

«Think of the environment, do not print this e-mail»

The controversial role of technological innovation

Climate Change / Changing behaviors - Anne-Laure Ligozat - Cogmaster - 2020

Who am I?

Computer scientist

Research topic: environmental impact of ICT (Information and
Communications Technology)



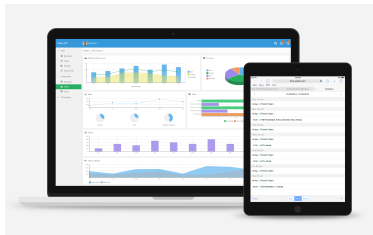
LIMSI (CNRS) /
LISN (CNRS, Université Paris Saclay)

+ EcoInfo



ENSIIE

How does technological innovation,
focusing on ICT,
influence climate change?



⇒ carbon footprint of ICT,
expressed in Global Warming Potential (GWP)
or Greenhouse Gases (GHG) emissions



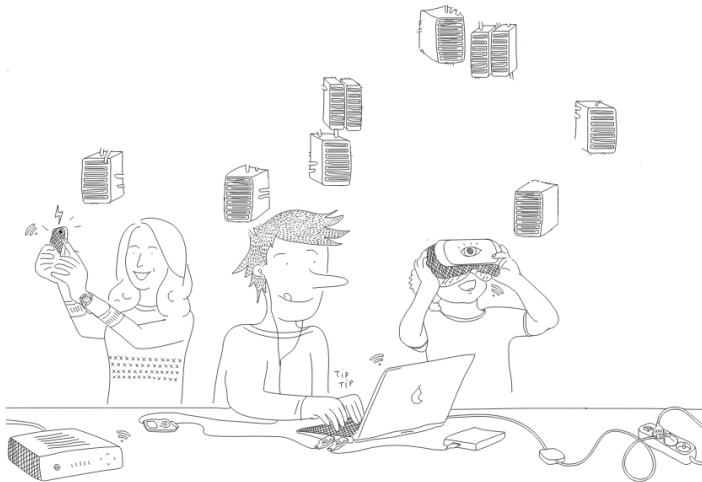
ICT is non physical, right?
It avoids the use of paper, ink, planes...

User devices...

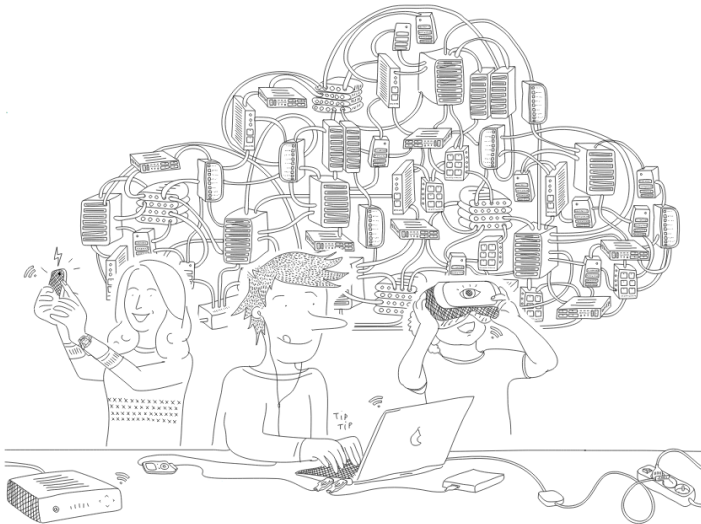


source: [ADEME](#)

+ Data centers and servers



+ Network infrastructure...



ICT, a non-polluting industry?

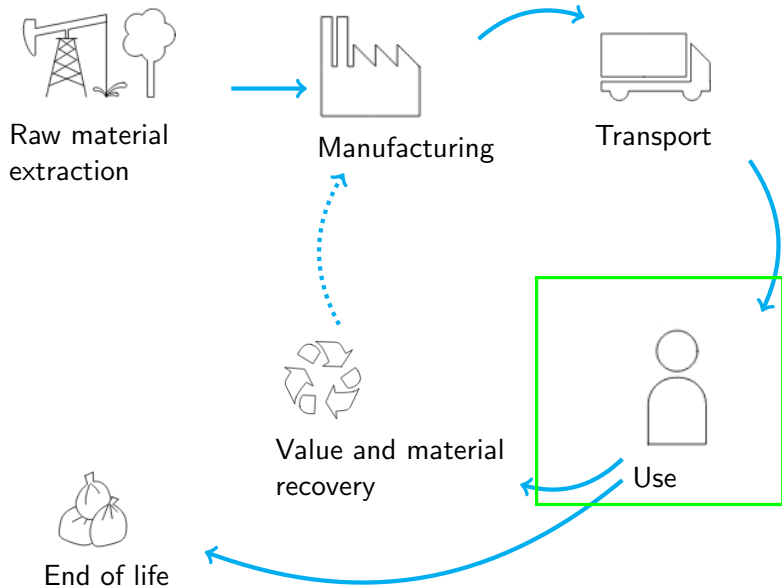
environmental footprint largely under-estimated by its users:

- ▶ "invisibility" of infrastructures
- ▶ cloud services
- ▶ miniaturization of devices

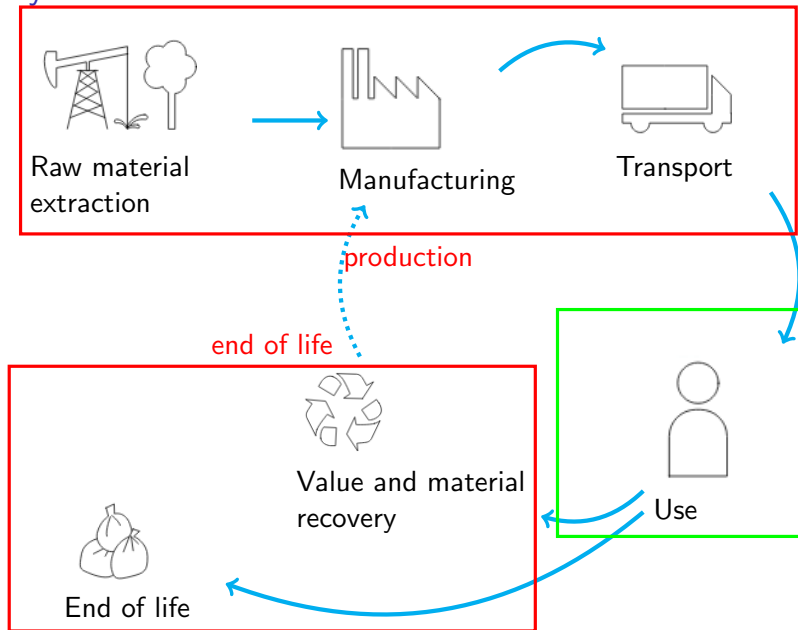


So let's minimize
our consumption of energy?

Lifecycle of ICT

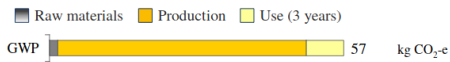


Lifecycle of ICT



Smartphone:
> 90% of its carbon footprint during production

(in France, excluding network usage)



GWP of each lifecycle phase for a smartphone with a global electricity mix [[Ercan et al., 2016](#)]

ELEMENTS OF A SMARTPHONE

ELEMENTS COLOUR KEY: ● ALKALI METAL ● ALKALINE EARTH METAL ● TRANSITION METAL ● GROUP 13 ● GROUP 14 ● GROUP 15 ● GROUP 16 ● HALOGEN ● LANTHANIDE

SCREEN

In Indium
O Oxygen
Sn Tin

Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.

Al Aluminium
Si Silicon
O Oxygen
K Potassium

The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al₂O₃) and silica (SiO₂). This glass also contains potassium ions, which help to strengthen it.

Y Yttrium
La Lanthanum
Tb Terbium
Pr Praseodymium
Eu Europium
Dy Dysprosium
Gd Gadolinium

A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

ELECTRONICS

Cu Copper
Ag Silver
Au Gold
Ta Tantalum

Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.

Ni Nickel
Dy Dysprosium
Pr Praseodymium
Tb Terbium
Nd Neodymium
Gd Gadolinium

Nickel is used in the microphone as well as for other electrical connectors. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.

Si Silicon
O Oxygen
Sb Antimony
As Arsenic
P Phosphorus
Ga Gallium

Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.

Sn Tin
Pb Lead

Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

BATTERY

Li Lithium
Co Cobalt
O Oxygen
C Carbon
Al Aluminium

The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

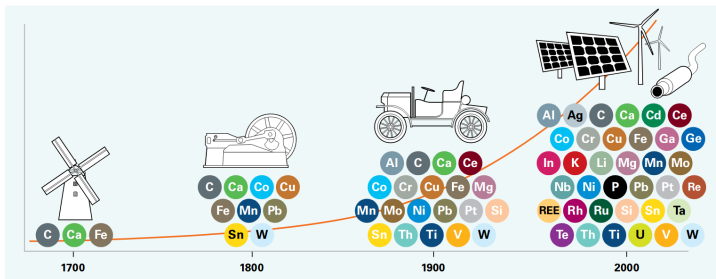
CASING

C Carbon
Mg Magnesium
Br Bromine
Ni Nickel

Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.

Production phase

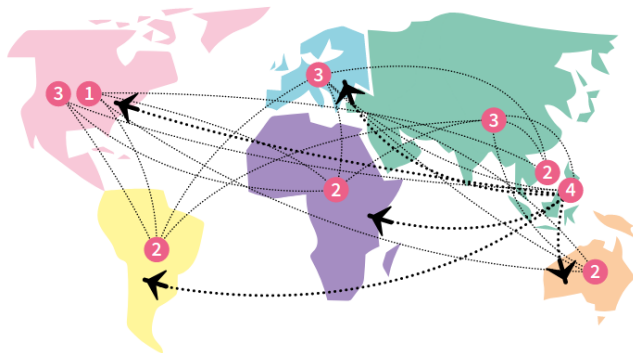
Material evolution



Elements widely used in energy pathways

Materials critical to the energy industry, Achzet et al., 2011

Production phase



1. Design. often in the United States.

2. Extraction and processing of raw material in Southeast Asia, Australia, Central Africa and South America.

3. Manufacturing of the main components in Asia, the United States and Europe.

4. Assembly in Southeast Asia.

↑
Distribution to the rest of the world, often by plane.

source: [ADEME](#) and [France Nature Environnement](#)

End of life phase

E-waste growth

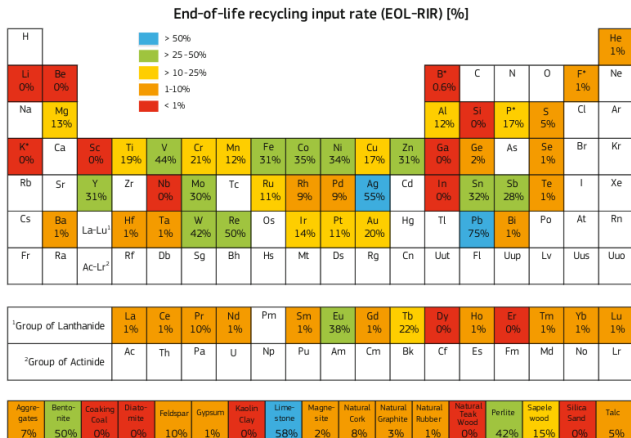


source: E-waste monitor 2020

End of life phase

Recycling

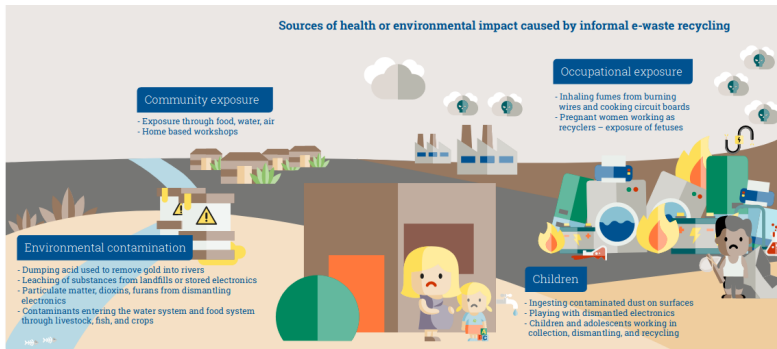
Figure 16.1: End-of-life recycling input rates (EOL-RIR) in the EU-28^{170,171}.



* F = Fluorspar; P = Phosphate rock; K = Potash, Si = Silicon metal, B = Borates.

source: [European Commission, Joint Research Centre, 2018]

E-waste health and environmental impact



source: E-waste monitor 2020

Environmental impact of ICT lifecycle



Global Warming Potential



Abiotic resource depletion



Blue water shortage



Human toxicity

...

civil aviation



2013

ICT



2018

automobile



2025

ICT \approx 4% of global GHG
with an 8% annual growth!

GHG emissions

Digital share and trajectories compatible with a 2 degrees scenario

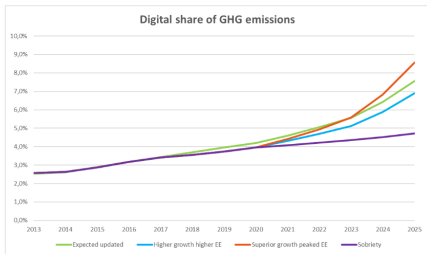


Figure 3: Evolution 2013-2025 of the share of digital technology in GHG emissions. The share of digital technology in GHG emissions. [Source: *Lean ICT Noteriks*] Forecast Model. Produced by The Shift Project from data published by *(Andrae & Edler, 2015)*

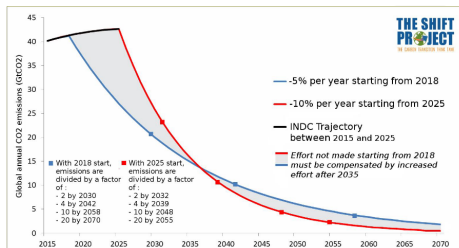


Figure 4: Emission trajectories compatible with a temperature increase limited to 2°C. [Source: *The Shift Project, 2016*]

Source : The Shift Project, 2018



But doesn't ICT help
reduce GHG emissions?

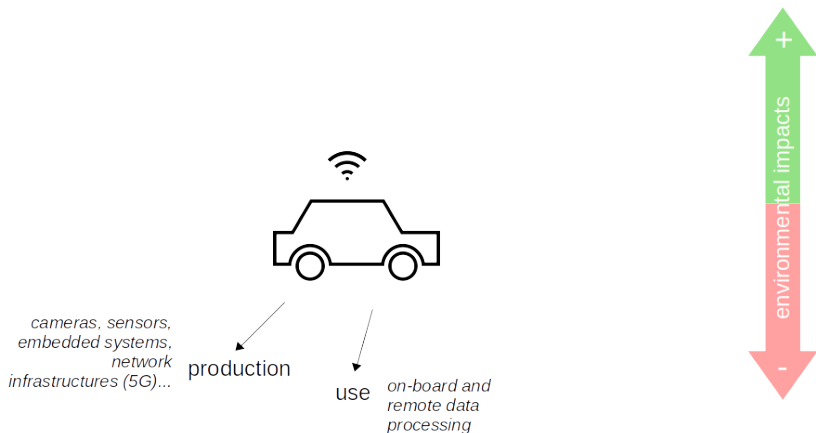
Types of ICT effects

type	perimeter	negative effects	positive effects
1 direct effects	technology	life cycle of ICT	n/a
2 enabling effects	application	induction	substitution
		obsolescence	optimization
3 systemic effects	economy & society	rebound effects	sustainable production and consumption
		emerging risks	

based on [Hilty, 2008, Hilty and Aebischer, 2014]

1st order effects

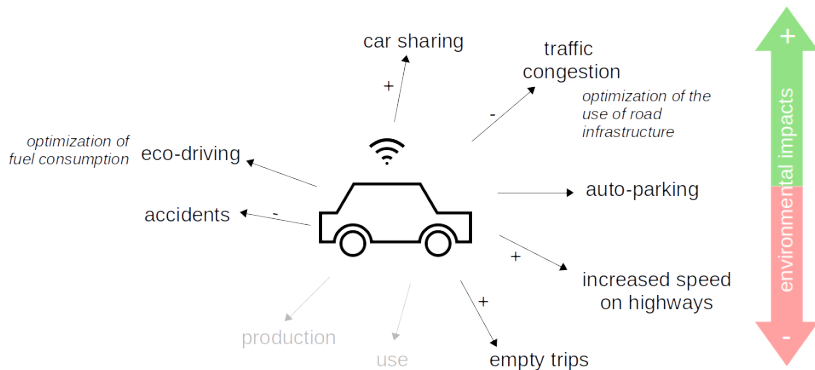
Autonomous vehicles



from Jacques Combaz and [Taiebat et al., 2019]

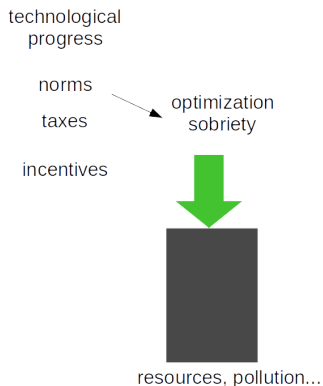
2nd order effects

Autonomous vehicles



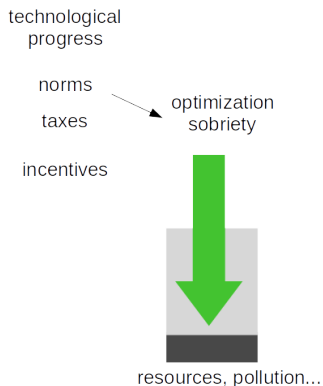
The rebound effect

Or why ICT emissions (and others) keep growing nonetheless...



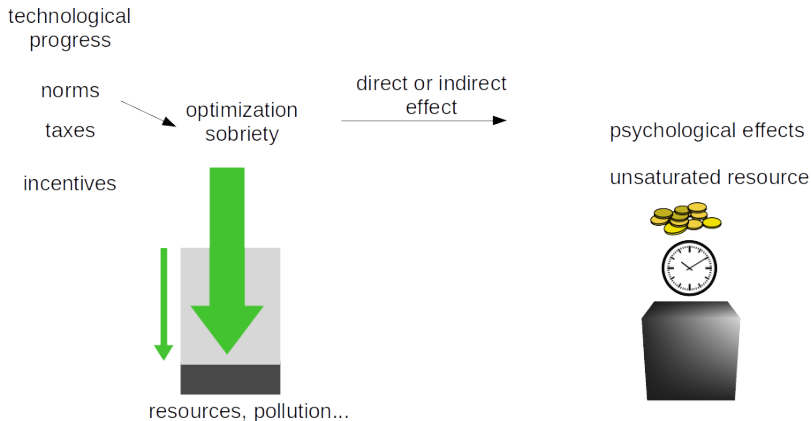
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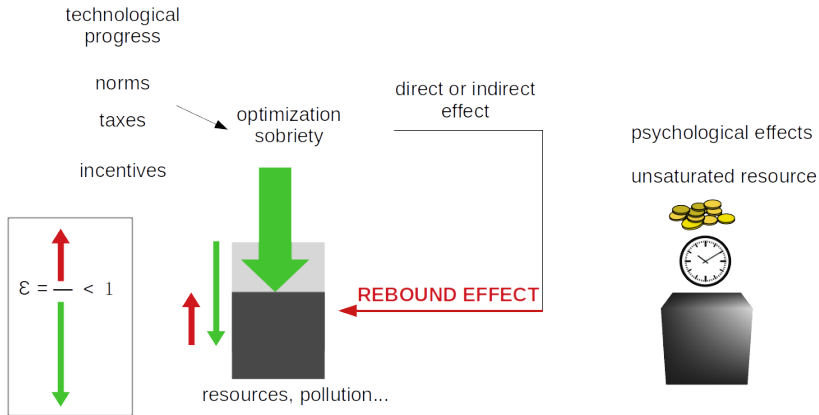
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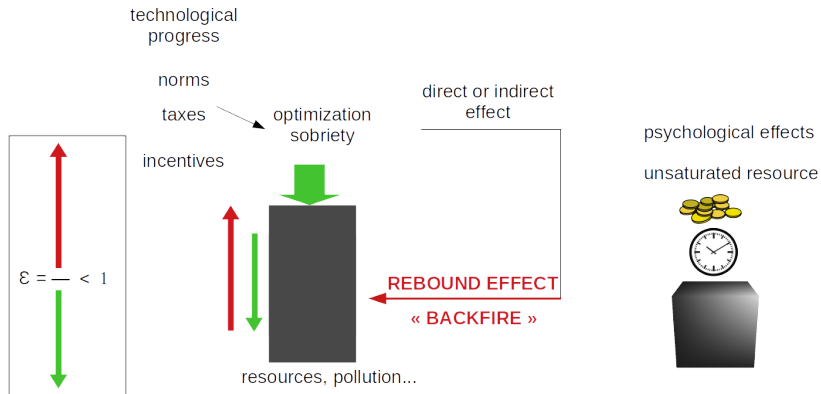
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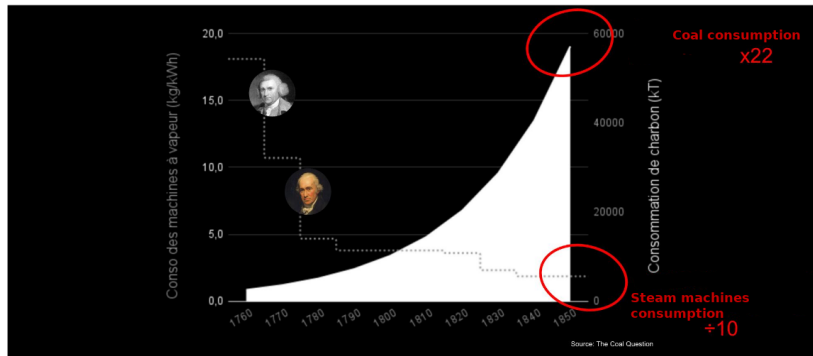


The rebound effect

Or why ICT emissions (and others) keep growing nonetheless...



Jevons's paradox



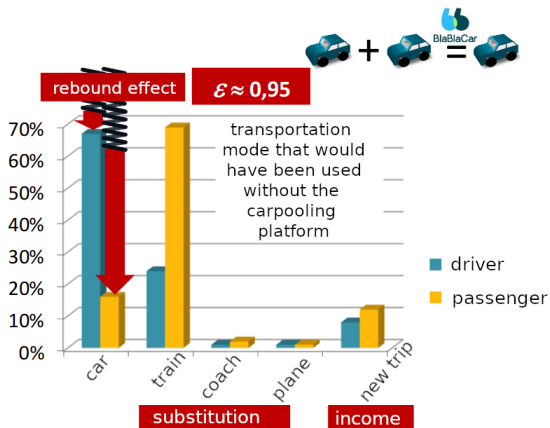
Another example: Blablacar

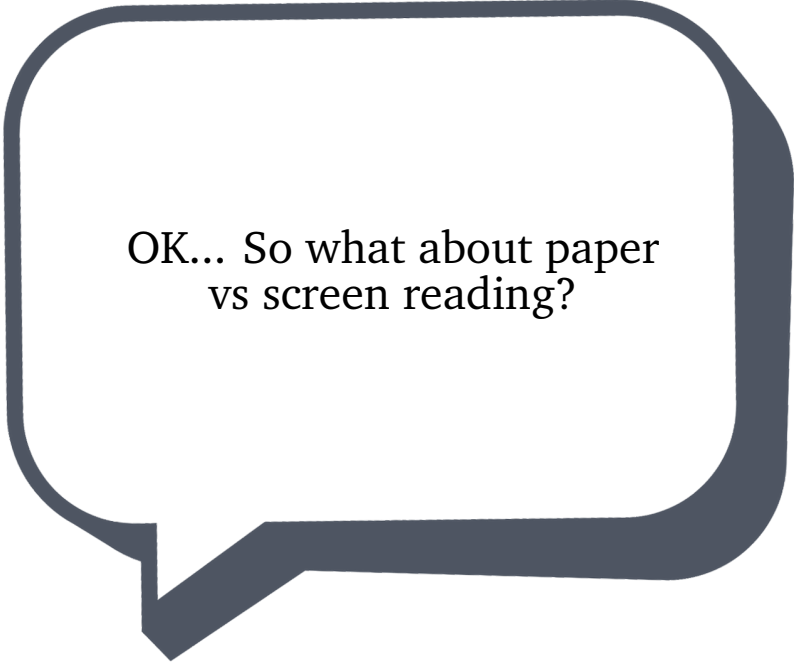


Main motivations:

- savings 69 %
- socialization 87 %

source : Ademe, 2015





OK... So what about paper
vs screen reading?



Emma.

Example: book vs e-reader




~ 1 to 3 kgCO₂e



~ 40 to 170 kgCO₂e

⇒ 3 to 35 books each year to make the e-reader more environmental friendly than books (with a 5 year lifetime for the e-reader)

sources: Base carbone Ademe and [[Wells et al., 2012](#)]



So back to an Amish
lifestyle right?

Key notion with ICT

=
Sobriety



Why is digital sobriety difficult to promote?

- ▶ requires systemic changes
- ▶ linked to political visions of the future, and in particular the notion of progress

Do we have a choice?

Limits to growth

Technological

Limits to gains in efficiency e.g. Moore's law or Koomey's law

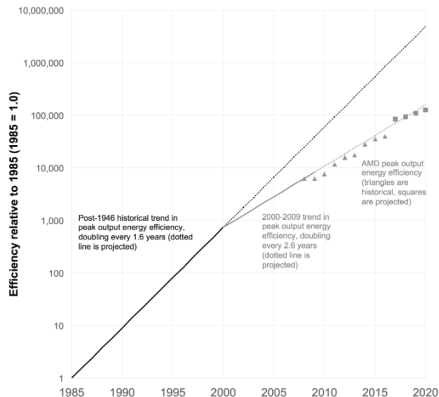


Figure 1: Peak output energy efficiency of computing, historical and projected

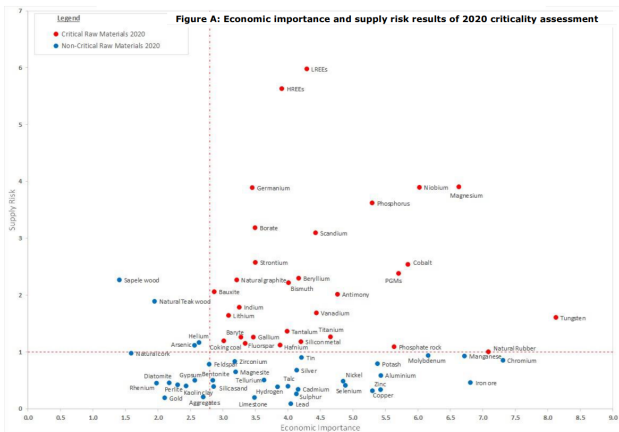
[Koomey and Naffziger, 2016]

Do we have a choice?

Limits to growth

Environmental

- ▶ resource (material and energy) depletion
- ▶ climate change...



source : [Blengini et al., 2020]

How to implement sobriety?

The Shift Project's recommendations for companies, organizations and governments

1. Adopt digital **sobriety as a principle of action**
2. **Inform** and spread awareness
3. Mobilize the lever of **public purchasing**
4. Allow companies and organizations to **manage the environmental dimension** of their digital transition
5. Carry out a **carbon balance of digital projects** to facilitate their prioritization
6. Improve consideration of the **systemic dimensions** of digital technology
7. Work at the **European scale** and with **international organizations**

How to implement sobriety?

As an individual

- ▶ acquisition
 - ▶ second-hand acquisition
 - ▶ use responsible criteria: repairability, recycling potential, energy use, local...



How to implement sobriety?

As an individual

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 - ▶ second-hand acquisition
 - ▶ use responsible criteria: repairability, recycling potential, energy use, local...
- ▶ use less
 - ▶ material: buy less often, make equipments last longer, use responsible software...
 - ▶ energy: turn off equipments, use energy-saving modes...
 - ▶ data storage and transfer



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As an individual

- ▶ acquisition
 - ▶ second-hand acquisition
 - ▶ use responsible criteria: repairability, recycling potential, energy use, local...
- ▶ use less
 - ▶ material: buy less often, make equipments last longer, use responsible software...
 - ▶ energy: turn off equipments, use energy-saving modes...
 - ▶ data storage and transfer
- ▶ end of life
 - ▶ donate equipment still in good condition, have it recycled by approved organizations



References I



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