Consommation énergétique du numérique (cen)

Introduction

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Outline

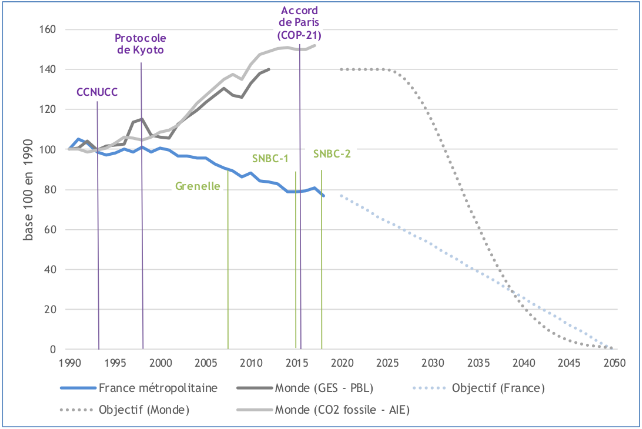
Outline

Consequences of the climate deregulation

https://www.noaa.gov/education/resource-collections/climate/climate-change-impacts

- Increasingly frequent periods of heat waves and fires
- Melting ice
- Sea level rise
- Increased storm intensity
- ...

Evolution of GHG [2] emission since 1990



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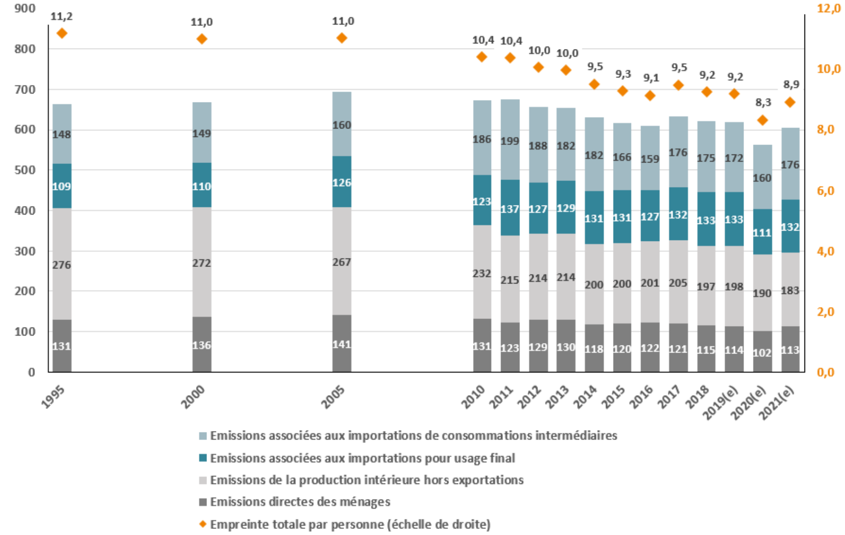
https://www.citepa.org/wp-content/uploads/publications/secten/Citepa_Secten-2019_Rapport_Completv3.pdf

1. CNUCC : Convention-cadre des Nations unies sur les changements climatiques
COP : COnference of Parties on climate change
SNBC : Stratégie Nationale Bas-Carbone
2. GHG : Greenhouse gas measured by $CO_2 - eqg$

Evolution of France GHG footprint 1995-2021



https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/styles/max_1300x1300/public/2023-03/empreinte_carbone_1995_2021_graphique_1.PNG

SNBC Stratégie Nationale Bas Carbone [3]

- Towards GHG neutrality in 2050

Divide by 4 French GHG footprint

- $600MT$ in 1990 ($\approx 10T/person$)
- ↘ $140MT$ in 2050($\approx 2,3T/person$)

3. Laws 08/2015 on climate plan, 11/2019 on energy and climate

SNBC Impact for the Industries

- Reduce industry GHG (Greenhouse gas) footprint
  - ↘ 35% period 2015-2033
  - ↘ 81% period 2015-2050
- Financial support $\subset$ criterion on reduction of GHG
- $>$ 50 employees $\implies$ Should establish a greenhouse gas emission report [4]
- Numeric impact is included in those emission reports

Scope 1 : Direct emission (e.g. boiler)

Scope 2 : Indirect emission through electricity use in the company (e.g. Wh consumed by computers)

Scope 3 : Other indirect emission (e.g. buy AND sell of product and services)

- Mozilla example *https://blog.mozilla.org/wp-content/blogs.dir/278/files/2021/02/Mozillas-2019-Greenhouse-Gas-emissions-baseline_2020-11-18.pdf*

4. Decree no. 2021-1784 of December 24, 2021

Michelin testimony

MICHELIN

Video

France : The REEN law (11/2021) [5]

Réduire l'Empreinte Environnementale du Numérique

Extraits de la loi

- Délit d'obsolescence programmée
- Réduction des taxes pour les Data Centers vertueux
- Enseignement supérieur
  - « La formation aux outils et ressources numériques dispensée aux étudiants de l'enseignement supérieur comprend un volet consacré à l'impact environnemental du numérique. »
  - « Elle vérifie, pour les formations d'ingénieurs en informatique, la validation d'une attestation de compétences acquises en écoconception logicielle. »

5. *https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000044327272*

L'INGÉNIEUR RESPONSABLE, DIPLÔMÉ DE TELECOM SUDPARIS, SE DOIT DE :

1. Maitriser les notions scientifiques de base liées à l'écologie et à l'environnement.

2. Cette maitrise lui permet de Conceptualiser et Modéliser les enjeux environnementaux de l'activité humaine.

3. Connaître les enjeux du numérique (évolution du secteur, des infrastructures, des usages) et Réaliser la nécessité du développement d'un numérique écologiquement responsable.

4. Connaître les impacts environnementaux directs du numérique.

5. Savoir identifier les impacts environnementaux indirects du numérique.

6. Mesurer les impacts environnementaux du numérique car il connait les méthodologies, leurs avantages et leurs limites.

7. Comparer plusieurs services numériques à travers le prisme de leur impact environnemental direct et indirect.

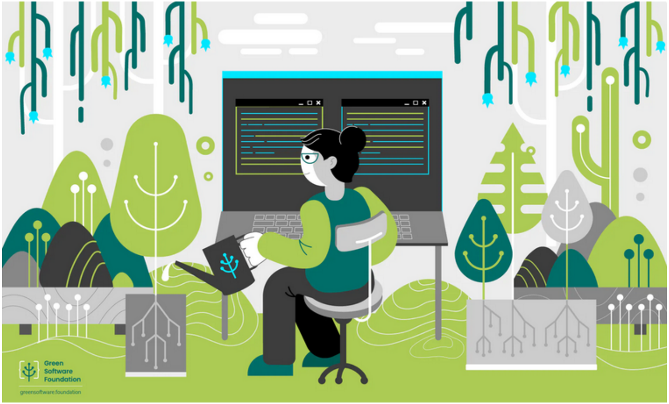
8. Concevoir des solutions et services numérique durables car il sait Prendre en compte l'ensemble des conséquences environnementales dès la conception d'une nouvelle technologie, d'un service ou d'un appareil numérique.

9. Mettre en œuvre le numérique au service de la transition écologique (IT for Green) car il sait Analyser et Optimiser le rôle positif que peut y prendre le numérique.

10. Appréhender avec lucidité les forces et faiblesses d'un service … développement d'un numérique responsable.

Sustainability and your future profession ?

Green Software Developer



Sustainability and your future profession ? (cont.)

Sustainability Consultant

Sustainability and your future profession ? (cont.)

Founder of a Green Tech startup

Outline

IT for green

- IT is crucial for implementation of prediction climate models (including ocean, atmosphere,...)
- IT is crucial to preserve the biodiversity (to predict the disappearance of species)
- IT is crucial to develop agriculture that optimizes resources (water, energy) and the use of pesticides
- IT is crucial for energetic transition : smart grids with renewable energy sources (solar, wind, hydrogen,...)

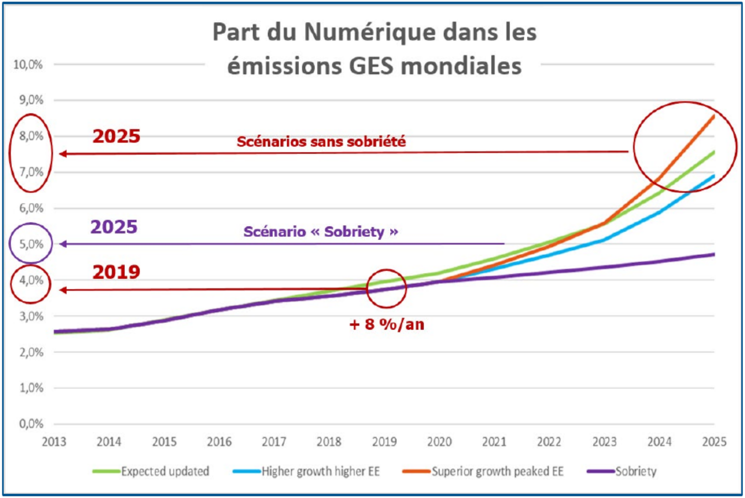
Qarnot : use of IT energy for heating

https://qarnot.com/fr

IoT for green

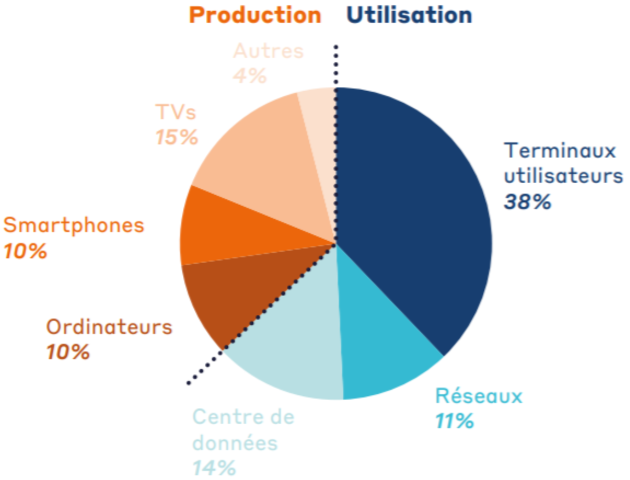
https://www.quora.com/What-is-green-IoT

GHG evolution [Shift, 2021]



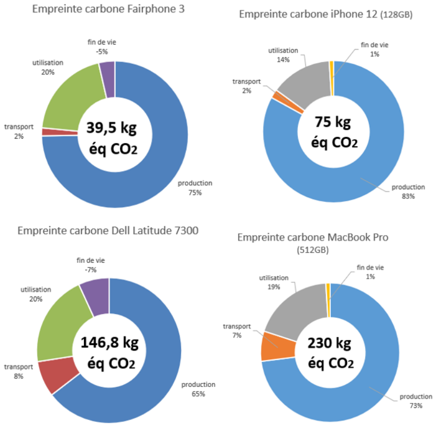
https://theshiftproject.org/article/impact-environnemental-du-numerique-5g-nouvelle-etude-du-shift/ ⚠ estimation

Distribution of IT GHG footprint (e.g.2019)



https://theshiftproject.org/article/impact-environnemental-du-numerique-5g-nouvelle-etude-du-shift/ ⚠ estimation

Distribution of personal device GHG footprint



https://www.ecoconso.be/fr/content/quelle-pollution-le-numerique-entraine-t-il-sur-lenvironnement ⚠ estimation

What about your personal device ....? How long do you keep your device ?

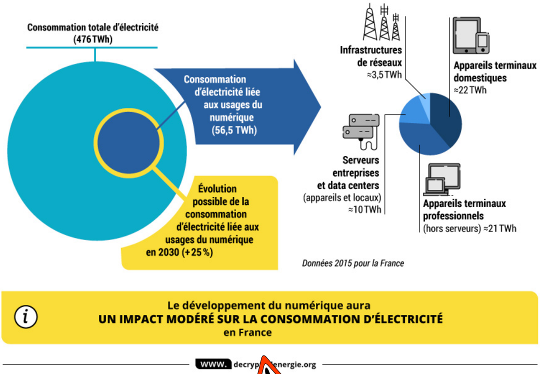
https://dataviz.boavizta.org/manufacturerdata ?

Numeric electrical consumption

World In 2019, ICT represents 5,5% of total electricity consumption *www.greenit.fr*

France In 2015, ICT consumes 56 TWh - 12% of electricity consumption

www.notre-environnement.gouv.fr



decrypterlenergie.org estimation

From KWh to $CO_2 - eq$ emissions

IT services consume electricity (KWh)

- How much $CO_2 - eq$ is emitted per kWh of electricity consumed ($gCO_2 - eq/kWh$) ?
- Depends on the mix energetic of each country
  - Electricity map Real time data *https://app.electricitymap.org/*
  - RTE Real time data in France
    - Mix energetic *https://www.rte-france.com/eco2mix/la-production-delectricite-par-filiere*
    - gCO_2/kWh *https://www.rte-france.com/eco2mix/les-emissions-de-co2-par-kwh-produit-en-france*
    - « En 2022, l'intensité carbone de l'électricité et de la chaleur produite par le groupe EDF s'établit à 50 gCO_2/kWh » *https://www.edf.fr/groupe-edf/produire-une-energie-respectueuse-du-climat*

From KWh to $CO_2 - eq$ emissions (cont.)

? In which country is running my service ?

⚠ Services are distributed (end user Terminal and Clouds) spread over several countries

Outline

Raise of the number of daily life equipments

2012	2017	2022
2 smartphones	4 smartphones	4 smartphones
2 laptops / computers	2 laptops / computers	2 laptops / computers
1 tablet	2 tablets	2 tablets
1 DSL/Cable/Fibre/Wifi Modem	2 DSL/Cable/Fibre/Wifi Modem	3 DSL/Cable/Fibre/Wifi Modem
1 Printer / scanner	1 Printer / scanner	1 Printer / scanner
1 Game console	1 Game console	1 Game console
	1 connected television	3 connected television
	2 network attached storage	1 network attached storage
	2 eReaders	2 eReaders
	1 smart metre	1 smart metre
	2 connected stereo systems	3 connected stereo systems
	1 energy consumption display	1 energy consumption display
	1 Internet connected car	2 Internet connected car
	1 pair of connected sport shoes	3 connectes sport devices
	1 pay as you drive device	2 pay as you drive devices
		1 digital camera
		7 smart light bubles
		5 internet connected power socker
		1 weight scale
		1 eHealth device
		1 intelligent thermostat
		4 home automation sensors

Figure 9 : Équipements numériques dans un foyer de 4 personnes dans un pays de l'OCDE
(Source : (GSMA, 2015))

https://theshiftproject.org/article/impact-environnemental-du-numerique-5g-nouvelle-etude-du-shift/

Number of connected equipments/type

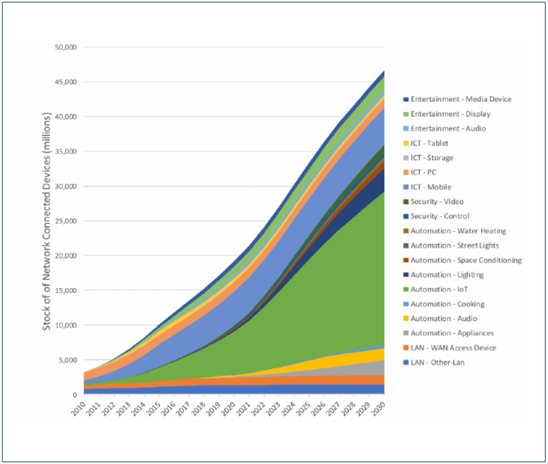
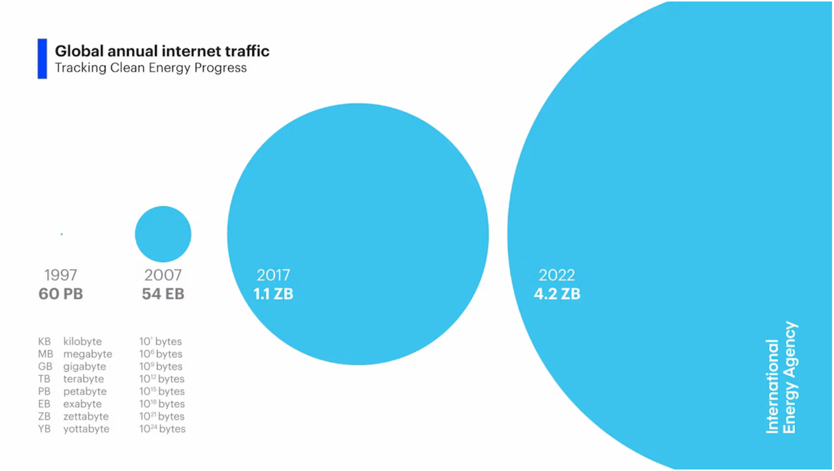


Figure 7 : Evolution des parcs d'équipements connectés dans le monde
(Source : (IEA 4E EDNA, 2019))

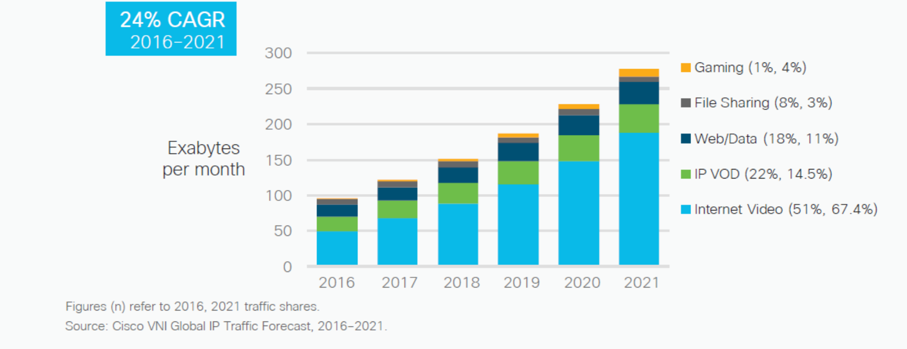
https://theshiftproject.org/article/impact-environnemental-du-numerique-5g-nouvelle-etude-du-shift/

Explosion of data traffic



https://www.iea.org/reports/digitalisation-and-energy

Explosion of data traffic (cont.)



https://theshiftproject.org/article/impact-environnemental-du-numerique-5g-nouvelle-etude-du-shift/

Outline

Youtube case : Gnamgnam style video clip

4,5 billions of views 2012/2022

estimation ! Energy consumed to view this 4mn ??$KWh/view$

- Once :$0,04 KWH$ [6]
- 4,5 billions : $0,04 * 4.500.000.000 = 180.000.000 KWH = 180 GWH$

Comparison

- Given that one french consumes 7MWH/year in 2020
- $180 GWH \equiv$ yearly energy consumption of 25 700 …for one video clip

6. estimation from the Shift Project [Efoui-Hess, 2019]

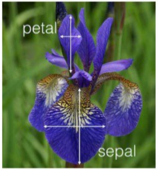
AI case

estimation ! The amount of computational power required to run large AI training models has been increasing exponentially, with a 4 month doubling time [Hao, 2019]

- Training a single neural network model today can emit as much carbon as five 🚗 in their lifetimes ($\approx 40 * 5 = 200\,TCO_2$)
- Training an AI model on a simple dataset[Podder et al., 2020]
  - Classify Iris flowers in different species

Impact of the accuracy on Energy (in Joules) :

Supervised learning *classification* problem
(using the Iris flower data set)



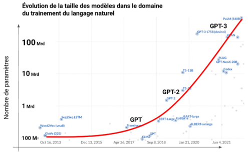
Training / test data

Features				Labels
Sepal length	Sepal width	Petal length	Petal width	Species
5.1	3.5	1.4	0.2	Iris setosa
4.9	3.0	1.4	0.2	Iris setosa
7.0	3.2	4.7	1.4	Iris versicolor
6.4	3.2	4.5	1.5	Iris versicolor
6.3	3.3	6.0	2.5	Iris virginica
5.8	3.3	6.0	2.5	Iris virginica

- 96.17% : 964 J
- 96.17%+1,74% : 964+2815 J
- 96.17%+1,74%+0,08% 964+2815+3856 J
- Accuracy/energy balance ?

ChatGPT case

Estimation
[DataForGood, 2023, Luccioni et al., 2023]



https://ourworldindata.org/grapher/artificial-intelligence-parameter-count

Learning phase

Depends on many parameters (model size, computer location)

GPT3 : 175 000 000 000 parameters → 10 000 GPU for 15 days → 1 287MWh (443g $CO_2 - eq$/kWh) →
552 tonnes $CO_2 - eq$ /learning (use)

- Consider the number of learning phase/year and the production of the computers ...

Inference phase

Depends on many parameters (number of users, location of servers ...)

GPT3 : 3 617 servers HGXA100 + 28 936 GPUs (changed /6years) →
121 350 tonnes $CO_2 - eq$ /Year (on the server side, production +use)

Bitcoin case ₿

⚠ *estimation !*

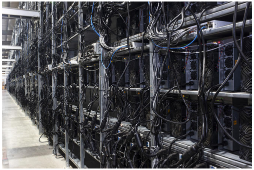


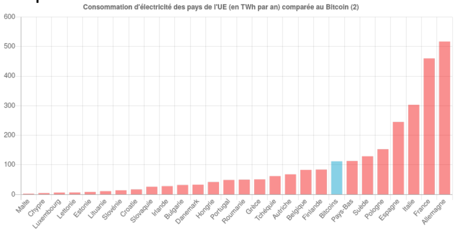
Figure – Bitcoin mining machines, warehouse in Rockdale, Texas (USA)

https://lejournal.cnrs.fr/billets/le-reseau-bitcoin-une-erreur-follement-couteuse

[Delahaye, 2022]

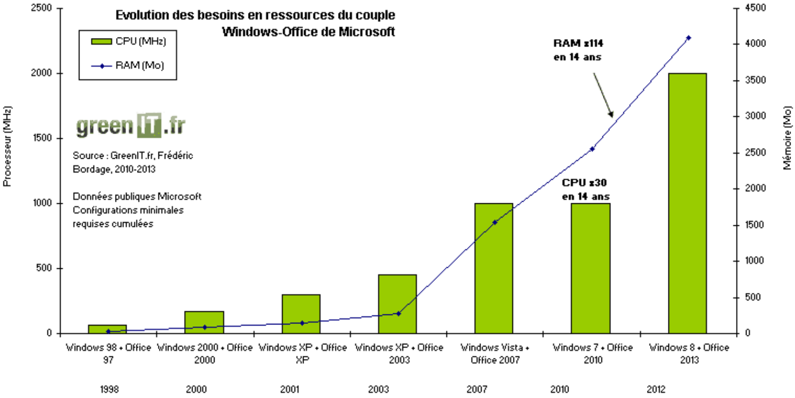
- Election of miners by proof of work
  - Miners work to solve complex math problems that are of no use at all

$\Longrightarrow$ 112 TWh /year in 2022 [Perea, 2022]
$\equiv$ 0,56% total world energy consumption
$\equiv$ 9 nuclear power station for 1 year
$>$ than 20 european countries electricity consumption



💡 Other strategies could/should have been chosen at the conception (2009)

Obésiciel



https://www.greenit.fr/2010/05/24/logiciel-la-cle-de-l-obsolescence-programmee-du-materiel-informatique/

Eco-conception : Do we keep all the features ?

Outline

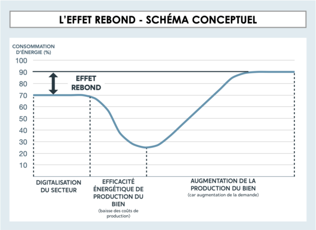
Efficiency

As an engineer you may/will work on

- digital energy efficiency and eco-conception
  - software, architecture, modelisation, network ...

but ....

Rebound effect



https://www.projetpangolin.com/la-pollution-numerique/

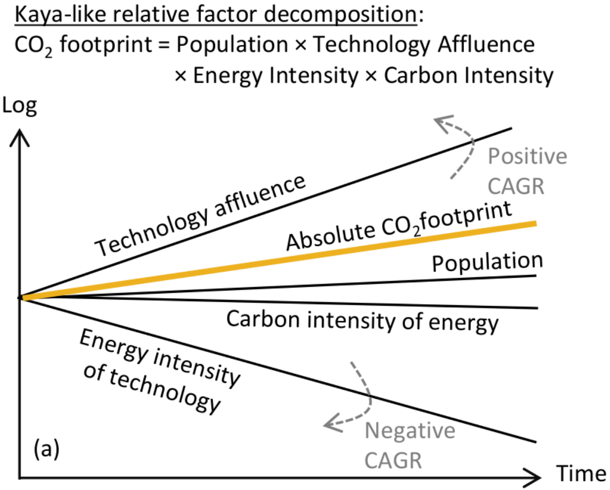
- With time digital technologies have gained in energy-efficiency
  - Direct effect : energy reduction / usage unit
  - Indirect effect or rebound effect : modification in terms of usage that does not necessarily lead to less usage of energy
    - e.g. increase in the usage that leads to an increase in terms of energy (commonly known as the Jevons paradox)
    - Remark : Difficulty to measure rebound effect

Rebound effect (cont.)

Example

- Imagine that you reduce the energy consumption of training a neural network by 50%.
- Hence, data scientists saw an opportunity to improve the model by increasing the complexity of the neural network and the size of the input data.
- Although you have a more energy-efficient network, you might not be saving energy.

Efficiency and $CO_2 - eq$ footprint



[Bol et al., 2021][7]

7. CAGR : Compound annual growth rate ; Affluence : usage rate/person ; Carbon intensity : gCO_2/KWh ; Energy intensity :KWh/usage

Outline

Conclusions

- Even if it seems mostly virtual, IT has environmental impacts (GHG emission, mineral resource usage, water pollution)
  - Production phase has the highest impact
    Augment the lifetime of devices ; Reduce the number of devices (devices/user or devices/computation) ;
  - Deployment choices may have an impact
    Reduce the number of active computers ; choose the location of data centers according to their electrical mix ; choose the less impacting implementation of services
  - Eco-conception is necessary to both reduce the number of devices and the electrical consumption of the software

Conclusions (cont.)

- Even if numeric services are complex, industrials have to
  measure, estimate, reduce environmental impact of their IT services
  - Measure electrical consumption (of a device, a software)
  - Model electrical consumption (of a data-center, of a service)
  - Life cycle assessment (impact of a system during all its lifecycle)
- Keep in mind
  - IT for green may save energy : balance energy consumed vs energy saved
  - Efficiency may have direct (positive) impacts but also indirect effects (called rebound effects that may be positive or negative)
  - Environmental impact go further than GHG emission, consider also : limited natural resource consumption, water consumption

Outline

Web portal and contact

Web Portal : *https://www-inf.telecom-sudparis.eu/COURS/fisa-cen*

Contact : *mailto:hind.castel@telecom-sudparis.eu, chantal.taconet@telecom-sudparis.eu*

Coordinatrices

Hind CASTEL

Chantal TACONET

Objectives of the teaching unit

- Understanding the impact of digital technology on electricity consumption
- Analyze the energy impact of current digital use cases
- Calculate and model the electrical consumption of a complex system
- Think about the environmental impact of all your future engineering projects (student and professionnal)

Content

- INTRO/USECASE Intro (3H30)
- MESURE **Terminal** : Computer energy consumption measure and software energy efficiency (3h30)
- CLOUD **Cloud**-Model Data/center energy consumption (7h00)
- RESEAU **Network** wired/wifi/cellular 3G/4G/5G comparison (3h30)
- IOT IoT and LCA (Life Cycle Assessment) (4h30)

Evaluation

- Present one article (10 points)
- Lab reports (7 points)
- QCM (3 points)

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