CNRS - INP - UT3 - UT1 - UT2J

Institut de Recherche en Informatique de Toulouse

Sustainable computing ?

Georges Da Costa

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https://www.irit.fr/~Georges.Da-Costa/

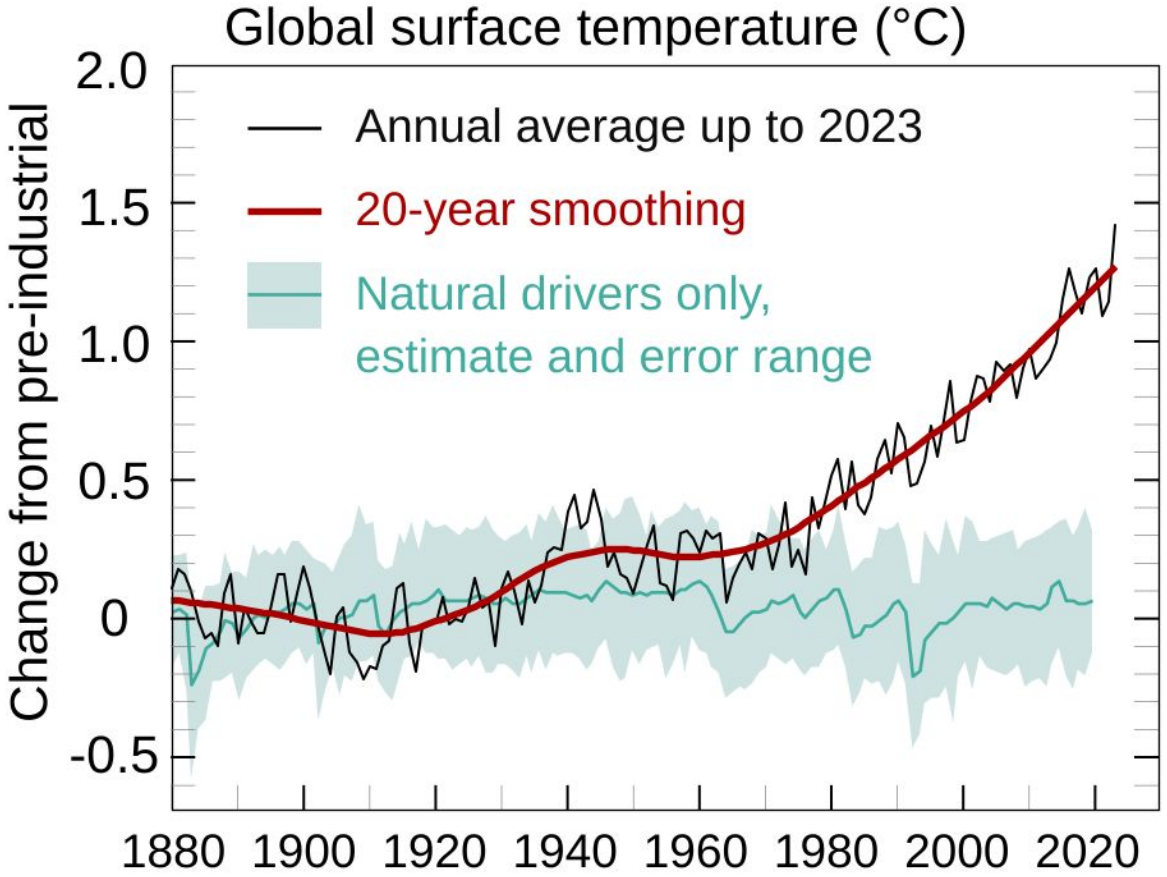
PROGRAMME DE RECHERCHE
NUMÉRIQUE POUR L'EXASCALE

Climate change and energy

An on-going climate change

Global surface temperatures 1880 to 2023 (relative to 1850 – 1900 average)

Source: wikimedia

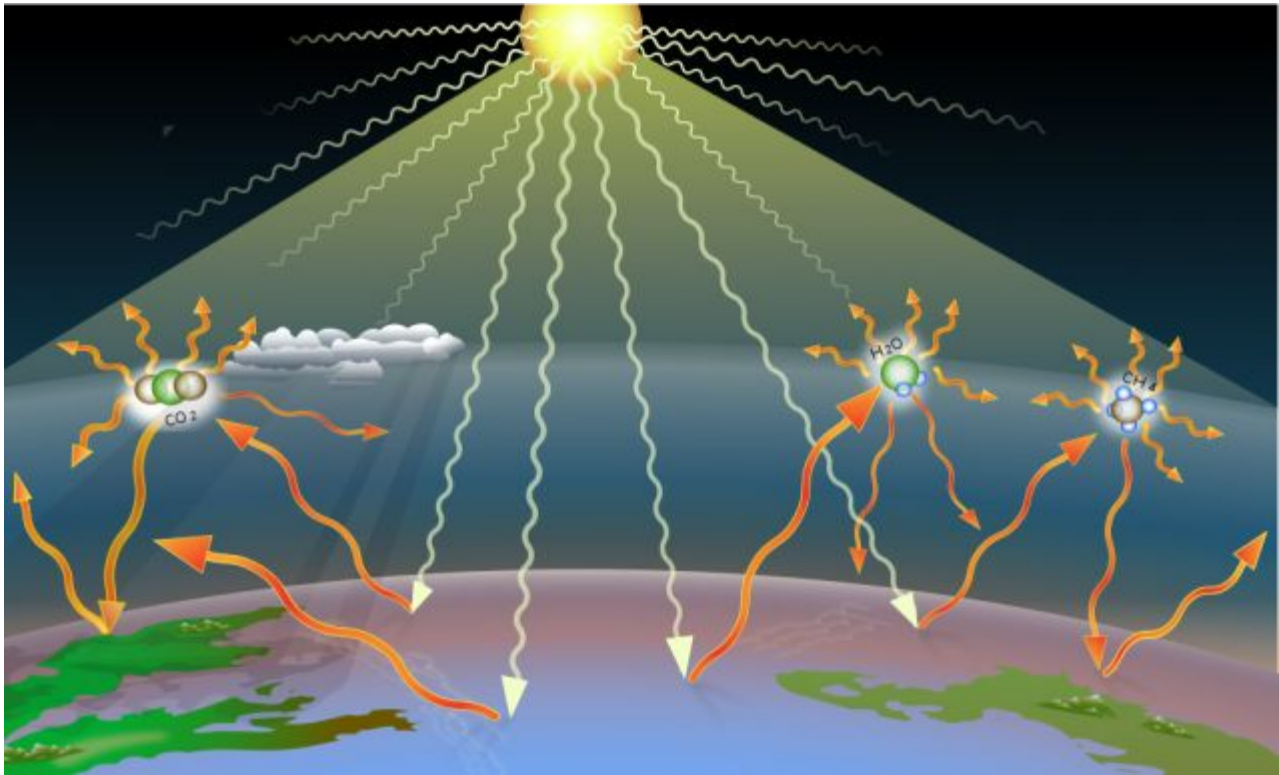


The main source is well known

greenhouse effect

Mostly

- CO_2
- H_2O
- CH_4



A loose necktie on Wikimedia Commons

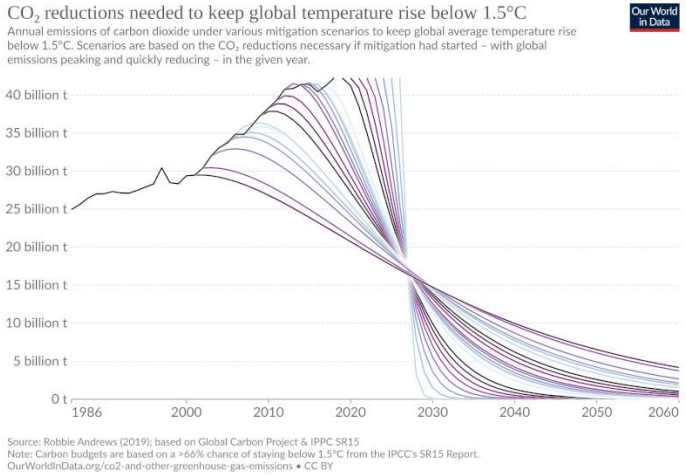
A fragile balance

Historically: 750 GT/year emitted and absorbed

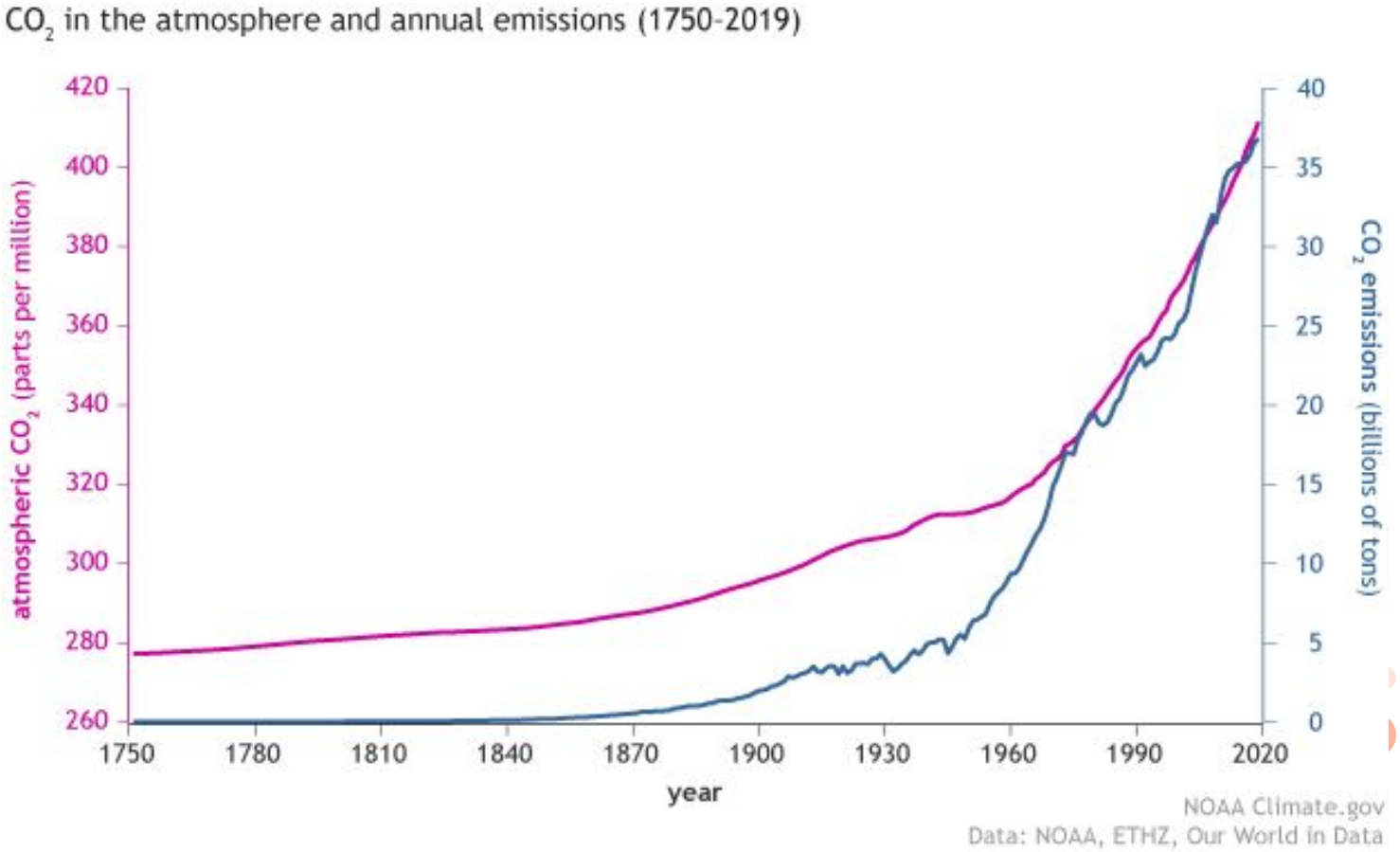
- H_2O and CO_2
- Methane CH_4, nitrous oxide N_2O and ozone O_3
- CO_2, CH_4 and N_2O account for 96% of the 7 GHGs covered by the Kyoto Protocol

Long duration

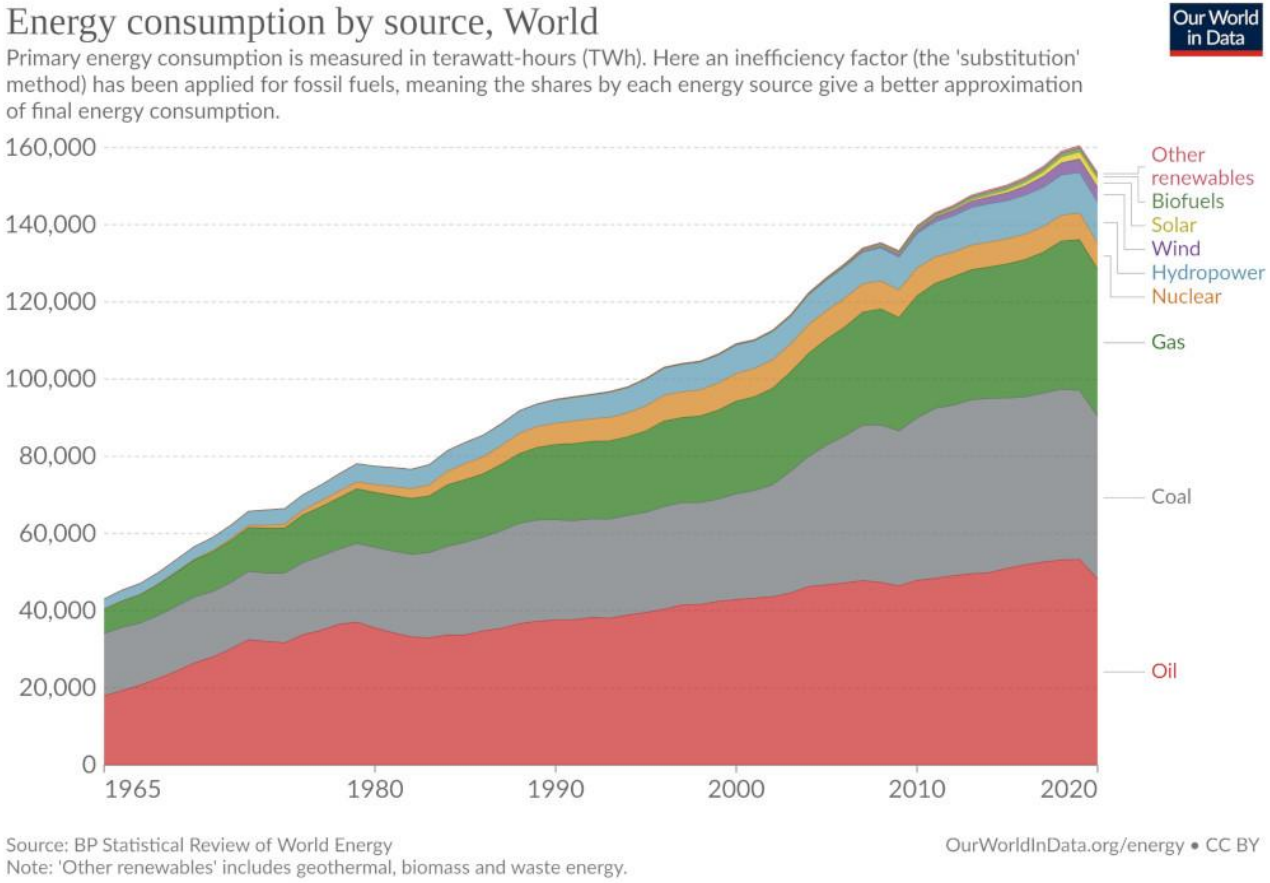
- 100 years for CO_2, 9 years for methane



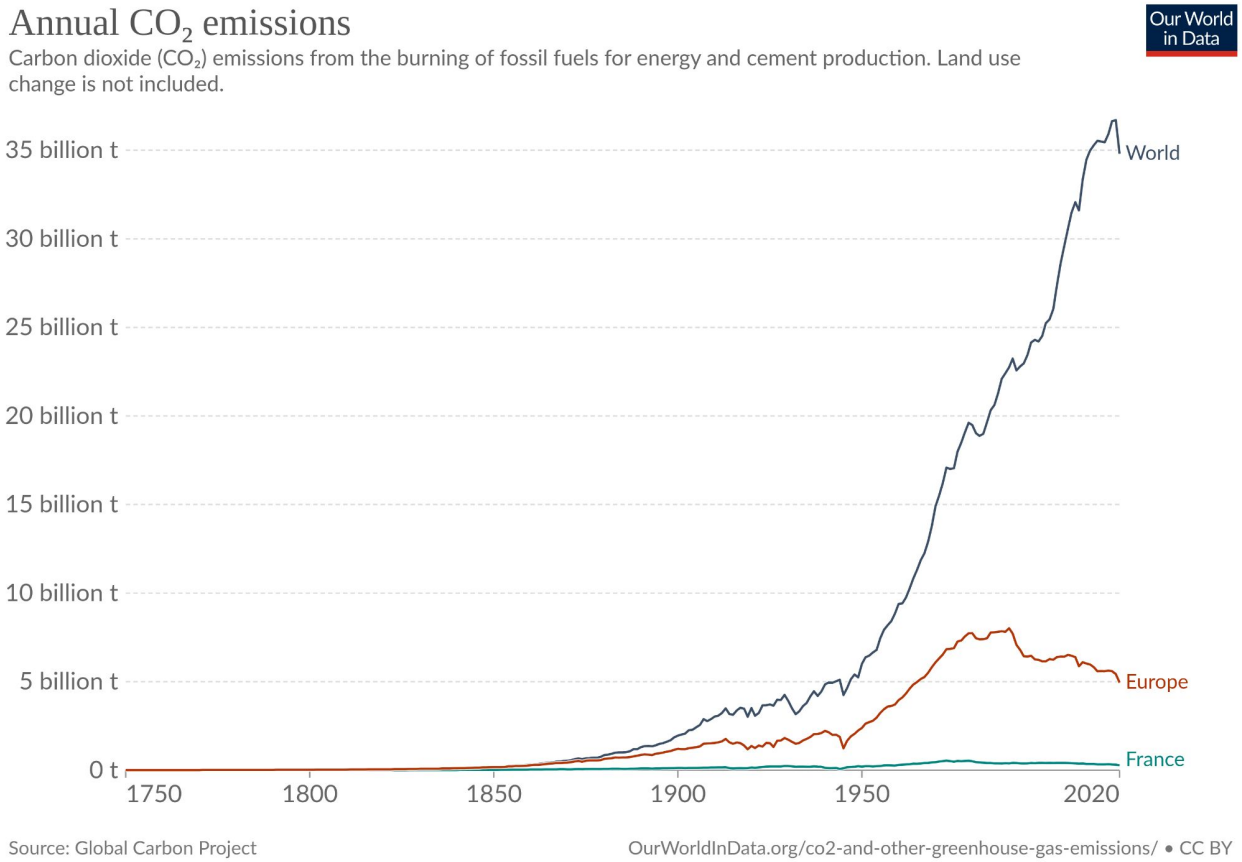
CO_2 and industrial revolution



Global energy mix



Energy-related CO_2 production

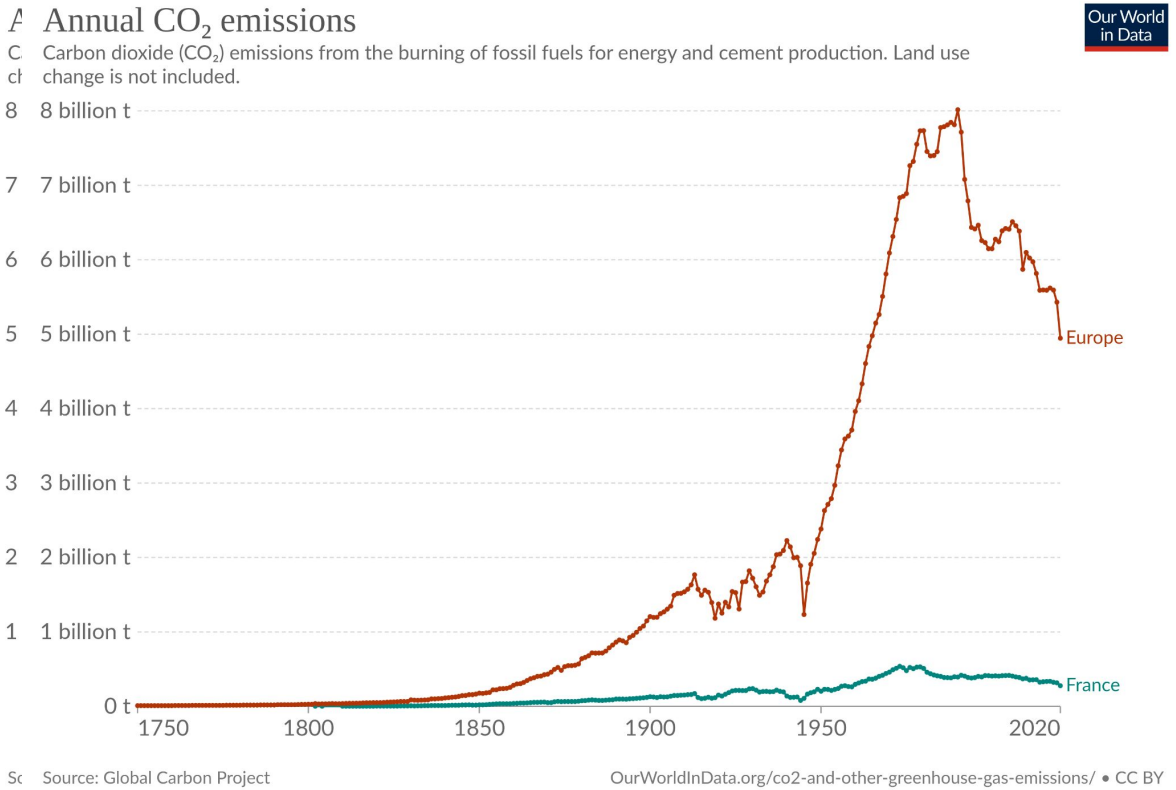


Zoom in Europe and France

CO_2 per person

- France : 4.6
- EU : 6.4

WorldBank



The difficulty of 100% renewable energy

Uncontrollable sources

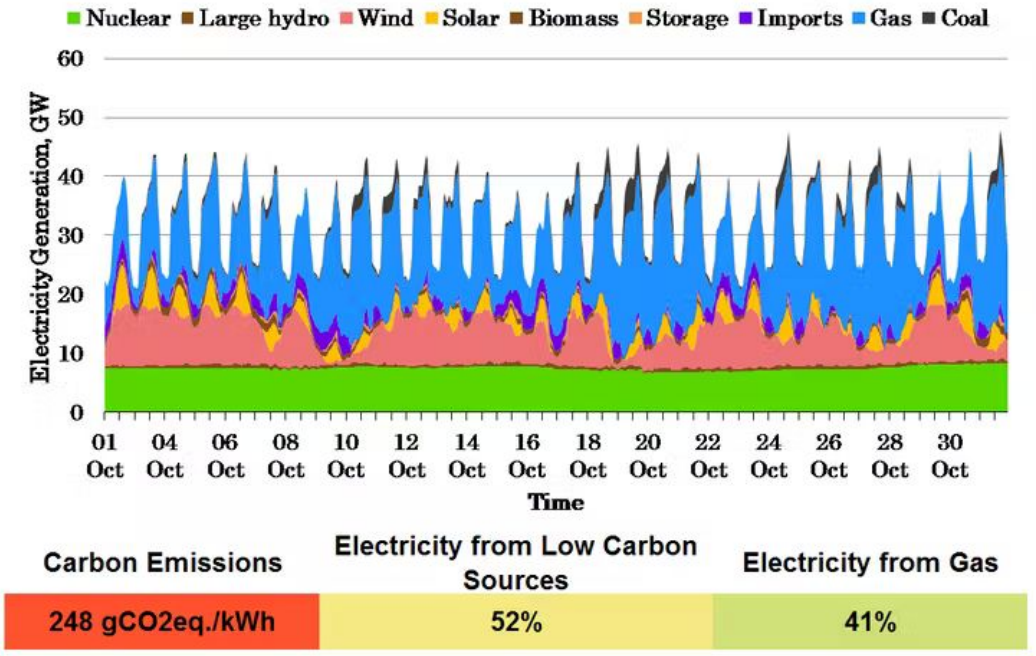
- Renewable

Constant sources

- Nuclear

Auxiliary sources

- Hydraulic, fuel, coal, …



British electricity generation in Oct. 2018

Dr Andrew Crossland/MyGridGB

Energy sources

Nothing is carbon-neutral

	Coal	Diesel	Natural gas	Wind turbines	Photovoltaic	Nuclear	Geothermal	Hydraulic
g CO2 eq/kWh	1000	780	443	14.5	44	66	38	12

Lifespan, production, transport, installation, maintenance

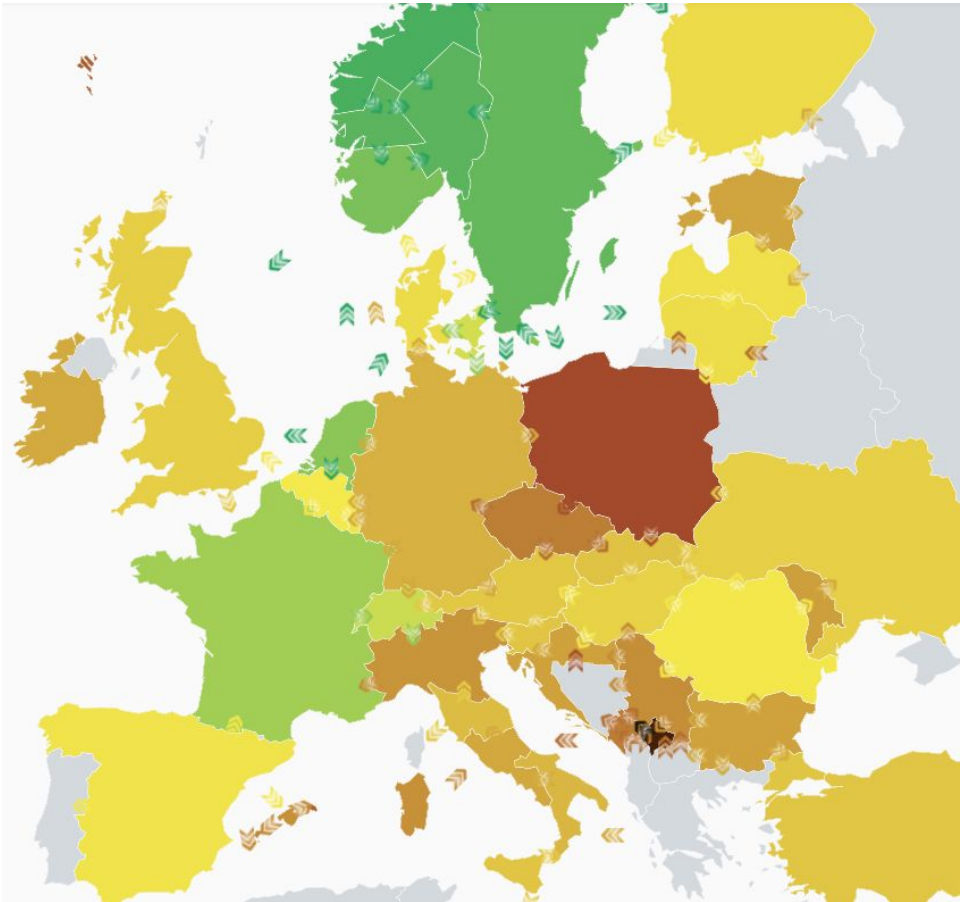
https://bilans-ges.ademe.fr/documentation/UPLOAD_DOC_FR/index.htm?renouvelable.htm

An interconnected system

At multiple levels

- Regional
- European

https://app.electricitymap.org/map

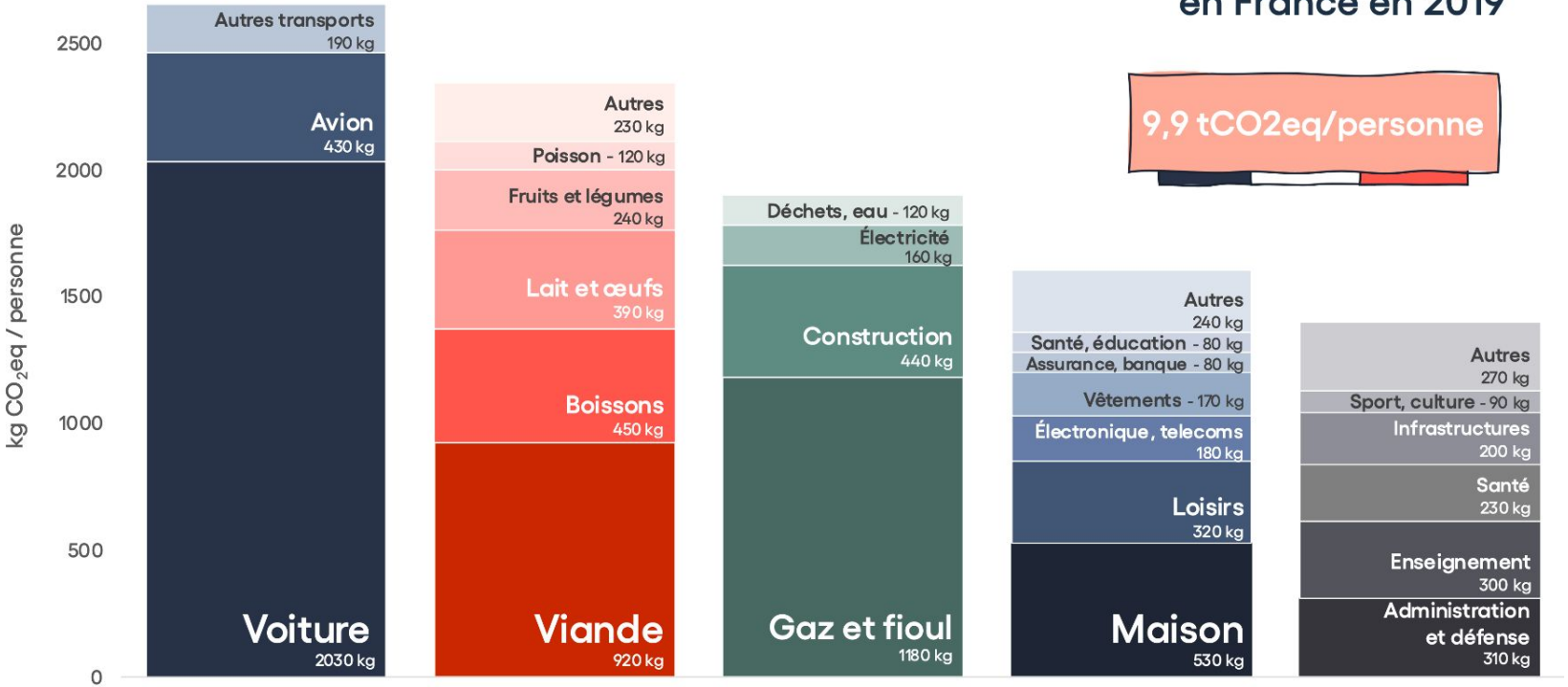


Invisible and visible consumption

Energy Slaves

carbone4 MY CO_2

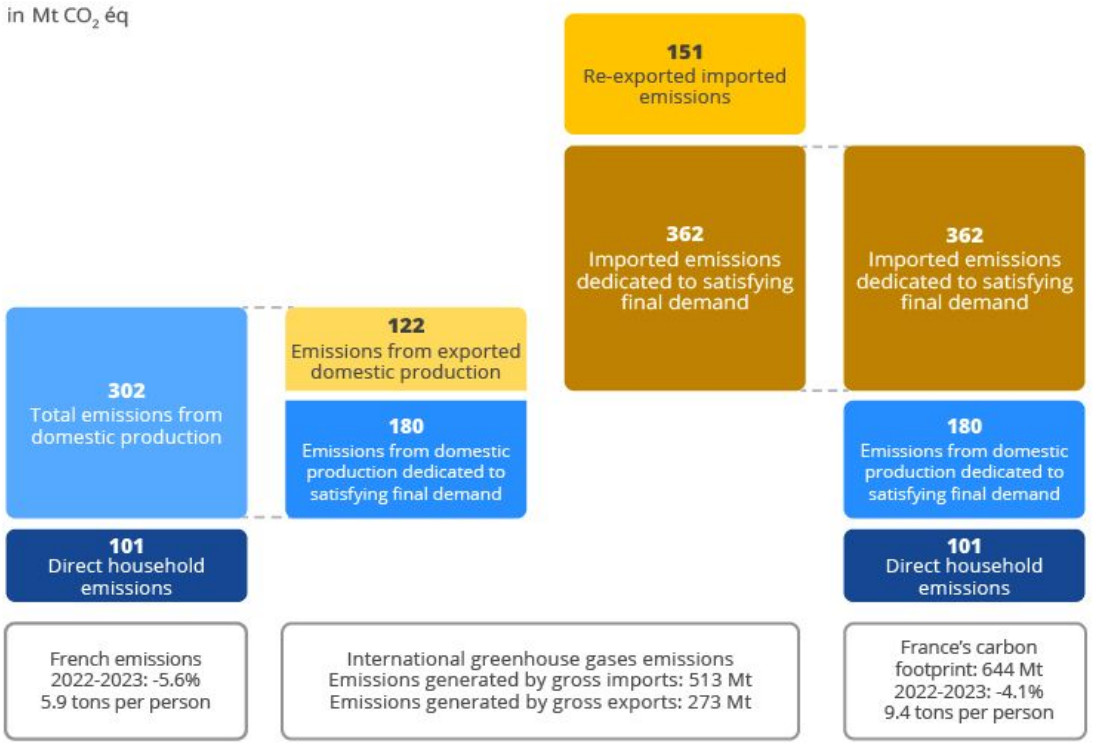
Empreinte carbone moyenne en France en 2019



Gaz inclus : CO2 (hors UTCATF France), CH4, N2O, HFC, SF6, PFC, H_2O (trainées de condensation).
Source : MyCO2 par Carbone 4 d'après le ministère de la Transition écologique, le Haut Conseil pour le Climat, le CITEPA, Agribalyse V3 et INCA 3.

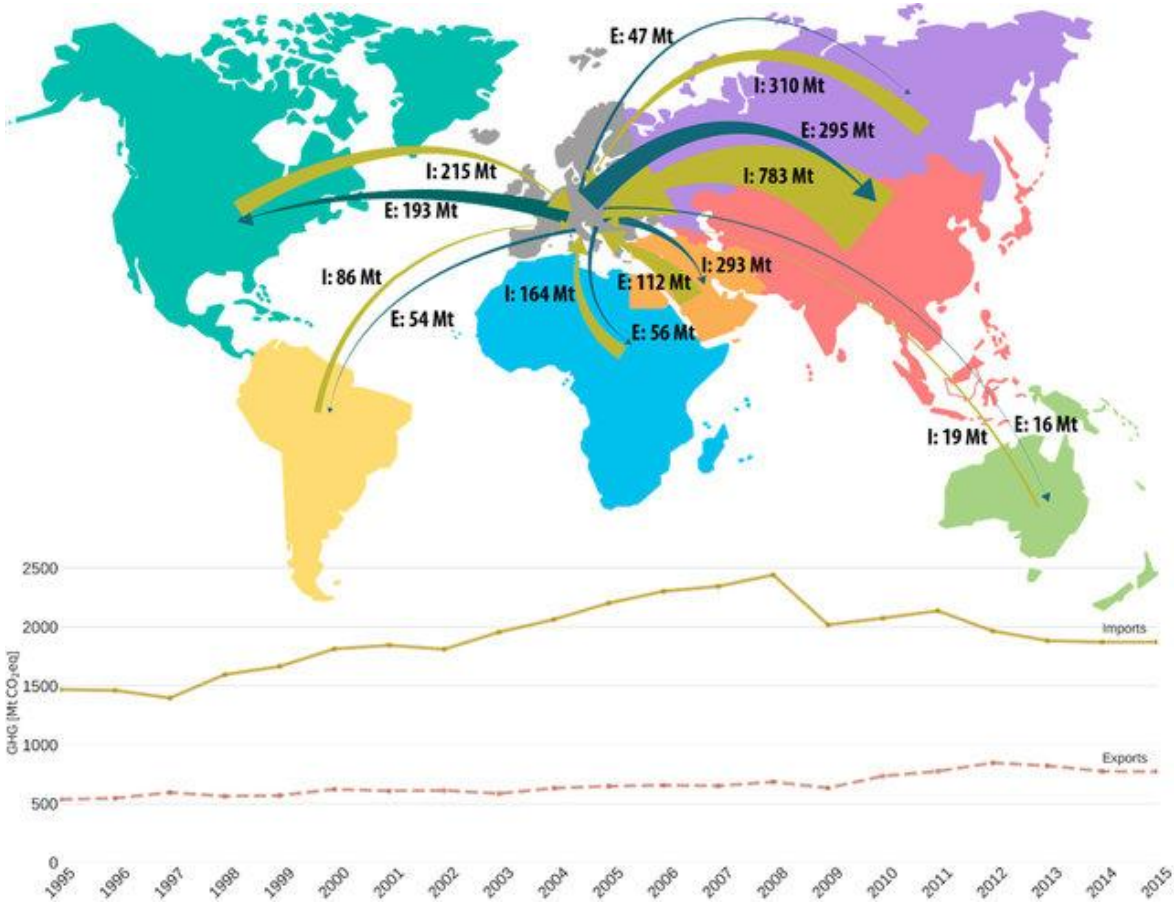
Includes imported emissions

Source Insee



European import/export carbon footprint

A global problem



Richard Wood et al. 2019

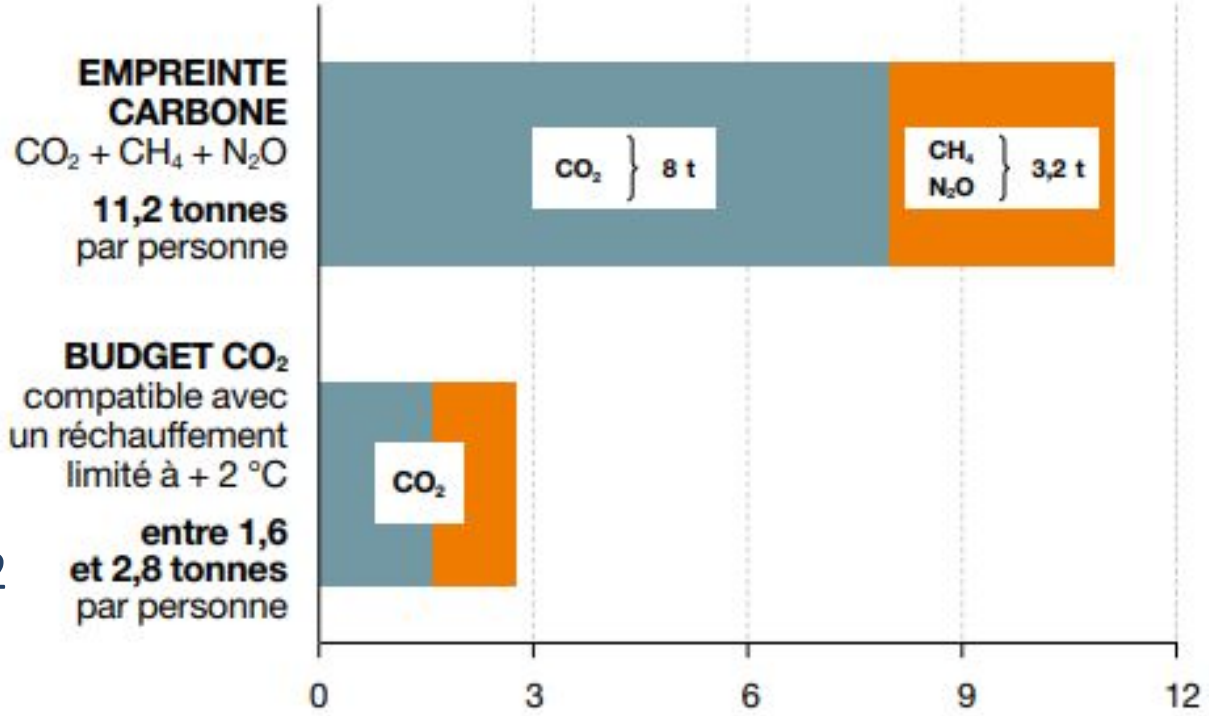
A change of civilization is needed

Objective

- Divide by 6

Current part of the digital sector

- 0.8Teq on the 11.2
  GreenIT 2019



Champ : France métropolitaine + Drom (périmètre Kyoto).
Sources : *GIEC ; Citepa ; AIE ; FAO ; Douanes ; Eurostat ; Insee.*
Traitements : SDES, 2019

Environmental impact of digital technology

Part 1 : The digital world

?

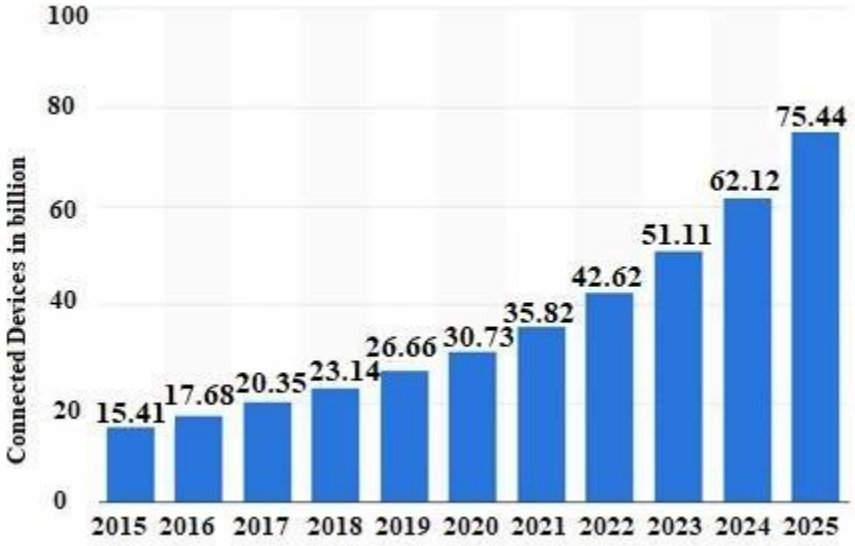
How many digital devices does an European owns?

1. Less than 6
2. 6 to 10
3. More than 10

Connected devices

Excluding computers and smartphones

	World	France
Devices	34 billions	651 millions
Users	5 billions	58 millions
Ratio	4	15
Daily usage	6h42	4h38



Cloud services

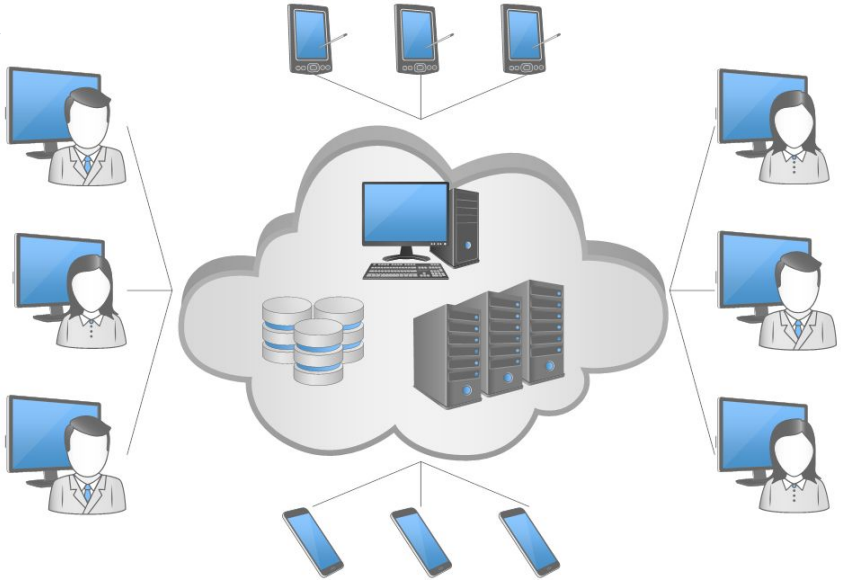
Web sites, banks, snapchat, amazon, …

Keyword: virtualization / transparency

Independents :

- From the place
- From the device/hardware

Infinite



?

Comparison between video playing

- Online
- Local

Example of a web page

https://www.enseignementsup-recherche.gouv.fr/fr

Browsing this webpage needs

- 1 download
- 2 to 9 downloads
- More than 10 downloads

And encompass the usage of

- 1 remote server
- 4 remote servers
- Impossible to know

?

Example of a web page

https://www.enseignementsup-recherche.gouv.fr/fr

- 1.50 g of CO2 per visit
- 46 files
- 4.3Mb
- 1.15s of total download

https://www.websitecarbon.com/

At the center of Internet: data centers

A physical infrastructure

Farms of servers

Each with multiple services

- Web pages
- Search engine
- Text of new articles
- Authentification
- Domain name service
- Picture database
- …

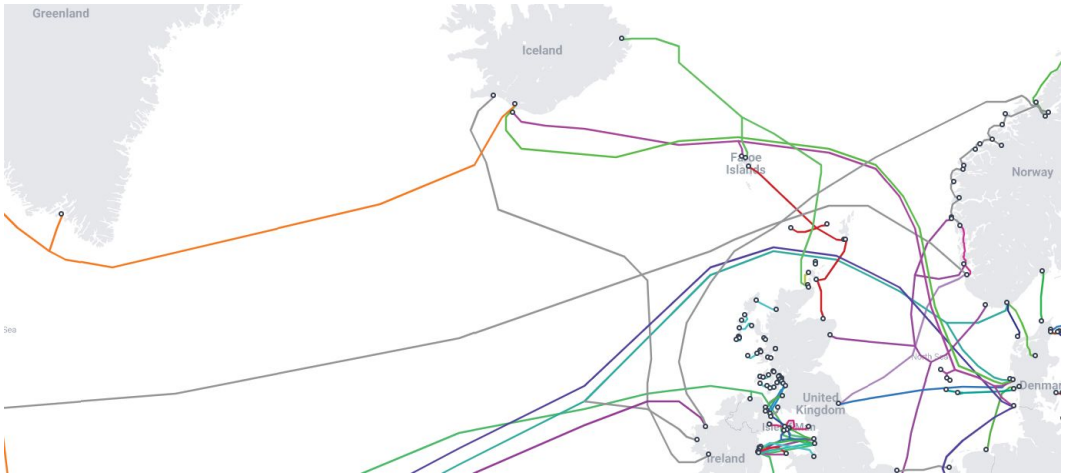
wikipedia

Internet: World-wide cooperation of DCs

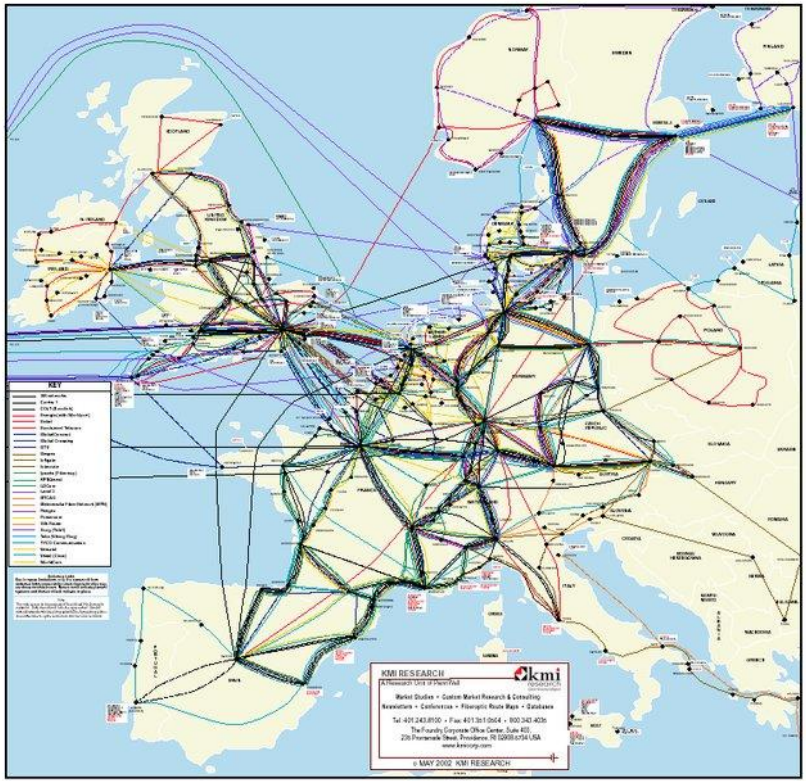
A physical infrastructure

Spine of Internet:

- International network of fiber
- Geopolitical importance



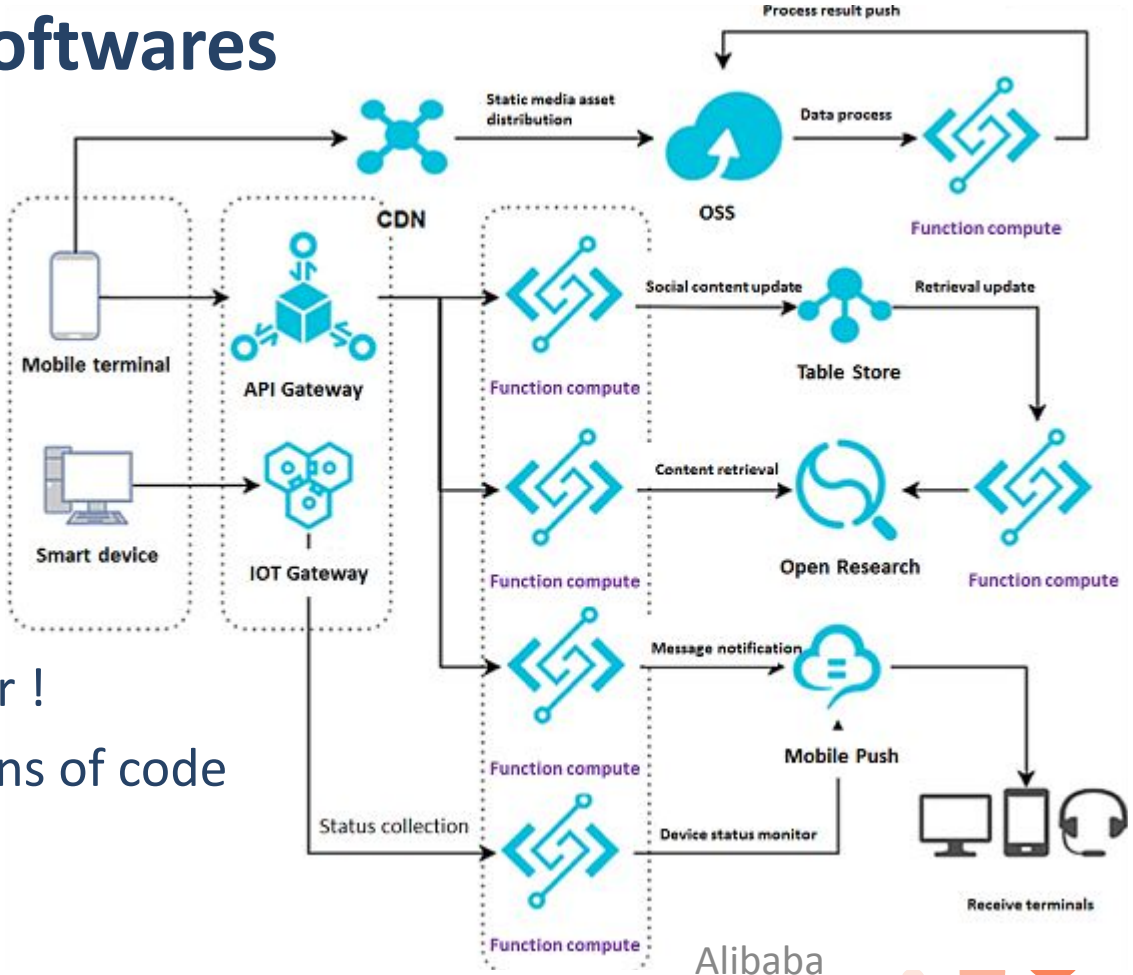
https://www.submarinecablemap.com/



Laura A. Schintler et al. 2005

Complex softwares

A logic infrastructure



Softwares are split

- In tasks
  - Simplification
  - Delegation
- Duplicated
  - Speed, resilience

Dr. Frankenstein monster !

- Facebook : 50 millions of code lines
- TikTok : 15 millions

Environmental impact of digital technology

Part 2 : Environmental impact

Small-quizz

Is my footprint mainly linked to

1. Data centres and their electricity consumption?
2. The intermediate network (access provider, fibre optics, backbone)?
3. The equipment I own directly?

?

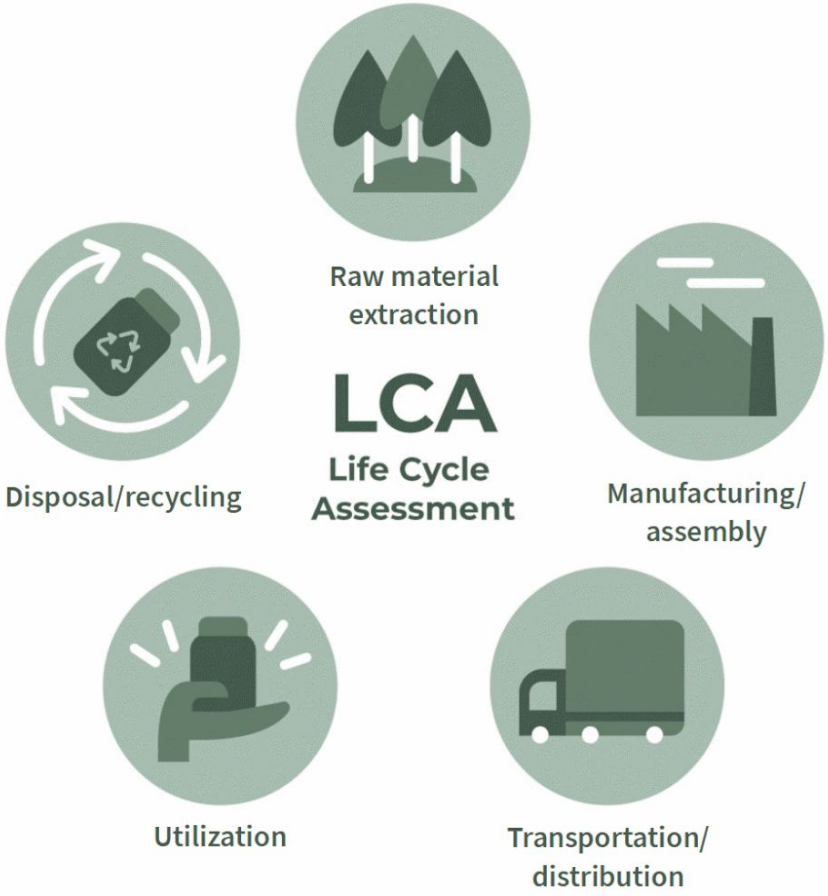
Does this footprint come from

1. My actual usage?
2. The manufacture of the equipment?
3. Other source(s)?

LCA: Life Cycle Assessment

Beyond energy alone

- Abiotic resources
  - kg equivalent antimony
- Climatic impact
  - kg equivalent CO_2
- Water depletion
  - l or m^2 of water
- Primary energy
  - Wh



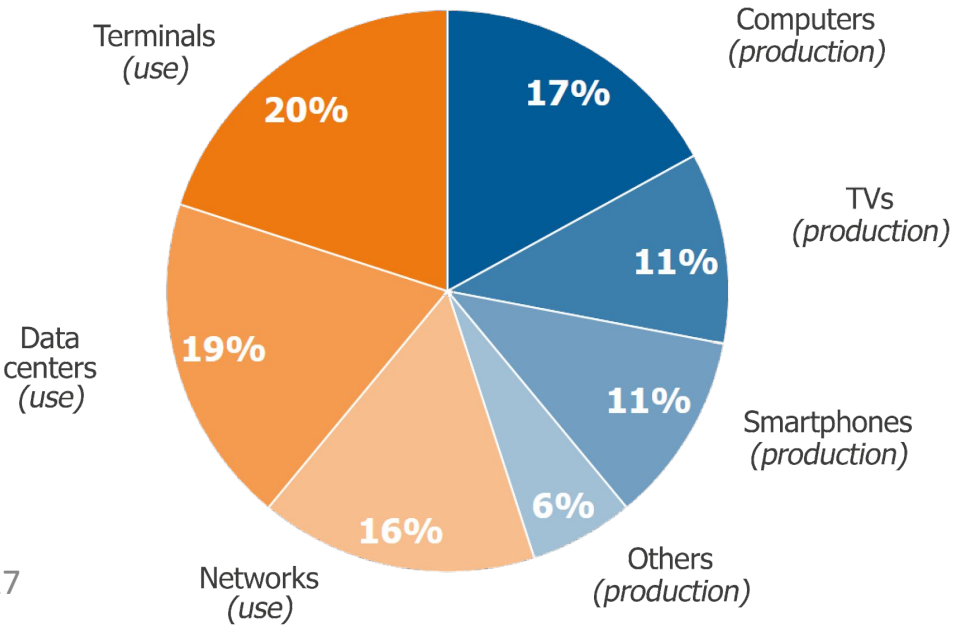
Distribution from users to data centers

Datacenter :

- High efficiency
- No screen
- Always on
- High computing per Watt

	Users 34Mds	Networks 1.5Mds	Datacenter .07Mds
Energy	60	23	17
GHG	63	22	15
Water	83	9	7
Electricity	44	32	24
Resources	75	17	8

Zoom on Energy



Distribution of the energy consumption of digital technologies for production (45 %) and use (55 %) in 2017

[Source : Lean ICT, *The Shift Project* 2018]

Costly steps:

- Extraction and refining
  - 1 T coper = 100 T to extract
    Safe Drinking Water Foundation, 2017
- Component manufacturing
  - Silicon purification
    - 2MW per kg
    - 20l of water per cm^2
    - 1% without any defect
    - Toxic substances, arsenic, antimony, phosphorus, hydrogen peroxide, nitric, sulphuric and hydrofluoric acids

ecoInfo 2010

Trends

Usage only

Different models:

- Calculation method
- Degree of change

Similar conclusions:

- Explosion

Even sufficiency is not sufficient to reach a reduction

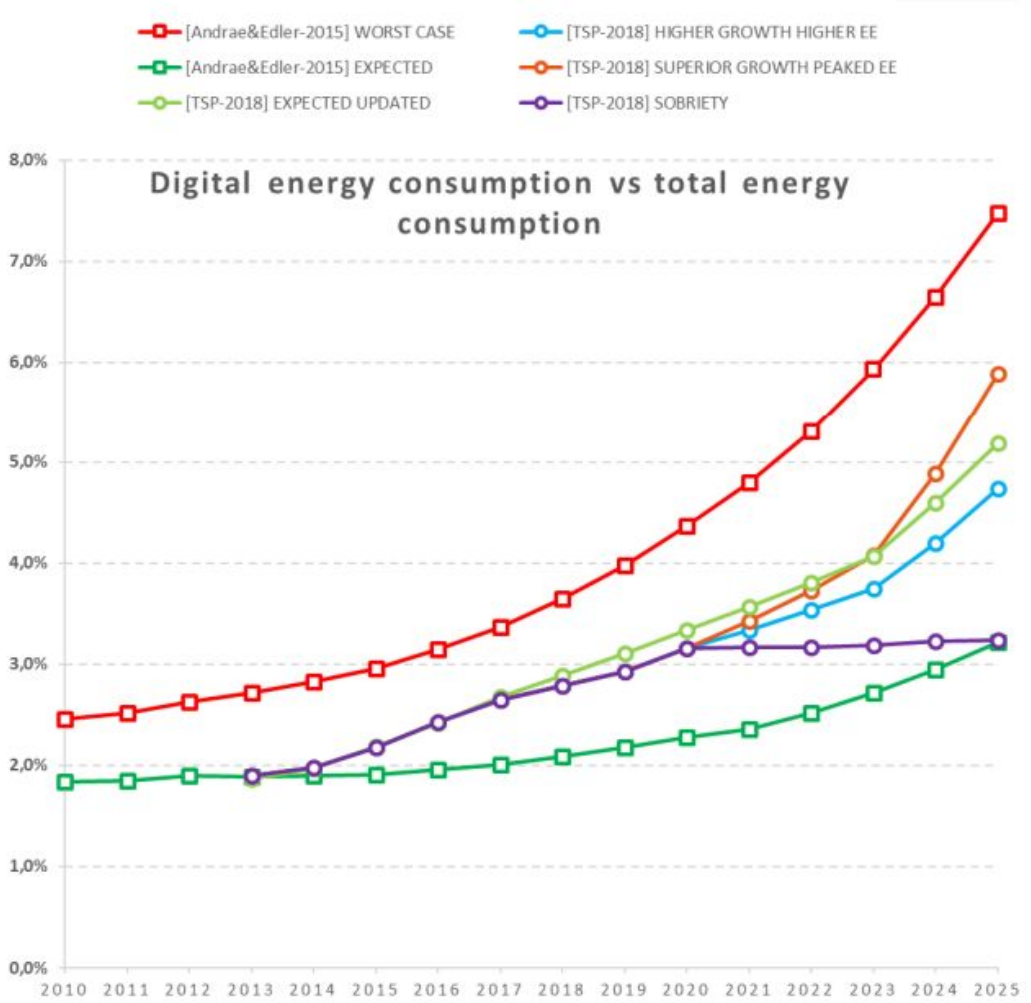
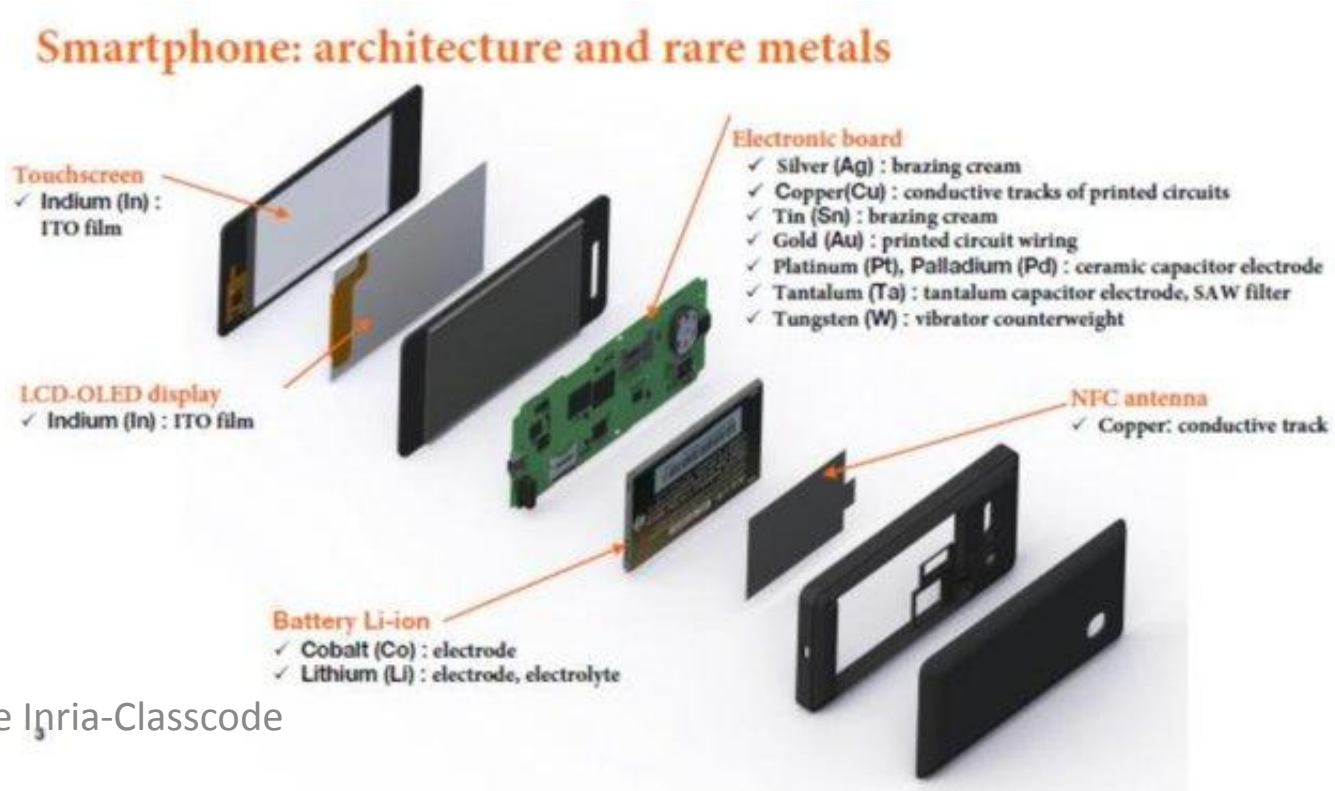


Figure 2: Evolution 2010-2025 of energy consumption of digital technology versus world energy consumption[9].
[Source: [Lean ICT Materials] Forecast Model. Produced by The Shift Project from data published by (Andrae & Edler, 2015)]

Example: A smartphone

Smartphone Apple 12

- 83% production
- 2% transport
- 14% usage
- 1% end of life



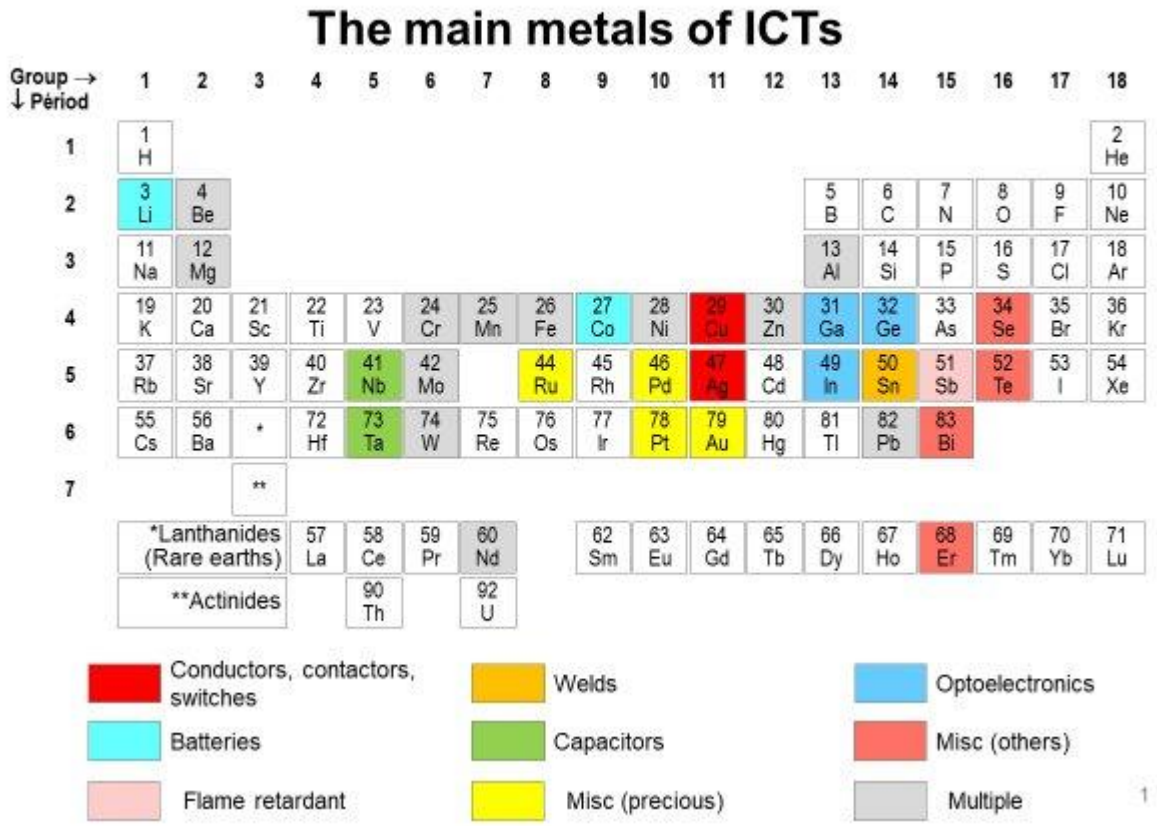
MOOC Impact du mumérique Inria-Classcode

Use of rare materials

Geopolitical tensions

Limited resources

Tensions in usage



The main metals of ICTs.

Bihouix P. , 2015

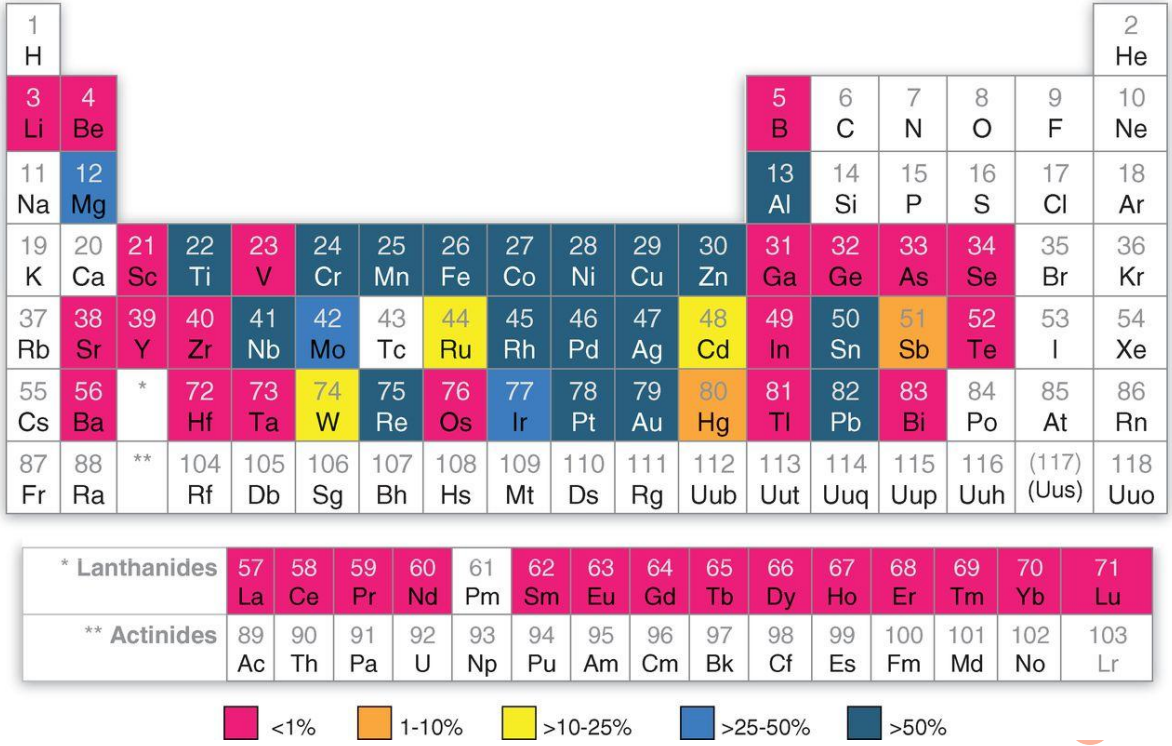
A difficult recycling

Profitable reserves depleted in 30 years

(greenIT)

Challenges in Metal Recycling

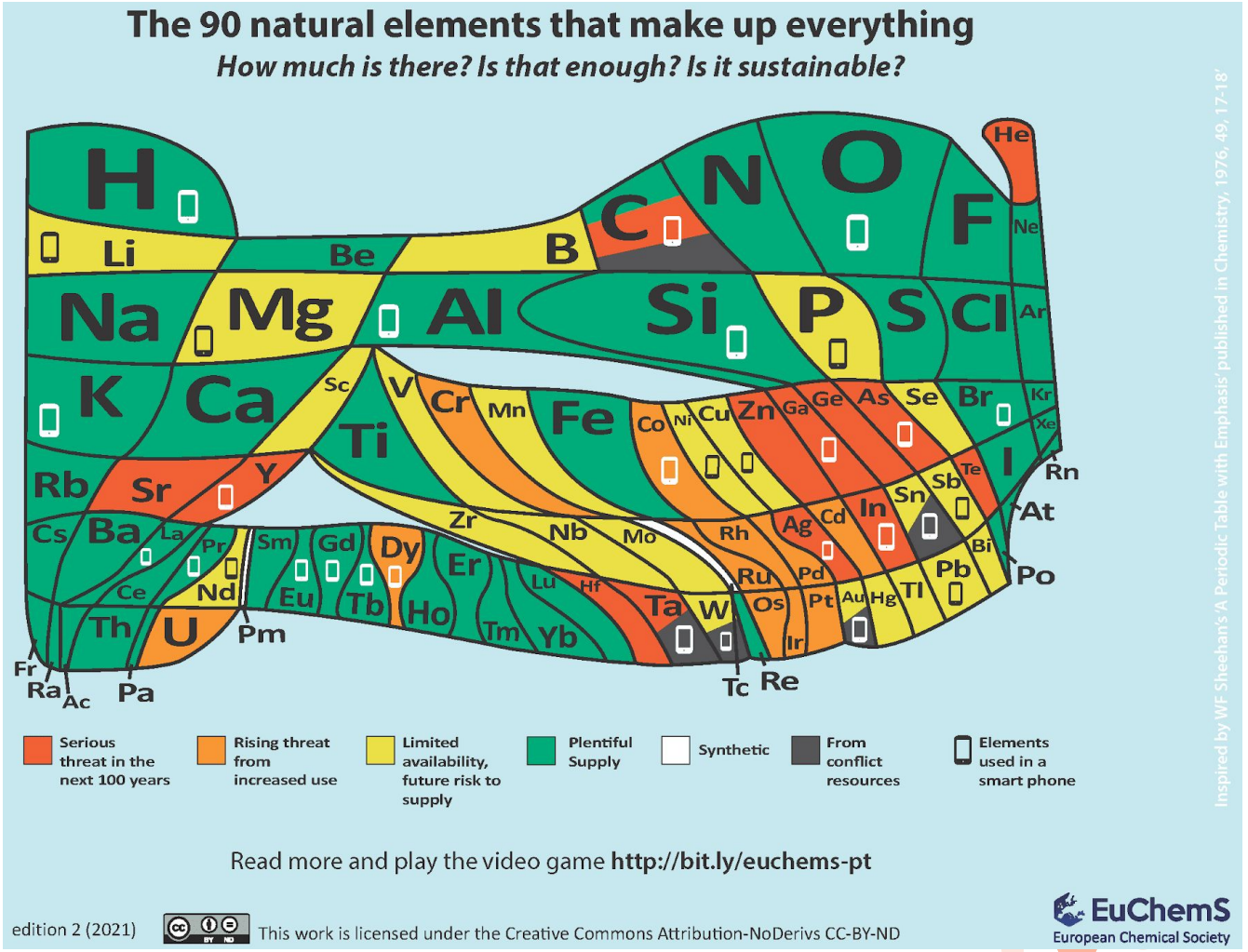
2012



Size : Availability

- Atmosphere
- Earth's crust

Link



Service LCA

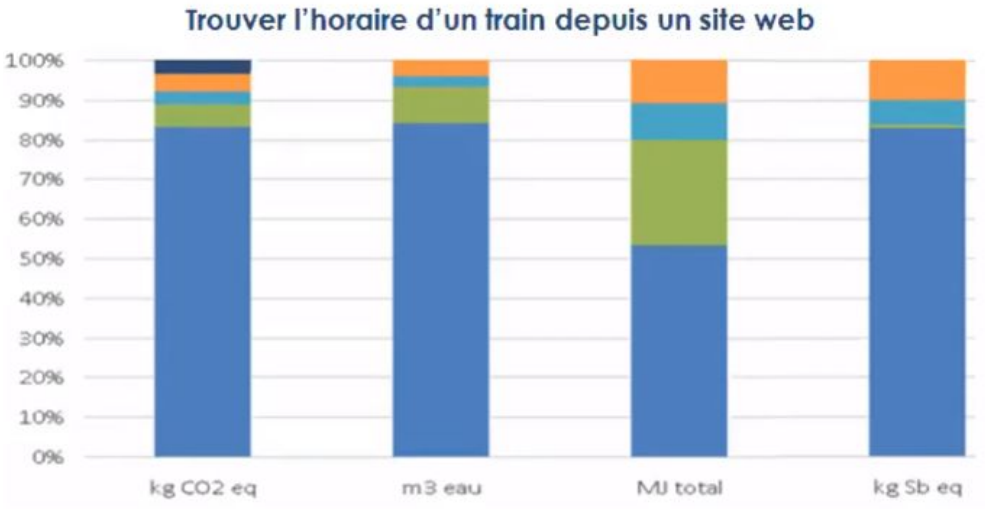
- Manufacture of the user terminal

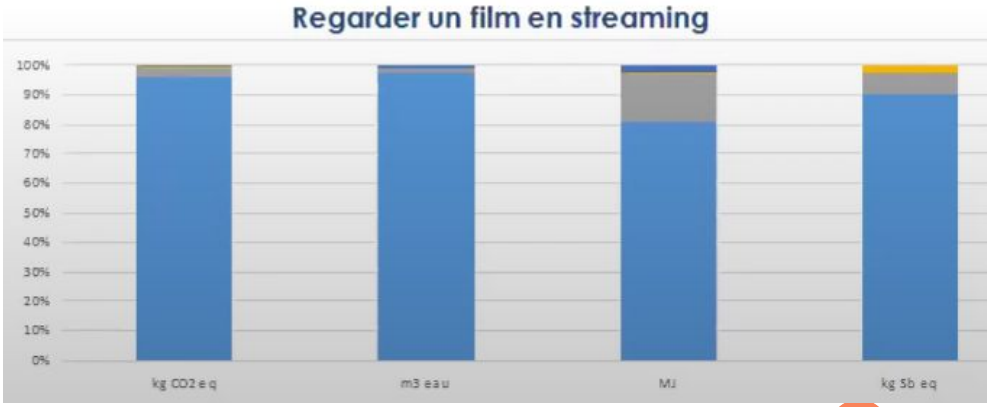
Most cost are before

- Usage
- Even switching-on

Important to remember

- Reduce obsolescence
  - Of personal devices
  - Of Internet





Environmental impact of digital technology

Part 3 : Take action

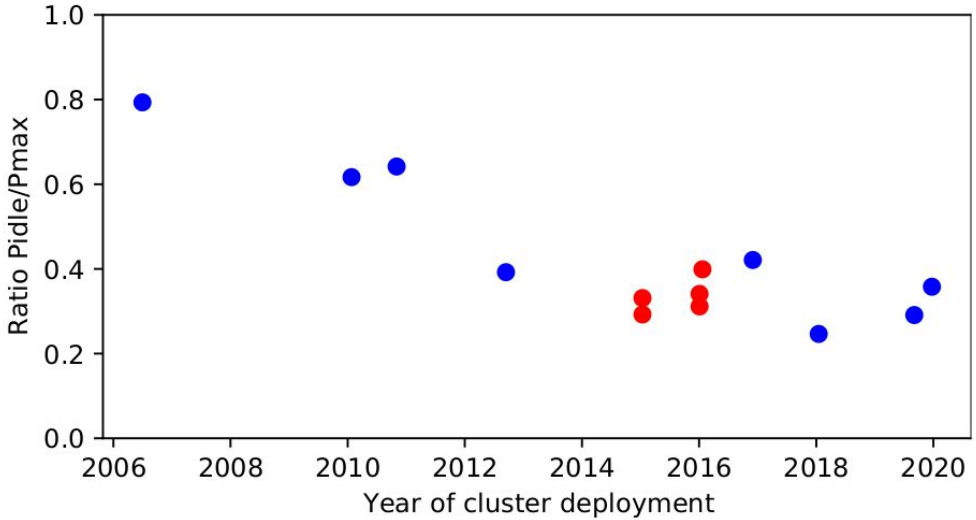
Improve the hardware

Even idle a computer consumes electricity

In 2000 a server was consuming 80% of its maximum just for being switched on

Now 20 to 30%

Recycling issues, obsolescence



Koomey's Law : Performance per Joules : double every 2 years

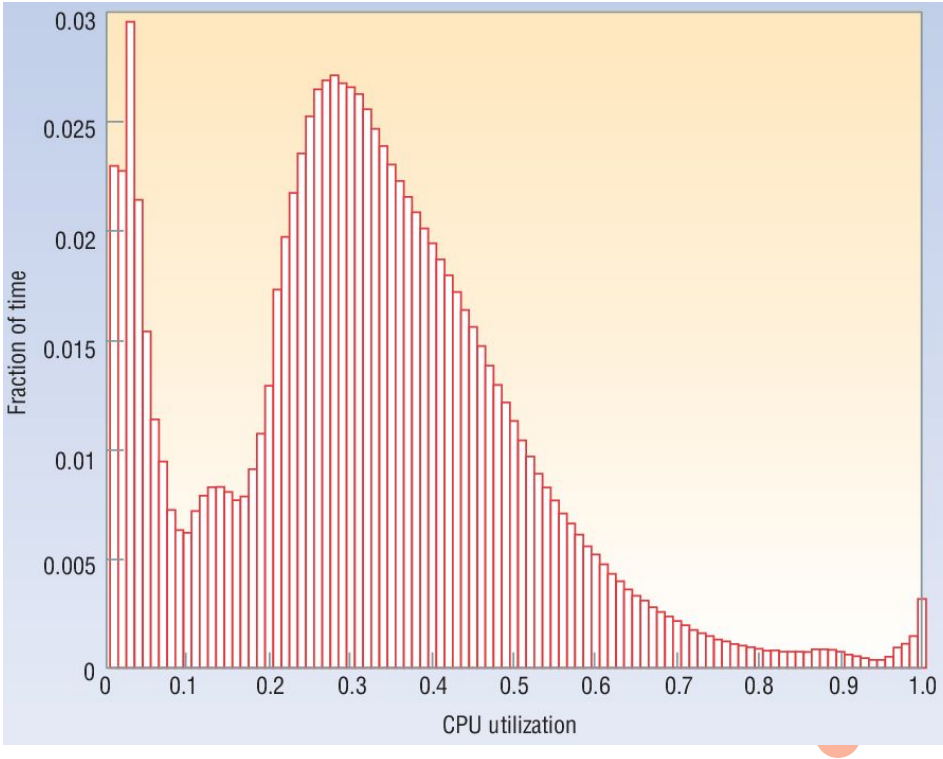
Improve the management

At the infrastructure level

Servers often underutilized

A mean usage of

- 30% in data centers (now more toward 70%)
- Even less for personal computers



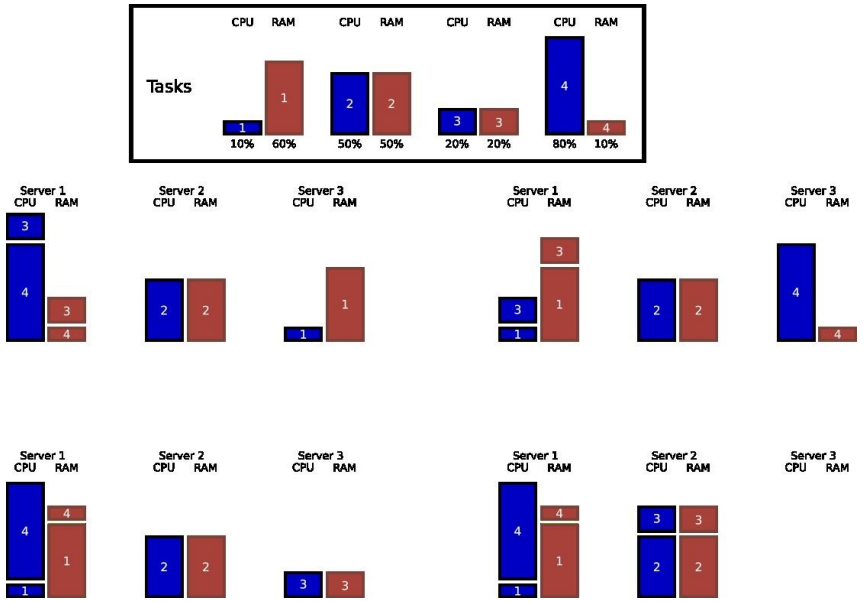
The Case for Energy-Proportional Computing

Improve the management : Consolidation

Virtualization techniques in data centers

Algorithms for

- Sharing the resources
- Move the applications where they impact less
- Switch off idle servers



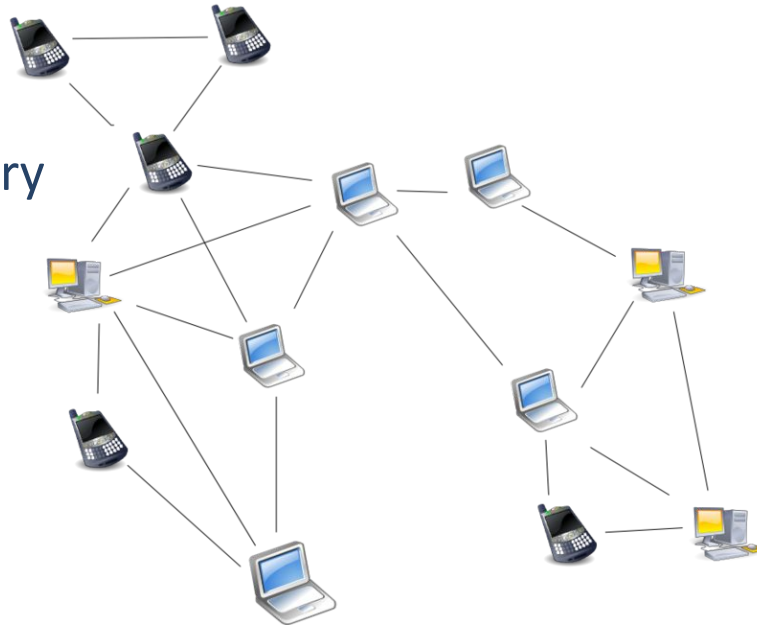
Improve the softwares: Eco-design

- I understand the number of software features
  - Avoiding bloatware
  - Data volume and digital sobriety
- I understand what I am doing
  - Detailed analysis of initial requirements
  - Behaviour measurement
- I favour open source: reusing and contributing to the commons
- I plan software management
  - Increasing lifespan
  - Continuous improvement

Je code : les bonnes pratiques en éco-conception de service numérique à destination des développeurs de logiciels

Decentralising the internet

Web 3.0 but the real one



Direct communications without intermediary

- Less infrastructure
- More resilience
- Wifi-direct / Wi-Fi ad hoc

Blockchain

- Yes but in 5 years

Improve usage

Moderation in consumption does not mean renunciation.

Only use useful features.

- HD video on your phone?
- Back up all your photos for eternity?

Use appropriate means.

- 5G on the train?
- Cloud-only services?
- Photo transfer: Cloud or phone to phone?

Word processing, Presentation, Spreadsheet

Local	0.2 ➔ 0.5W
Online	1.7 ➔ 7.8W
Offline with saves	.8 ➔ 2.9W

Taking action

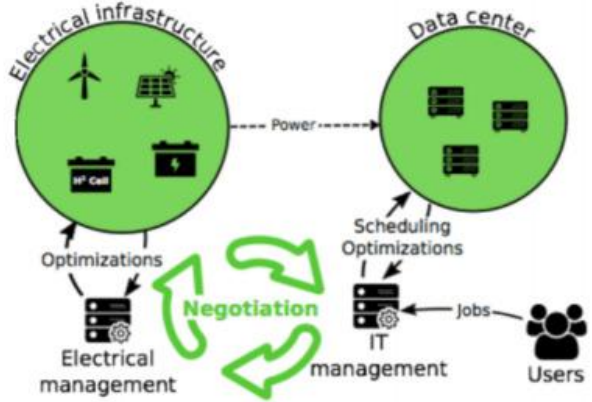
At the personal level

- Do not increase the rate of equipment ownership.
  - Mutualise (smartphone = Swiss Army knife) and sharing.
- Extend the lifespan.
  - Reuse, repair.
  - Second-hand.
  - Consider when purchasing.
- Turn off unused devices.
  - Internet box (7 to 10W, equivalent to an energy-efficient refrigerator).
- Moderate usage
  - 4G consumes 23 times more than WiFi (especially on aeroplanes)
- Collect waste
  - Reused, repaired, recycled and decontaminated

Scaling

At the institutional level (professional, academic, …)

- Reduce equipment levels
  - One desktop or laptop computer is sufficient, as is one monitor
  - Reuse at end of life
- Manage travel
  - Carpooling, public transport, fleet of vehicles
- Aim for eco-design
  - Take it into account in your activity
  - Aim to reduce it as part of your activity
- Manage consumables.
  - Recycled paper, green electricity.
- Measure/evaluate.
  - LCA of an activity (not of software).



Some openings

A.I.

?

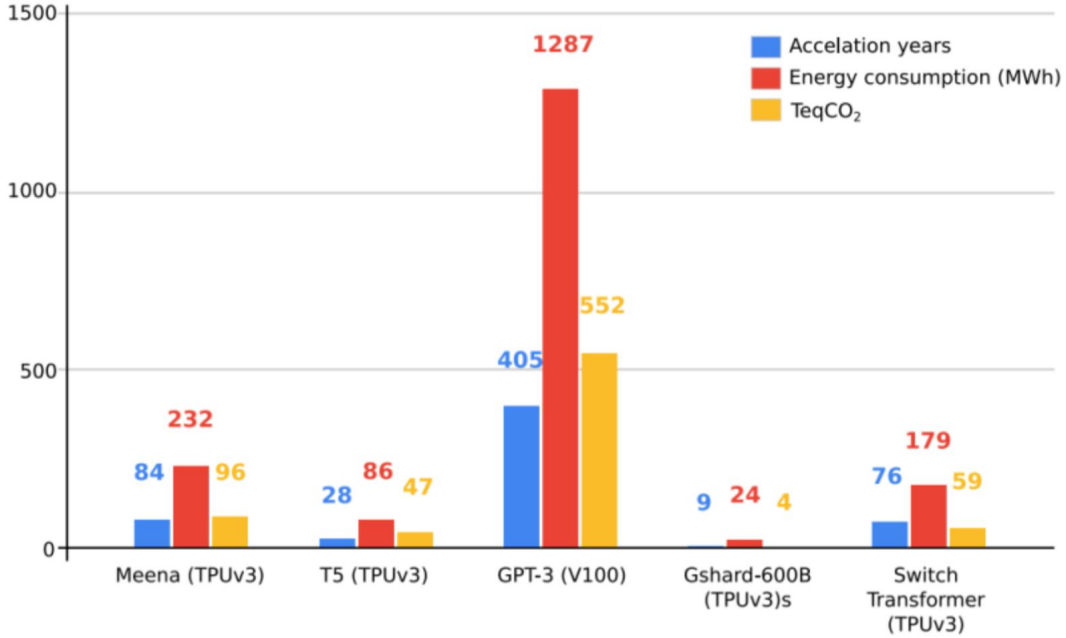
Artificial intelligence

Deep Learning

GPT-3

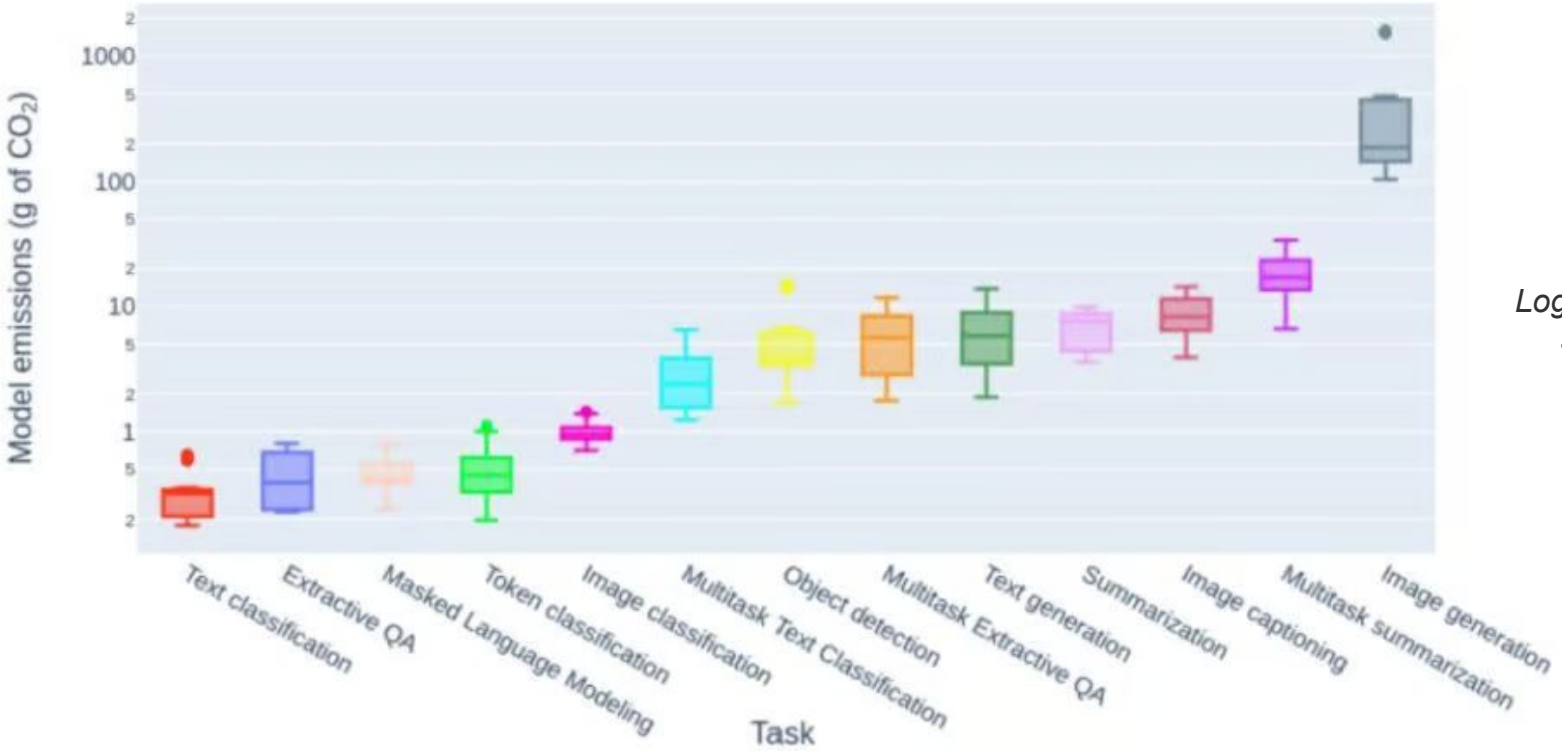
- Creation and synthesis of documents
- 1TeqCO$_2$ = 1 return trip Paris-New York
- 100k€ of electricity

But “free” usage



The Conversation, Denis Trystram, 2021

More details on A.I. phases



Logarithmic scale

Source Source Source

Some openings

Low Tech Internet

?

Keep It Simple Stupid

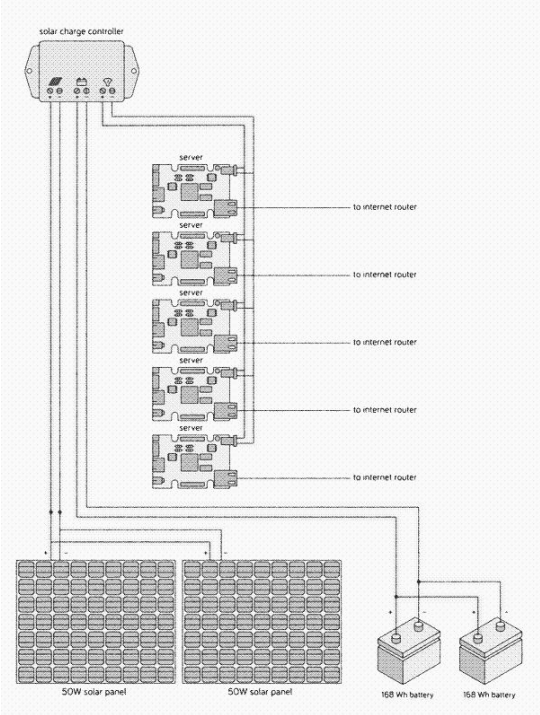
Low tech magazine

Optimization

- Software
- Hardware

Simplification

- Capacity
- Expectation



https://solar.lowtechmagazine.com/

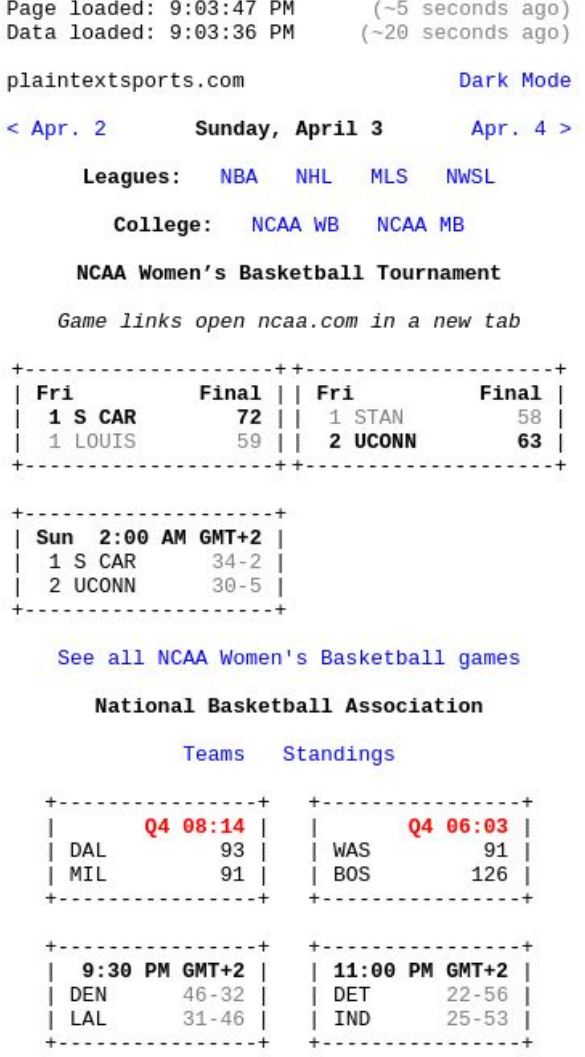
Keep It Simple Stupid

Live sports results

Purely software optimization

- 23 matches
- 300kB transferred from one server
  - Estimation for a mail: 75kB on average
- 3 round-trips
- Simple to display (eq. 0g CO_2)

https://plaintextsports.com/



Some openings

Rebound effect

?

Rebound effect (Jevons paradox)

improved coal efficiency → increased consumption

Type of effect	Level of influence	ICT as a solution	ICT as a problem
1st order (direct)	ICT itself	Producing more with less	ICT life cycle: Production, Use, End of life
2nd order (indirect)	ICT applications in other sectors	Optimisation effects, substitution effects	Induced effects
3rd order (systemic)	Social change	Profound structural change towards a dematerialised economy	Rebound effects, new critical information infrastructures

? What rebound effects have you experienced in your use?

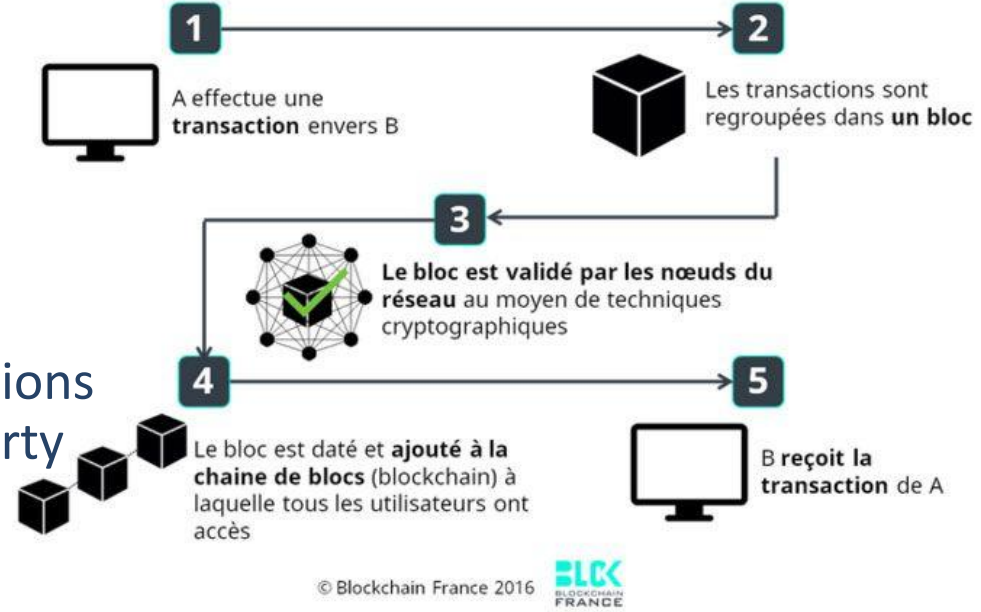
Some openings

Bitcoin, blockchain, NFT

?

Bitcoin / NFT

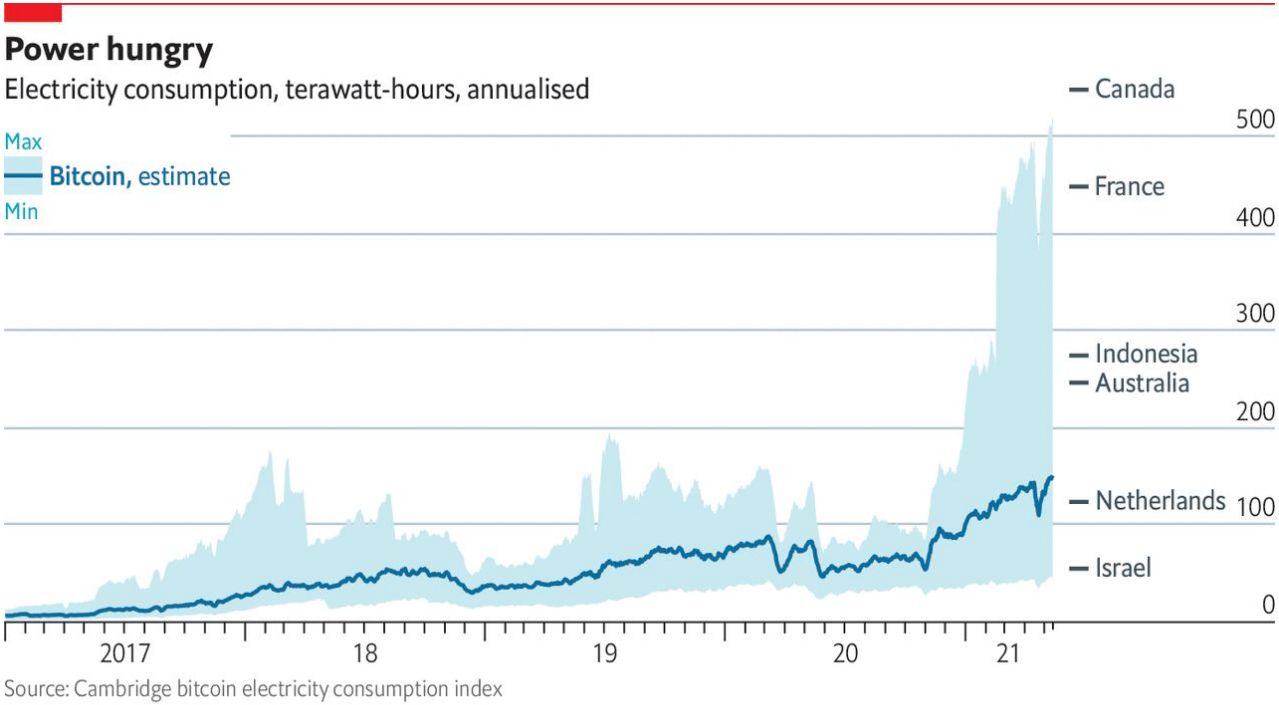
BlockChain principle



- Information storage/transactions
- Replaces the trusted third party
- All participants
  - Record all transactions
  - Verify all transactions
  - Often, ‘verifying’ provides a benefit
- Bitcoin:
  - Transactions: transfer internal value (divisible)
- NFT:
  - Transaction: transfer an internet address

Bitcoin / NFT

Bitcoin : 1,000,000 bitcoin miners



Intrinsic value

Creating uniqueness

Value of a

- BitCoin
- NFT

?

Bitcoin / NFT

Adding value to what can be copied for free

Affluent society, zero marginal cost

Culture: Ian M. Banks

- Virtually infinite resources and colonialism

The Diamond Age: Neal Stephenson

- Hierarchical (noble) control of resources

Star Trek

- Replicator and altruistic vision and colonialism

In the real world: Promise of fusion

Some openings

Video Games

?

The rise of mobile

A new category, new usages

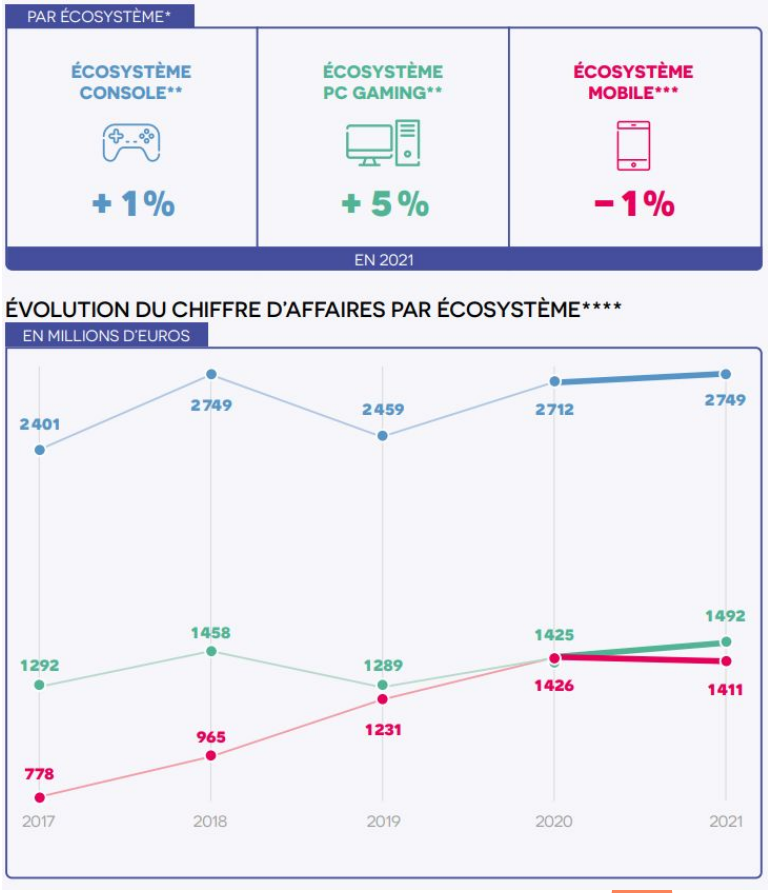
Overall market stability

- PC, Console

Strong growth in the mobile market

- x2 in 5 years

SELL 2021



Cloud gaming

Everything is done in a data centre; only the display and interaction are local.

Complex subject matter

Positive

- Servers 100% utilised
- Modular vision

Negative

- Hidden costs
- Additional network cos
- Rebound effect

2020: 36 million players

2022: £3.2 billion market

Augmented reality / Virtual reality

Still as complex as ever

Positive

- Fewer materials than a large television

Negative

- Double the processing (resolution, latency)

Thanks

POUR UNE INFORMATIQUE ÉCO-RESPONSABLE

Super thanks to Denis Trystram