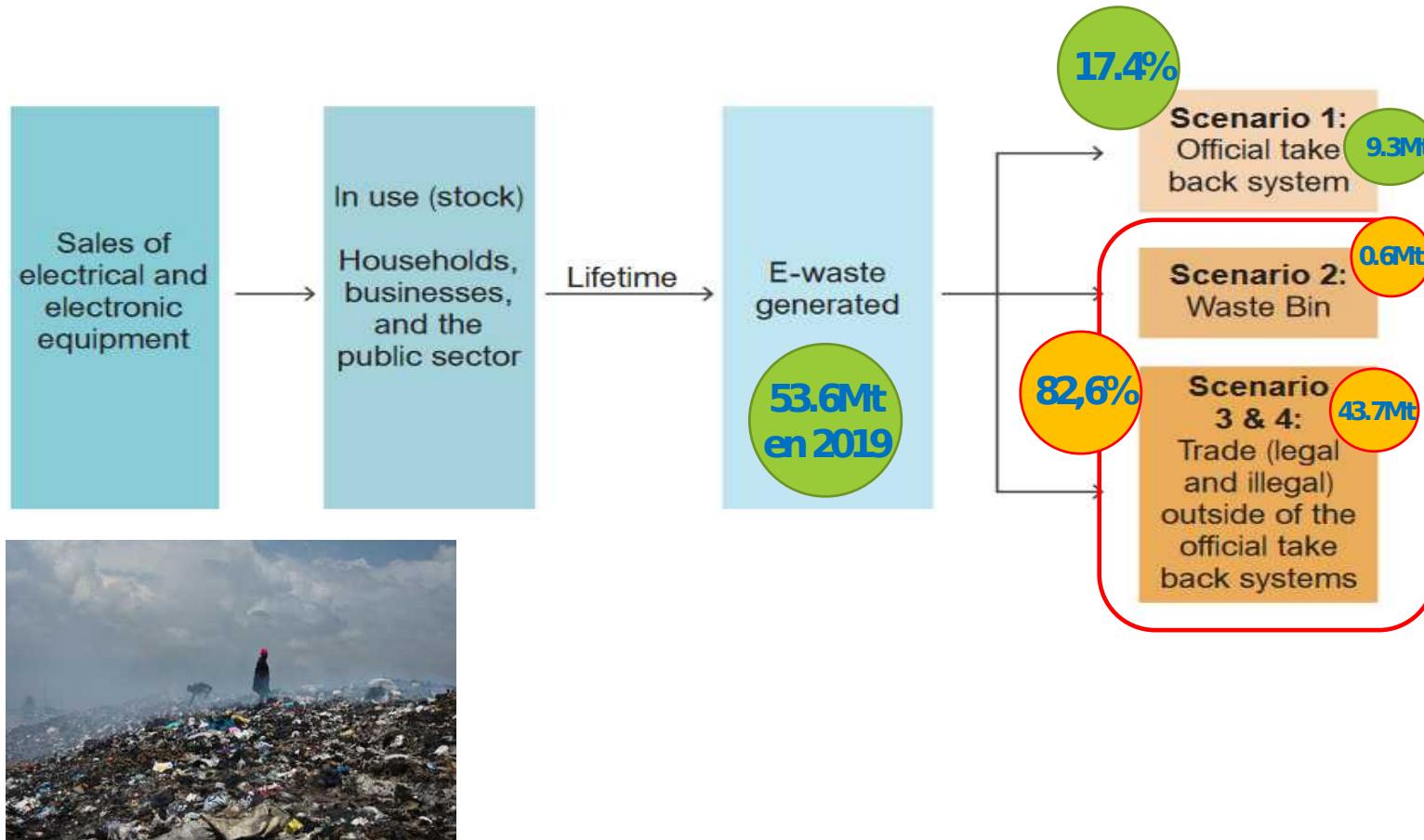
# Direct Impacts : Electronic Waste

Petit cours de conversion...  
44.7 millions de tonnes  
=4500 tours Eiffel



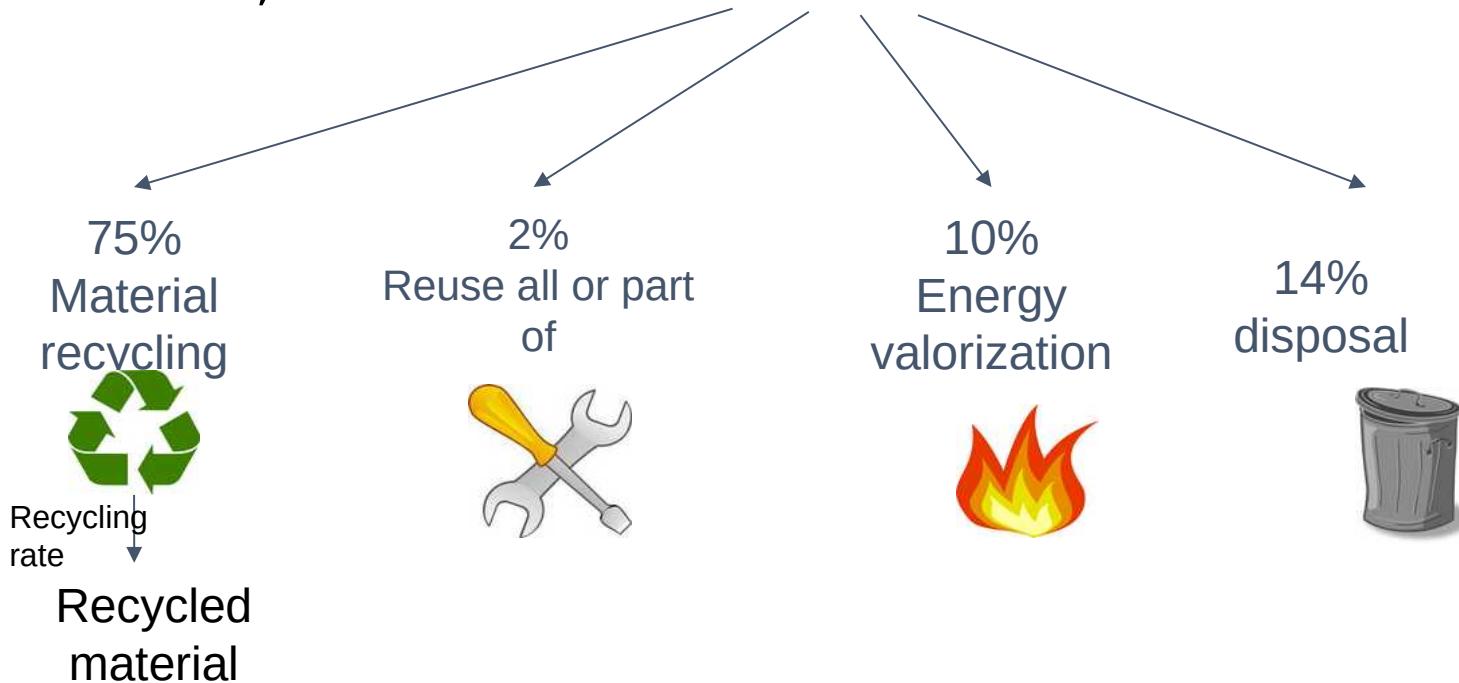
Source : Global E-waste Monitor 2020, Forti, Baldé, Khuer et al, <http://ewastemonitor.info/>

# Direct impacts : Electronic Waste



# ■ Direct impacts : Electronic Waste

in France, it's a little bit better: 47.5% collected in 2019



# Direct Impacts



<https://ici.radio-canada.ca/info/2019/05/coltan-republique-democratique-congo-mines-enfants/>



75 MT in  
2030



<https://terresdesavoirs.fr/les-impacts-du-numerique-environnement/>



<https://www.novethic.fr> - Article



# ■ Hardware: acting at the first level

- Provide the «right » service which **meet to needs**,
  - ⇒ **Properly sizing** when purchasing,
- Make your equipment **lifespan** as long as possible
  - **Mutualize**
  - **Reuse**
- Purchase hardware material with **responsible purchasing criteria** (fair trade, origins, standards, recycled and recyclable),
- **Recycle** in a responsible and certified sector
- Open Hardware (Open Source Hardware Association : <https://www.oshwa.org/>)

# Software



- **Smartphones : more than a million software per store**; one in four unused and 59 % used only once
- **Application size** : from a few hundred to a few billion lines of code
- And more **hardware** to develop & distribute

## What is not useful

- Advertising,
- Poorly designed software
- Fat software and digital services



## Some direct impacts

- Energy consumption
- Performance,
- Technological and hardware performance race

# ■ Software : acting at the first level



plaquette éco-conception  
logicielle

Je code : les bonnes pratiques en écoconception de service numérique à destination des développeurs de logiciels

## An eco design approach

- Before : think, control the number of features, reuse software bricks, plan the management of the software...
- Development Phase : analyse code and measure performances
- After : choose shared and/or local hosting, opening code,
- **EcolInfo software eco-design brochure** :  
<https://hal.archives-ouvertes.fr/hal-03009741/>

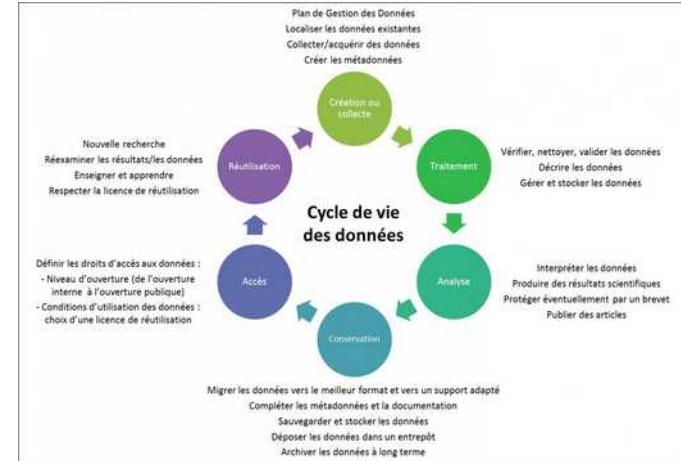
## Other solutions to investigate

- Think **reuse, mutualization** : **Open Source could be a good answer**
- **Think «Sustainable Digital Services »** , and so, think out of the box :-)



## Data Focus

An **unusual** approach of the most **immaterial** aspect which is **indeed the main and only reason** of the existence of digital technologies



Impacts at each stage of the Data Life Cycle

**Data is the main reason of the existence of software and hardware technologies** that enable us to acquire, storage, processing, archiving and reuse these data.

# Data, it's important

- Data is often **precious, useful and unique** (trace of a past moment).
- **Raw data (from observation) is often unusable.** It must be processed, analyzed, interpreted, associated with other elements, and therefore, new data called **metadata** that makes it useful and usable, sustainable, exchangeable for decision-making or better knowledge.
- Its **acquisition** (in situ campaigns, satellites, many hours of calculation, medical instruments, underwater probes, etc...) is generally **expensive both ecologically and financially**
- Its **exploitation** generates **knowledge**, « **wealth** » or "added value." However, the "value" of data remains subjective, depending on its usage and the user. History proves, nonetheless, that knowledge brings numerous advantages, and as a matter of fact, **organizations battle to gather data.**

# Data is a tool of power

- Knowledge and wisdom development
- Mechanism of control

**Data manipulation and & data surveillance**

The data in computer science is the digital representation of a physical or mental information

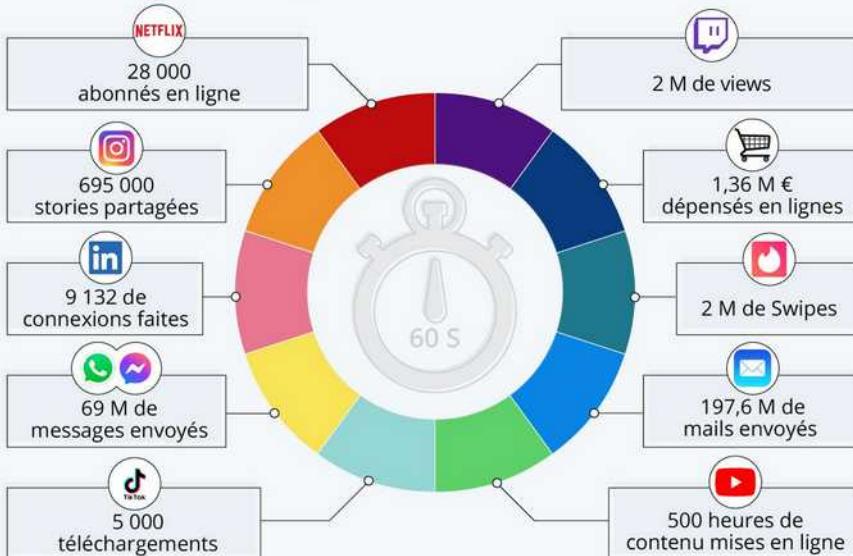
- Political, financial and commercial **power**
  - suggestions,
  - influence,
  - Psychological manipulations (taking advantage of our cognitive biases: e.g. impulse buying vs. acting quickly,
  - Fake news,
- **Addictions** & use of available brain time
- Analyse of emotional states, psychological **profils**,
  - 250 **likes** are enough to establish an accurate « OCEAN » profile
- **Big Brother society** (China),
- « filter bubble » (isolation) & **disinformation**



# Data usage

## Une minute sur Internet en 2021

Estimation de l'activité et des données générées sur Internet en l'espace d'une minute



Source : Lori Lewis via AllAccess



statista

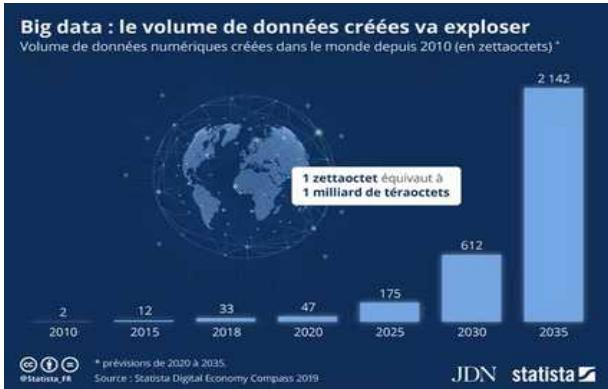
### GLOBAL APPLICATION CATEGORY TRAFFIC SHARE

Rank	Category	Global Traffic Share (%)	YoY Change (%)	Notes
1	VIDEO STREAMING	60.6%(+2.9) ↓	22.2%(-0.1) ↑	
2	WEB	13.1%(-3.8) ↓	10.3%(-10.6) ↑	
3	GAMING	8.0%(+0.2) ↓	4.9%(+2.2) ↑	
4	SOCIAL	6.1%(+1.1) ↓	7.6%(+3.8) ↑	
5	FILE SHARING	4.2%(+1.4) ↓	30.2%(+8.1) ↑	
6	MARKETPLACE	2.6%(-1.9) ↓	1.6%(-0.2) ↑	
7	SECURITY AND VPN	1.6%(+0.2) ↓	5.3%(-2.1) ↑	
8	MESSAGING	1.6%(-0.1) ↓	8.3%(-0.1) ↑	
9	CLOUD	1.4%(+0.01) ↓	9.0%(-0.3) ↑	
10	AUDIO STREAMING	0.4%(-0.5) ↓	0.3%(-0.1) ↑	



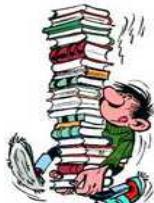
# Data volume

**En 2021, 60 Zo  
of generated  
Data**



## 60 Zo

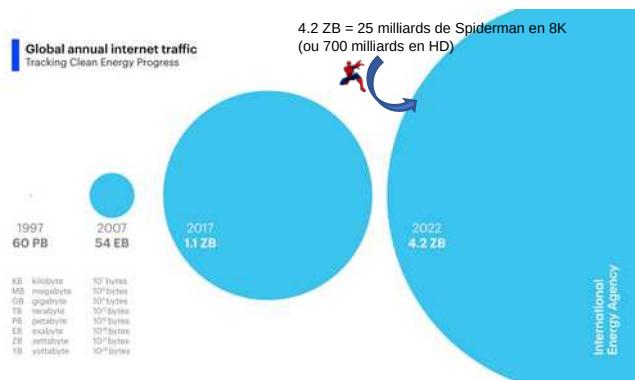
1 Zo = 1000 Eo → a stack of de 1500 billion CD-ROM (1,5 billion kms, 10 times the distance from the earth to sun)



Source : <https://www.iea.org/>

LMA & Master WAVES

Vidéo streams ~ 58% of overall download and 80 % of bandwidth (Shift Project article about The unbearable use of online video)



### Direct impacts

- Hardware (network, storage & processing)
- Energy consumption (network & storage)

### And indirect

- Dataveillance,
- Datapulation,
- Power

# Data : acting at the first level

- Think **sobriety** in the use and deployed solutions :
  - limiting data processing, exchanges and large scale storage.
- **Open Data & FAIR**
- Adopt institutional solutions without multiplying them
  - Alternatives / Refuse GAFAM Tools
- Limit streaming & video resolution
- Protecting your privacy (<https://disconnect.me>)
- Limit advertising, **uBlock** : <https://ublockorigin.com.fr>)

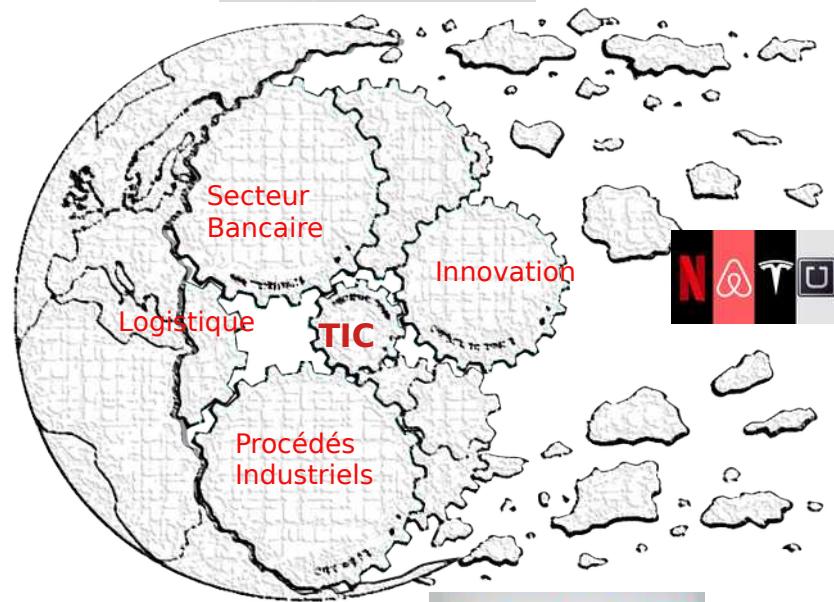
# Indirect impacts

## Environnement and Society

- ✓ **Acceleration** (flows, finances, good: temporal compression),
  - ✓ **Quick Obsolescence** (programmed..... or not),
- ✓ **Globalization & Increased dependencies**
  - ✓ **Increase complexity of our society** : stability ?
  - ✓ **Unequal power relations** favoring big private corporations
- ✓ An example of failure : **dematerialization**
- ✓ **Digital divide**,
- ✓ Optimization & **efficiency**,

## Rebound Effet or Jevons' paradox

- ✓ Cancellation of efficiency gains through growth in usage or detrimental uses



# Social and human impacts

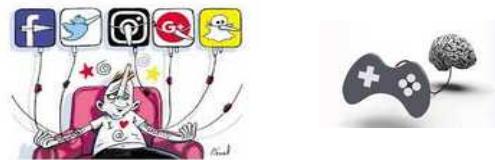


## Impacts on the individual

- **Concentration** : Studies by Gloria Mark, a researcher at the University of California Irvine, show that after being **interrupted**, it can take up to **23 minutes to refocus** on our work.
- **Information Fatigue Syndrome (IFS)** : a consequence is the inability to sort through the information to be processed ([https://en.wikipedia.org/wiki/Information\\_overload](https://en.wikipedia.org/wiki/Information_overload) )

## Addiction :

- Use of our cognitive weaknesses to reinforce the addiction to social networks: example: games and micro-reward systems, social networks and infinite scrolling.



# Ethical issues: a more systemic vision

## Ethical questions :

- **Radical monopoly** (Ivan Illich) : Monopoly induced by one or more brands or technology aiming at modifying, controlling and eventually forcing populations to radically modify (hence the epithet "radical") their daily habits, in particular by restricting their choices and their freedoms.
- **Challenging the concept of progress** itself (Sophie Wahnich, François Jarrige)
- We must question some ideas :
  - Technological neutrality
  - Dataveillance & datapulation,
  - Dilution of private and public life,
  - Fake news, orientation of populations, etc...



# AI Subject

Team Jorge



- The subject of AI and especially its recent developments crystallizes and concentrates many elements of questioning
  - Energy consumption, especially related to AI training
  - The use of "low cost" human resources for AI training
- Societal impacts & Legislation ?
  - Military use (autonomous weapons)
  - Conception of living beings via artificial wombs,
  - Big Brother Society
  - Deep Fake, éducation, manipulation
  - Transfer of cognitive biases based on the datasets used



<https://www.radiofrance.fr/franceinter/story-killers-derriere-un-journaliste-de-bfmtv-une-societe-de-desinformation-israelienne-3969106>

<https://siecledigital.fr/2020/10/08/lois-intelligence-artificielle-ethique-europe/>

# ■ Some first level actions

- Same than Data first level actions
- An one step higher : Reflecting on the meaning of one's work and activities → INRIA's SenS workshop

# Digital is concrete

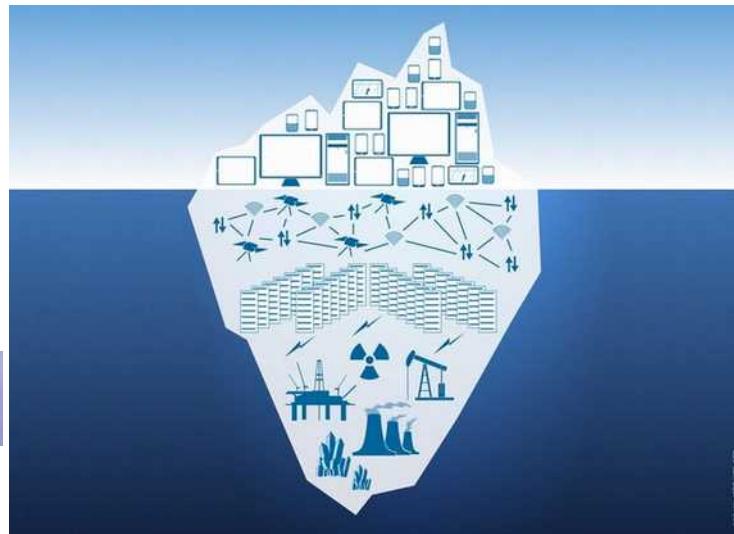
5 billion connected people



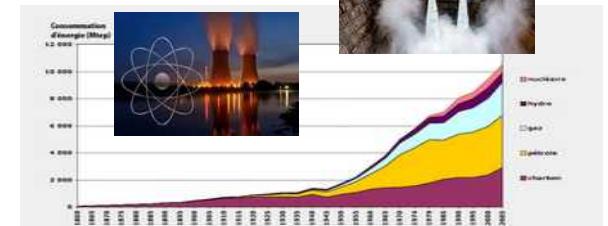
China produced 1.8 billion of smartphones en 2018 (Statista)



20 billion connected objects in 2013  
(Statista), 30 billion in 2023



Ressources



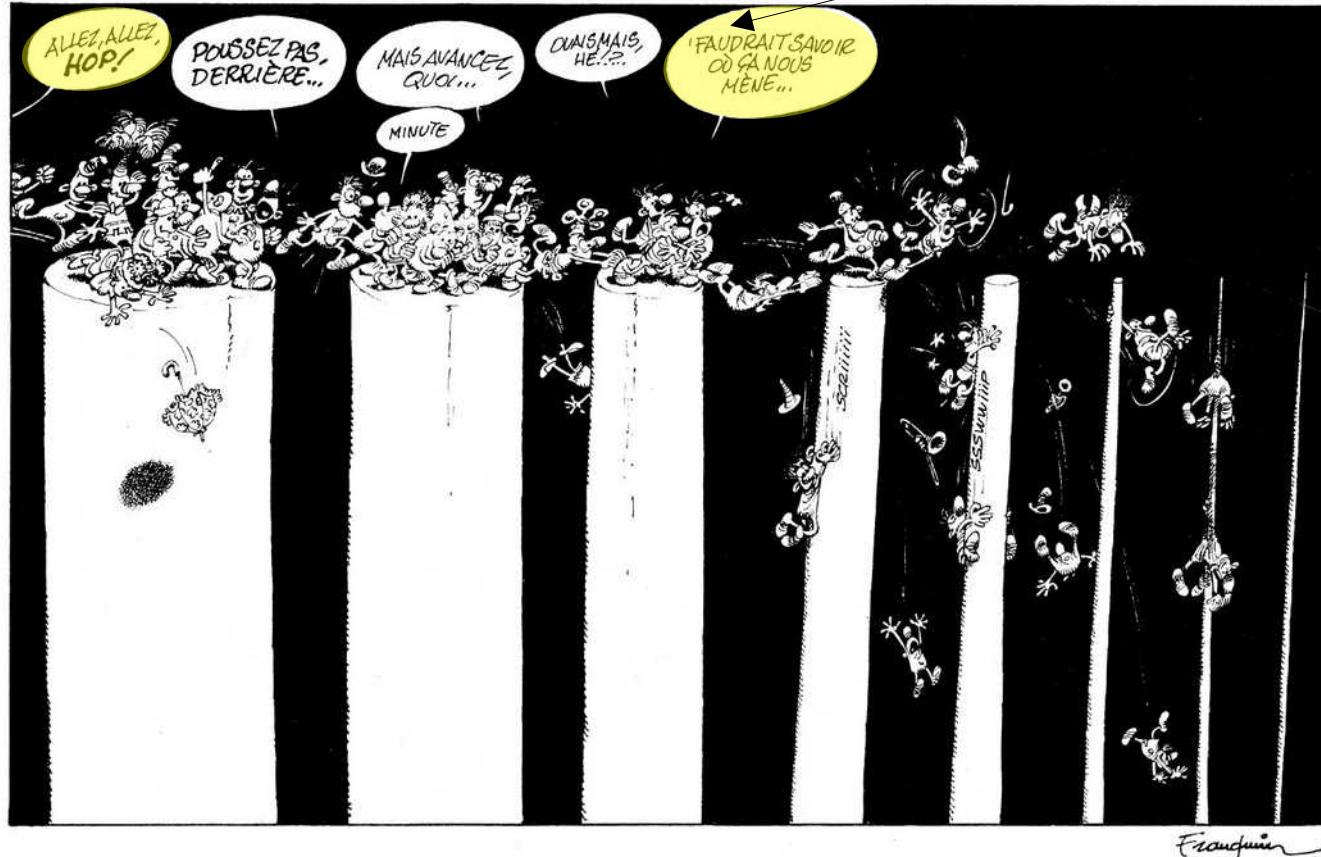
And also energy to make it all work

## Act ? Where and How ?



# To avoid this...

"Wondering where it leads us"



Franquin, a renowned cartoonist ;  
« Black Ideas Album »

But where and how to act ?

No simple or ready-made answer

# Act

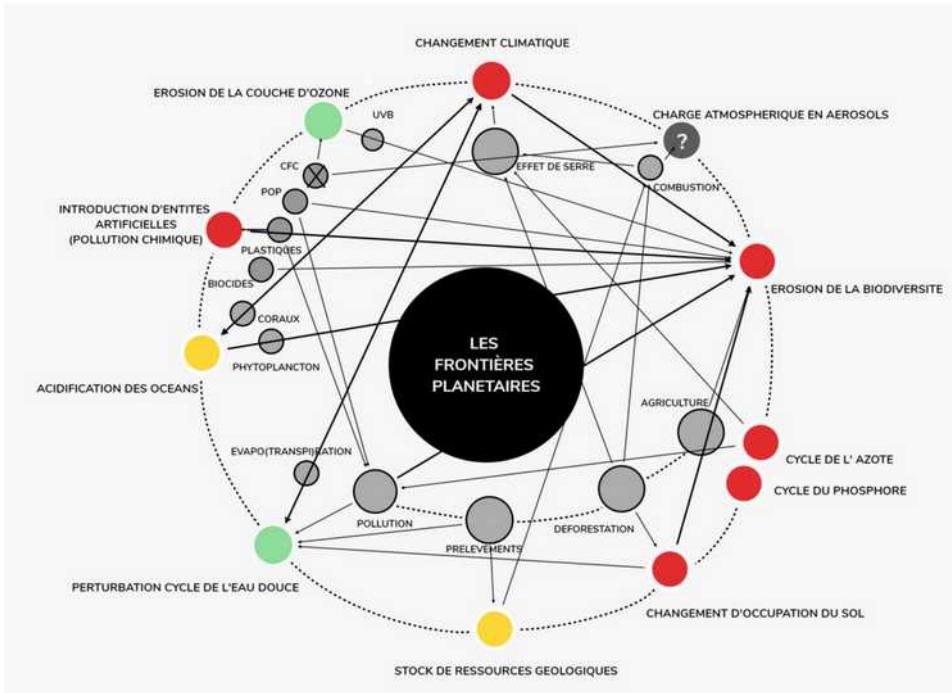
But where and how to act ?

No simple or ready-made answer

Accepting that we are facing a complex situation where elements interacts with each other . So, we have to adopt a systemic perspective to better understand and act in the right direction

# Complexity

Do not simplify without working on the **complexity** of situations,  
not reasonning in isolated silos : **complex thinking versus  
Descartes disjunctive model**

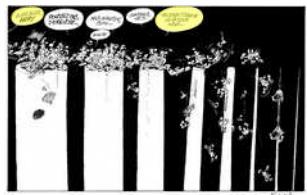


[https://fr.wikipedia.org/wiki/Pens%C3%A9e\\_complexe](https://fr.wikipedia.org/wiki/Pens%C3%A9e_complexe)

# Act

But where and how to act ?

No simple or ready-made answer



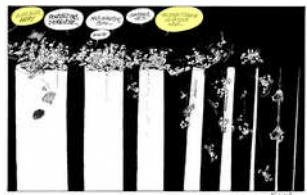
- Reflect even contemplate
- Slow down



# Act

But where and how to act ?

No simple or ready-made answer



- Contemplate
- Slow down



But ... be Careful...  
Reflect is the beginning  
of disobedience".

**Réfléchir\***  
c'est commencer à  
**Désobéir**

# Act

But where and how to act ?  
No simple or ready-made answer  
Slow down to contemplate

Five R's... →



# Act

But where and how to act ?

No simple or ready-made answer

Slow down to contemplate

Refuse, Reduce, Reuse, Repurpose, Recycle

- **Sobriety: satisfying our basic needs**, without creating new ones, by adopting a systemic vision and using as few resources as possible,

# Act

But where and how to act ?

No simple or ready-made answer

Slow down to think better

Refuse, Reduce, Reuse, Repurpose, Recycle  
Sobriety

- **Low Tech** : A frugal technology, resilient, robust, easy to maintain, low dependency, easy to understand, repairable, local, a real challenge for engineering

# Act

But where and how to act ?

No simple or ready-made answer

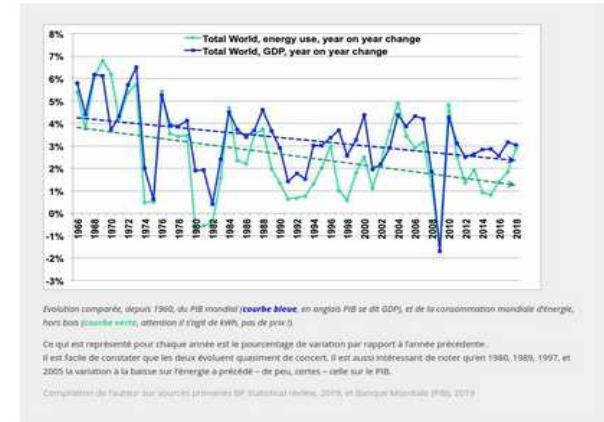
Slow down to think better

Refuse, Reduce, Reuse, Repurpose, Recycle  
Sobriety

« Degrowth ? A rude word ? » The decoupling of economic growth from the consumption of fossil fuels is an illusion as it stands.

⇒ change our indicators and de-digitize what can be

- Refuse the idea that «more is always better»
- Focus on **robustness** and **resilience** instead of **performance** ?
- Take the time to questionning our objectives and the meaning of our activities



# Act

But, Where and How to act ?

- Accepting and integrating complexity: complex thinking?
- Slow down to reflect even contemplate before you act face to the environmental emergency....
- 5Rs : Refuse, Reduce, Reuse, Recycle & Repurpose
- Sobriety, Low Tech
- Degrowth, resilience and robustness: giving meaning & changing our indicators

# Acting for an organization

- The weight of the action of organizations is much more powerful than individual acts  
(Carbone 4 study on the individual and collective share),
- Educational and research institutions have a specific role because they also transmit values and are an example of the possible.**

## FAIRE SA PART ?

### POUVOIR ET RESPONSABILITÉ DES INDIVIDUS, DES ENTREPRISES ET DE L'ÉTAT FACE À L'URGENCE CLIMATIQUE



# Act : legal support

- **French REEN Law (November 15, 2021):**
  - **Raising awareness** of the environmental impact of digital technology: Training from the beginning of the school year 2022 for all, eco-design (Jouzel report)
  - **Limit the renewal** of digital devices
  - Promote ecologically digital uses
  - Promote energy-efficient data centers and networks
  - Promoting a responsible digital strategy in the territories

# ■ Act : some additional leads

- **Think and Slow down**
  - Deploy **cross-functionnal working groups** and think beyond digital
  - **Give time and value involvement** of people acting on these themes
  - **To educate oneself**
  - **Questionning the meaning of our activities** (example of INRIA's SEnS workshop) and integrate this dimension into projects
- **Think eco-design, science & open data, FAIR**
  - For hardware, software and data

# Think out of the box



## SUSTAINABLE DEVELOPMENT GOALS



UN's Sustainable Development Goals.  
We have to work on all these goals to live in a sustainable world

# Act and pitfalls

GIEC 2025

Deadline is short.....

- Techno solutionnism : rebound effect, deployment delays and new problems
- Efficiency ⇒ rebound effect
- Barriers to action



# Barriers to action

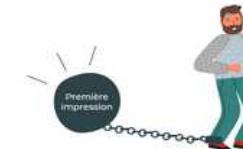
But why on earth aren't we reacting more strongly to this situation ?



Just a few things to start thinking about:

# ■ Biological brakes ?

- **The « Human Bug » : a brain not adapted to abundance ?** Meating, reproducing, acquiring power with the least possible effort and with the most informations possible (Thierry Ripoll, Sébastien Bohler)
  - *Beware of naturalism and simplification, an interesting but reductive look that does not take into account the weight of societal influence and the political scale of the current environmental crisis..*
- **Cognitive Biases** : distortion in the cognitive processing of information, systematic deviation of logical and rational thinking from reality in our « artificial » world



# Cognitive biases



Source :  
<https://www.linkedin.com/pulse/ostrich-effect-kamakshi-madankumar/>

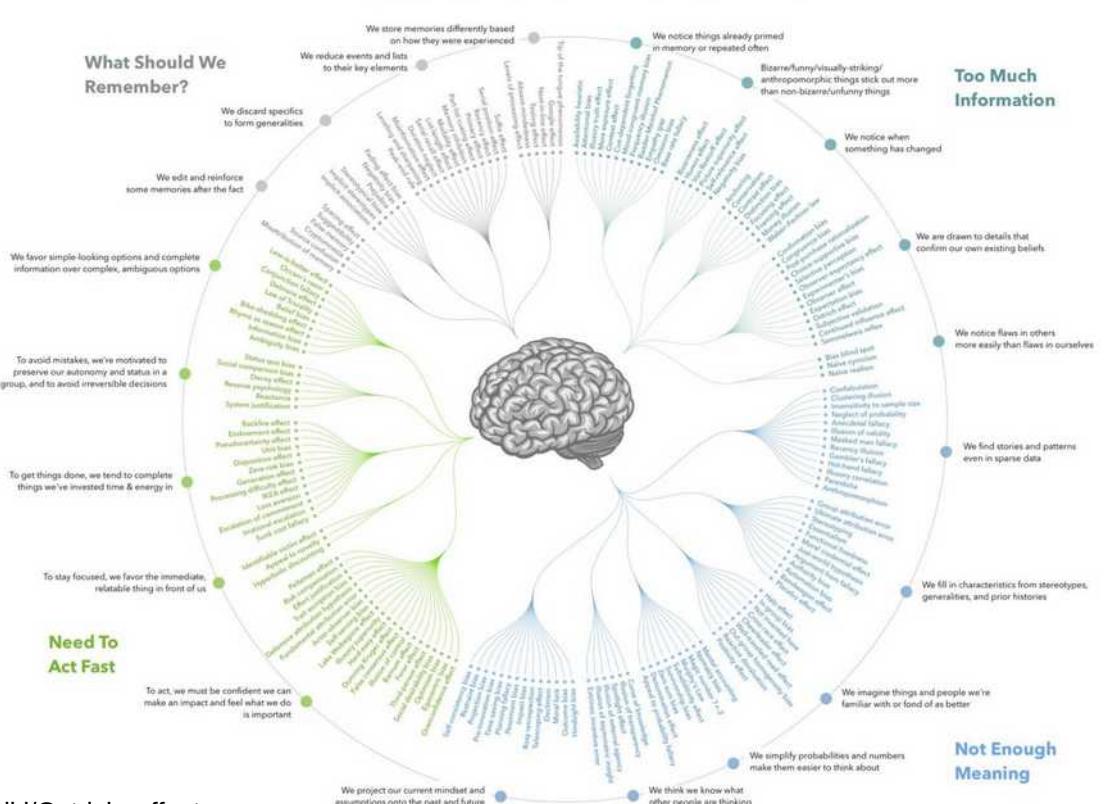


Source :  
<https://thedecisionlab.com/biases/loss-aversion>

Concept et catégorisation par Buster Benson – Design par John Manoogian III

[https://en.wikipedia.org/wiki/Ostrich\\_effect](https://en.wikipedia.org/wiki/Ostrich_effect)

## COGNITIVE BIAS CODEX, 2016



# Digital application

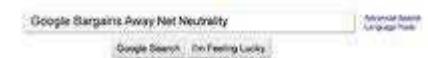
Tristan Harris, is an American Technology ethicist. He worked as a design ethicist at Google. Executive Director and co-founder of the Center for Humane Technology. :

*The major problem in technology isn't privacy, it's misalignment with our innate psychological vulnerabilities. As E.O. Wilson said :*

**« The problem of humanity is... We have paleolithic emotions; medieval institutions; and god-like technology »**

**DON'T BE  
EVIL\***

\*Unless It's Profitable



# Social brakes

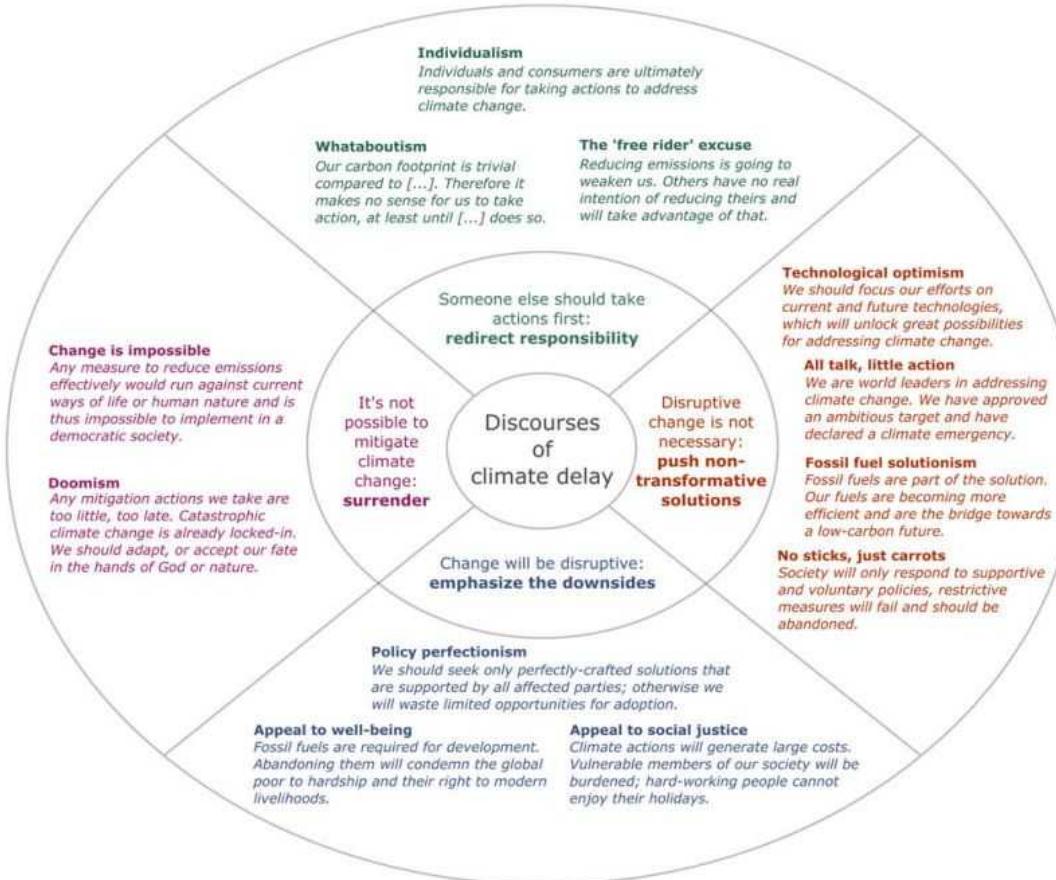
- **The economy of attention** : retaining the maximum amount of "available brain time" and monetizing the psychological profiles of users
- **Everything, right away** : digital technology increase our dependancy to the «immediacy ideology »
- **Submission to authority** (Stanley Milgram experiment)
- People would rather be electrically shocked than left alone with their thoughts (Timothy Wilson experiment)
- Using the scientific and **greenwashing** methods to divert attention (Total vs. climate change, tobacco companies, etc...)



<https://mbamci.com/economie-de-l-attention-et-design-dattention-1-2-avons-nous-perdu-notre-liberte-de-nous-concentrer/> & <https://www.reseau-canope.fr/la-course-a-lattention/regards-croises/economies-et-captation-de-lattention.html> & Reportage « La Fabrique de l'ignorance & Timothy D. Wilson et al. « Just think : The challenges of the disengaged mind ». Science 345, 6192, 2014. - <https://www.science.org/content/article/people-would-rather-be-electrically-shocked-left-alone-their-thoughts>

# The 12 discourses of climate delay

[https://www.cambridge.org/core/services/aop-cambridge-core/content/view/7B11B722E3E3454BB6212378E32985A7/S2059479820000137a.pdf/discourses\\_of\\_climate\\_delay.pdf](https://www.cambridge.org/core/services/aop-cambridge-core/content/view/7B11B722E3E3454BB6212378E32985A7/S2059479820000137a.pdf/discourses_of_climate_delay.pdf)



# Conclusion : enlarge your thinking

Refuse, Reduce, Reuse,  
Recycle and Repurpose



To do one's part



- Being in phase with environmental limits

- disconnecting from the dominant system

- Imagine a positive future without economic growth and digital tools ?

**Thinking to Stop silo reasoning, accept complexity**



**Robustness, Resilience, Simplicity, Versatility**

**Slow Down:**  
« Life is not a race»



**Sobriety & low tech**



To reach 25 % mark

<https://science.sciencemag.org/content/360/6393/1116.full>  
<https://usbeketrica.com/fr/article/une-minorite-de-25-suffirait-pour-faire-basculer-l-opinion>

# Thanks:-)

"Save a tree, eat an advertiser."



« The little that we can do, the very little that we can do, we must do it. »

Théodore Monod



"Let us the change we want to see in the world", Gandhi

# Sites WEB

## Quelques sites web

- Planetary boundaries: Guiding human development on a changing planet (<https://science.sciencemag.org/content/347/6223/1259855>)
- Jean Marc Jancovici (<https://jancovici.com/>)
- La sixième extinction
- Le climat en questions
- Évaluation des impacts environnementaux de l'informatique : Quels outils ? Quelles limites ?
- Une **infographie** sourcée
- **Adaptation du vivant**
- **EcoInfo** (<https://ecoinfo.cnrs.fr>)
- **ADEME** (<https://www.ademe.fr>)
- **Ouvrir la Science**
- Et tous les sites de qualité, les organismes de recherche, la presse de qualité écrite ou radiophonique, les associations (exemple : **WWF**)
- Suivre les évolutions législatives : Site du **Sénat**
- **Bon Pote**, un site de qualité sur les changements planétaires (en collaboration avec l'INSU) (<https://bonpote.com>)
- **Observatoires de l'ONU** :
  - **GIEC** (The Intergovernmental Panel on Climate Change ),
  - **IPBES** (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services ),
  - **IRP** (groupe international d'experts sur les ressources)
- **Objectifs Développement Durable de l'ONU** (<https://www.un.org/sustainabledevelopment/fr/objectifs-de-developpement-durable/>)



# Lectures



# ■ Context : The Anthropocene era

The Anthropocene is a new geological epoch characterized by humans emerging as the primary driving force of change on Earth, surpassing geophysical forces. It signifies not only the 'age of humans' but also an unprecedented planetary disorder. In 2000, American biologist Eugene F. Stoermer and Dutch chemist and Nobel laureate in Chemistry, Paul Josef Crutzen, first introduced the term « Anthropocene » to describe this new reality.

<https://www.vie-publique.fr/parole-dexpert/271086-terre-climat-quest-ce-que-lanthropocene-ere-geologique#:~:text=L'Anthropoc%C3%A8ne%20est%20une%20nouvelle,d'un%20ord%C3%A9%20plan%C3%A9taire%20in%C3%A9dit>

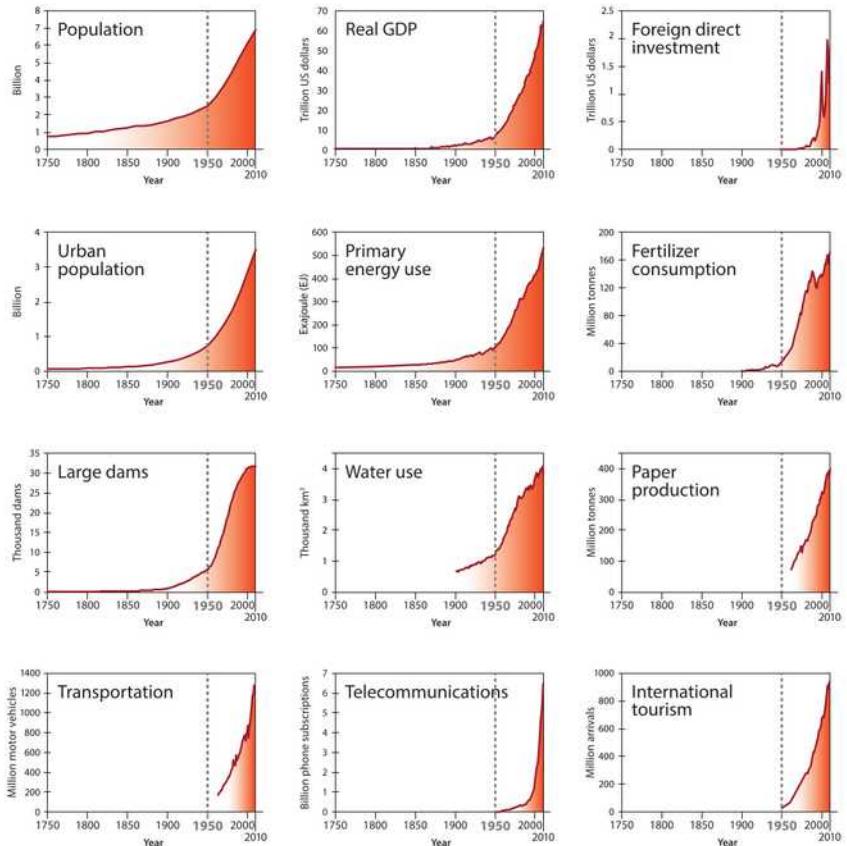
& <https://fr.wikipedia.org/wiki/Anthropoc%C3%A8ne>

# The Great Acceleration

12 indicators of socio-economic development :

- (1) Steffen et al. (2015), The trajectory of the Anthropocene: The Great acceleration, The Anthropocene Review  
(2) Charts based on US Census Bureau and UN population estimates. Image: DSS Research

## Socio-economic trends

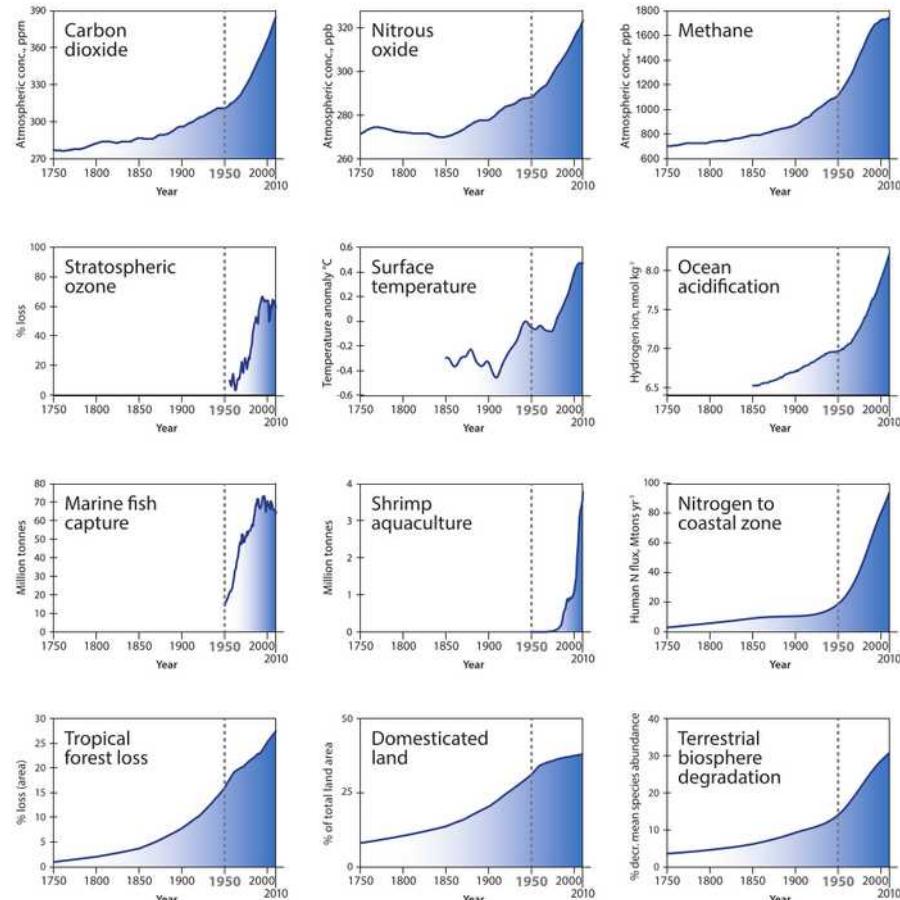


# The Great Acceleration

12 indicators of the evolution of the land system :

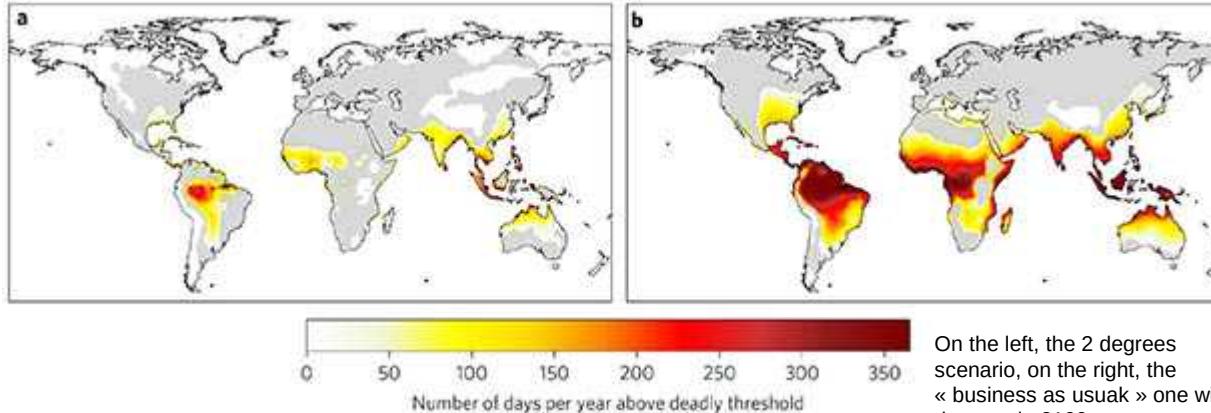
- (1) Steffen et al. (2015), The trajectory of the Anthropocene: The Great acceleration, The Anthropocene Review  
(2) Charts based on US Census Bureau and UN population estimates. Image: DSS Research

## Earth system trends

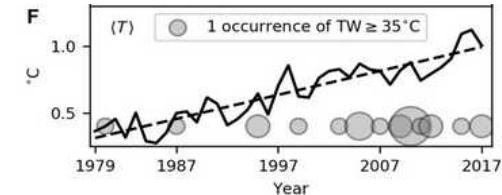


# Heatwaves and mortality

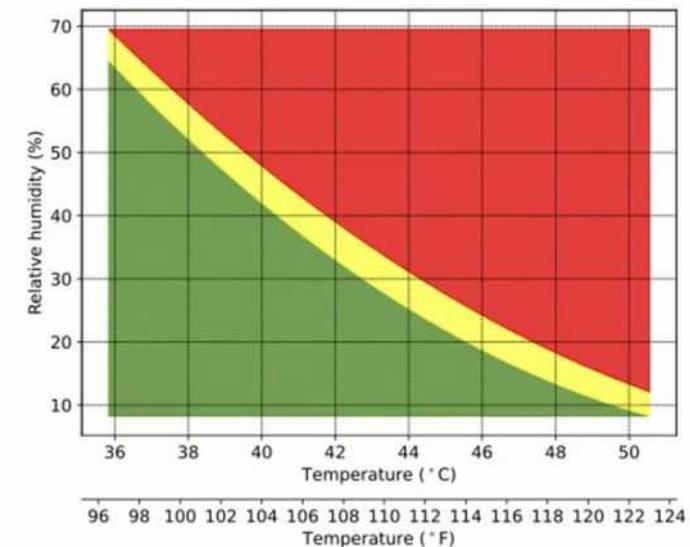
- Number of **humid heat anomalies** (lethal threshold due to Tw: 35 / 31 °C/100 % or 38 °C à 60 % / impossible sweating) explode:
  - Many areas of the planet will become uninhabitable



On the left, the 2 degrees scenario, on the right, the « business as usual » one with 5 degrees in 2100

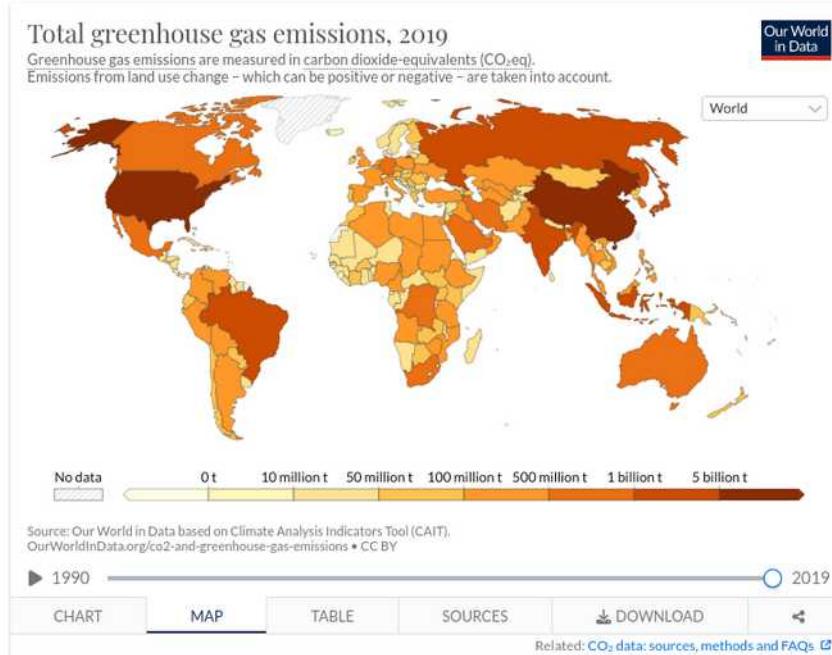


Global trends of humid heat : curve shows global annual average temperature (relative to 1850-1879) ; circles indicate TW occurrences above 35 °C.



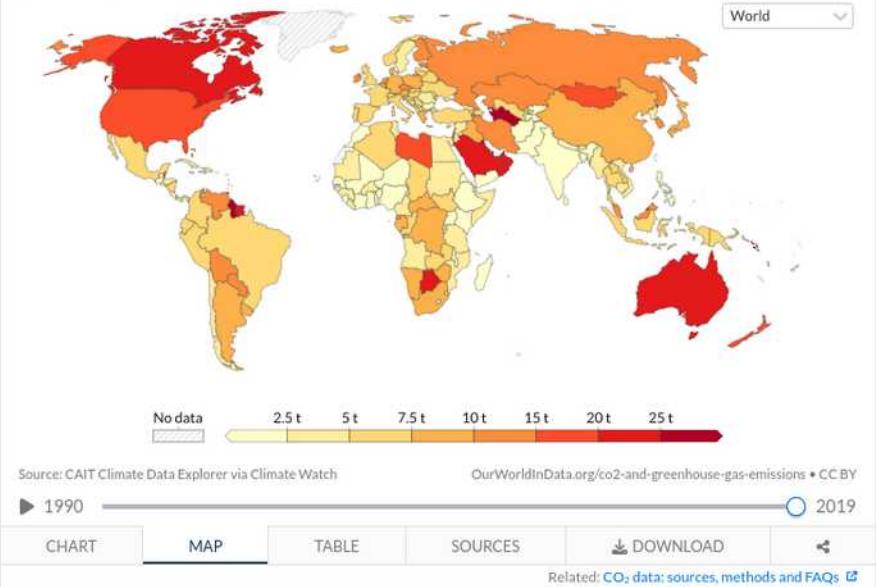
# Quelques ordres de grandeur GES

Greenhouse gas emissions by country



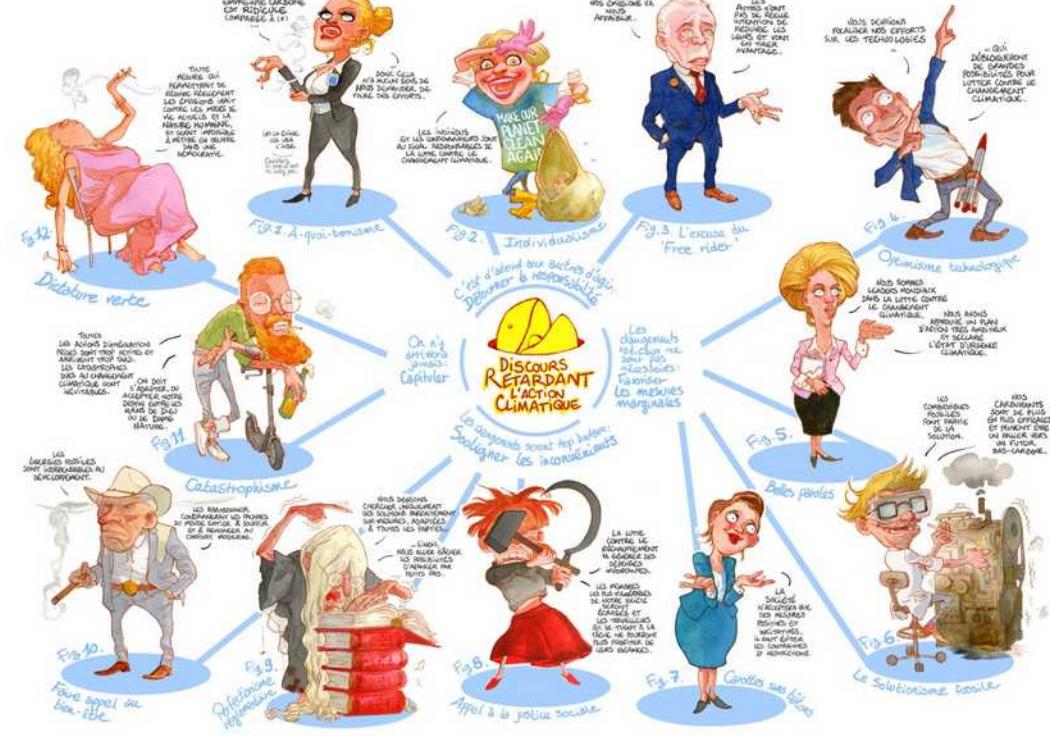
Per capita greenhouse gas emissions, 2019

Emissions are measured in carbon dioxide-equivalents. Emissions from land use change – which can be positive or negative – are taken into account.



<https://ourworldindata.org/greenhouse-gas-emissions>

# The 12 discourses of climate delay



# ■ Les 12 excuses de l'inaction

- « **C'est trop tard** »
  - ✓ *Oui, pour éviter les dégâts, non, pour vivre encore dans un monde soutenable*
  - ✓ *Plus nous attendons, plus les dégâts seront graves*
- « **Le changement est impossible** »
  - ✓ *Un beau contre exemple : la crise sanitaire*
- « **Le changement doit surtout être fait par les individus** »
  - ✓ *Les problèmes sont systémiques → changements structurels et non individuels*
- « **C'est d'abord aux autres d'agir** »
  - ✓ *Les Chinois par exemple ? Certes... mais les Chinois sont l'usine du monde*
  - ✓ *Et l'exemplarité reste un bon modèle à mettre en place -)*
- « **Si nous le faisons, d'autres vont profiter de nous** »
  - ✓ alors même que atténuation et adaptation vont pourtant nous permettre une plus grande résilience si on anticipe la situation qui nous attend plutôt que de la subir.
- « **L'optimisme technologique** »
  - ✓ *Un pari risqué....*

# ■ Les 12 excuses de l'inaction

- « Des paroles.. peu d'actes »
  - ✓ Des discours enflammés de mesures historiques bien peu suivi d'effets
- « L'efficacité énergétique »
  - ✓ Oui, mais l'effet rebond (Paradoxe de Jevons) veille ... :-)
- « Il faut compter sur le volontariat sans restreindre ni interdire »
  - ✓ no comment....
- « le perfectionnisme réglementaire »
  - ✓ Il y aura TOUJOURS des déçus, ce qui n'est pas une excuse pour ne pas agir par clientélisme électoral.
- « Abandonner les énergies fossiles, c'est abandonner les pauvres »
  - ✓ Le PIB et la croissance comme seul indicateur d'une société saine est la pire maladie que nous supportons aujourd'hui.
- « le coût des mesures pour le climat va réduire la justice sociale »
  - ✓ alors même que l'injustice sociale va en croissant tandis que le regard rivé sur les indicateurs économiques (PIB et croissance), le système actuel à creusé les inégalités sociales à un niveau inégalé dans l'histoire → La **décroissance** à ainsi pour objectif d'augmenter l'autonomie (tempérance, autogestion et démocratie directe) , la suffisance(justice distributive) et la care (non exploitation, non violence, solidarité humains et animaux) au nom de la soutenabilité, de la justice sociale et du bien être.

# Le triangle de l'inaction

## CLIMAT : DÉPASSER LE TRIANGLE DE L'INACTION

ATTRIBUER LA RESPONSABILITÉ AUX AUTRES ET LES ATTENDRE POUR AGIR NE PERMET PAS L'ACTION

6 "Les **politiques** défendent peu l'intérêt général, ils sont souvent là pour leur **intérêt personnel**."

5 "On a les **politiques que l'on mérite** : c'est d'abord aux citoyens de voter pour les politiques qu'ils désirent."

4 "Les **vraies ressources** sont aux **mains des entreprises**, l'Etat n'a pas les moyens de tout faire."



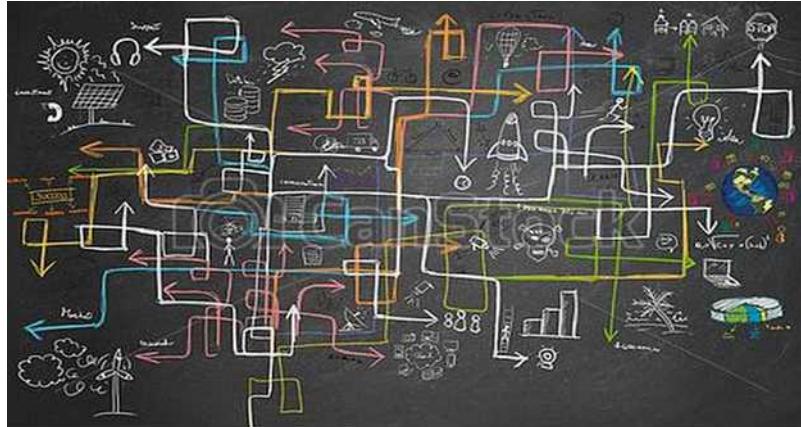
1 "Les **industriels**, les **lobbys** ont le **pouvoir** d'action et ils freinent au maximum les **initiatives écologiques**."

2 "C'est au **consommateur** de faire les choix, nous fournissons ce qu'il demande."

3 "C'est à l'Etat de fixer les **nouvelles règles** : si notre entreprise bouge avant nos **concurrents**, nous perdrons de l'argent."

# La complexité : un frein ?

“c'est trop compliqué”



© Can Stock Photo - csp24978474

**Paul Valéry** : « ce qui est simple est toujours faux, ce qui ne l'est pas est inutilisable. »



- La complexité représente pourtant “**une fausse bonne excuse**”.
- La complexité donne la possibilité d'**accéder à un horizon plus large d'alternatives**, ce qui nous permettrait non pas de nous abstenir, mais nous pousserait au contraire à œuvrer de façon avisée.
- **Comprendre les problèmes** demande de développer une **pensée complexe** et de **refuser le réductionnisme** → passage d'une pensée unidimensionnelle à une pensée multi dimensionnelle.
- **Refuser de penser avec son seul point de vue** (point de vue partial vs autres points de vue : « **le point de vue c'est surtout la vue d'un point** »).