STUDY

Environmental footprint of the digital world

- Third edition, 2025 -

ASSOCIATION green it

Authors

Study: Environmental impacts of digital technology in the world

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Summary

All over the world, digital uses are gaining ground. But what are the impacts of the digital environment, on a global scale, today? This study assesses the **environmental impacts of digital technology on a global scale**. The results of this study highlight that digital technology is anything but immaterial, with around **6 active devices per Internet user**. Thus, if digital technology were a country, it would emit as much Greenhouse Gases (GHGs) as **twice the emissions of Canada** or **5.5 times the emissions of France**.

Among the indicators that stand out in particular, the **contribution of digital technology to the depletion of mineral and metal resources stands out**, surpassing the global warming potential indicator for the first time in the order of the indicators that carry the most weight.[1]

Digital technology contributes to tensions over resources and does not exist without these minerals and metals, which are finite resources, on which other sectors such as health, energy infrastructure and defense also depend. Making excessive use of digital technology thus contributes to jeopardizing the availability of these resources for future generations and the energy transition.[2]

This example shows the usefulness of a multi**-criteria Life Cycle Assessment** (LCA), the evaluation method used for this study. Using a multi-criteria analysis thus makes it possible to **avoid causing pollution transfers due to a lack of consideration of an indicator in decision-making**. As such, it is hoped that social impacts, such as human exploitation, can also one day be considered quantitatively for these assessments.

At the global level, unlike the European and French scales, the use phase has proportionally more impact than the manufacturing phase, except for the contribution to the depletion of mineral and metal resources and ionizing radiation emissions, indicators for which the manufacturing phase remains predominant.

This study also highlights the relationship between the impacts of digital technology and the sustainable budget to remain below the critical threshold of planetary boundaries. Thus, **digital technology consumes 40% of an Internet user's sustainable annual budget, a sustainable budget to stay below 1.5°C of global warming** in accordance with the Paris Agreement.[3] This clearly appears disproportionate in relation to the essential needs: food, drink, housing, etc. The trajectory of digital technology is strongly trending towards a **systemic increase in the number of devices, uses, and the number of users, at the expense of environmental consequences**. This is particularly noteworthy when it comes to user equipment, **televisions**, **smartphones**, and **connected objects**. Similarly, the meteoric rise of **generative AI** in a short period of time is already visible in the environmental impacts of digital technology, totalling, **for servers configured for AI alone, between 1% and 5% of digital impacts depending on the indicators** (4% for GHG emissions).

Faced with these observations, our recommendations concerning the reduction of environmental impacts focus on **digital sufficiency** and the mechanisms to implement it, both on the reduction of impacts related to manufacturing and related to the use of digital equipment and services: **reassessing and limiting our uses, producing less equipment, and making them last longer.** These general recommendations are the subject of a dedicated section, which includes more specific ones intended for public authorities, organizations and citizens.

1 Despite a weighting method that is much more favourable to highlighting the potential for global warming. See the results of the weighting standardization and the weighting factors of the European Commission in the PEF methodology, dealt with in the appendix.

2 See the https://www.mineralinfo.fr/fr/substances?title=&field_usages_target_id=151&sort_by=field_criticite_a_plat_value website https://www.mineralinfo.fr/fr/substances?title=&field_usages_target_id=151&sort_by=field_criticite_a_plat_value, or the USGS data. To take an example on which many sectors such as digital technology depend: if nickel production in 2023 remained the same every year, there would be 36 years of nickel left before the known global reserves are depleted (calculated from https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-nickel.pdf).

3 The Paris Agreement | UNFCCC, https://unfccc.int/fr/a-propos-des-ndcs/l-accord-de-paris

Thanks

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- Gaël Duez (Green IO) for the highlighting of the study at Green IO Paris on December 5th, 2024.
- Our loved ones who supported us during the writing of the study.

Support us

This study was led and carried out entirely voluntarily by the members of the Green IT association. The association is financed solely by donations, memberships and calls for projects to which it responds.

To continue our actions (studies, advocacy, raising awareness among the general public, development of resources and free tools...), we need your support!

I make a donation

The Green IT association is recognized as being of general interest, *which allows you to deduct 66% of the amount of your donation from your taxes as an individual and 60% as a company.*

Join the association

The members of the association contribute their time and skills to its public awareness, research and advocacy projects. Membership is open only to natural persons. Legal entities that wish to support us can make a donation or contact us to set up a skills-based sponsorship agreement.

GLOSSARY

Sensitivity analysis: A type of analysis that is part of the impact interpretation phase of a life cycle assessment. It consists of varying a parameter (quantity, lifespan, mass, etc.) to study the influence on the results. This makes it possible to determine what the dimensioning parameters are and to estimate the uncertainty on the results and to strengthen the reliability of the study as a whole.

Life Cycle Assessment (LCA): A standardized assessment method for carrying out a multi-criteria and multi-stage environmental assessment of a system (product, service, company or process) over its entire life cycle (design, manufacture, use, end of life, etc.).

Application Specific Integrated Circuit (ASIC): An integrated circuit that is specialized for a specific type of application and cannot be reprogrammed once manufactured.

Blockchain: A blockchain is a digital ledger that securely records transaction data across a distributed network of computers. Blockchain ensures data integrity due to its immutable nature resulting from cryptography and consensus mechanisms. Thus, once the information has been recorded, it cannot be modified retroactively. Blockchain is the foundation of cryptocurrency networks like Bitcoin and Ether.

TV box: external device connected to the TV allowing the use of multiple sources, cable or terrestrial wave, by satellite, or by internet (IPTV). Internet-connected equipment allows applications to be used to consume video services provided by streaming or VOD platforms.

Eco-design: A methodical approach that takes into consideration the environmental aspects of the design and development process with the aim of reducing negative environmental impacts throughout the life cycle of a product.

Final energy: The so-called "final" energy is that which is used to satisfy the needs of man.

Final energy consumption is equal to primary energy consumption minus all energy losses along the industrial chain.

Primary energy: Primary energy refers to the different sources of energy available in nature before transformation.

Feature phone: (also called basic mobile phone) A mobile phone limited to basic telephony functions, mainly telephone calls and sending and receiving SMS and managing a phonebook. Some multimedia features (photography, MP3 player, etc.) may also be available.

Field-Programmable Gate Array (FPGA): An integrated circuit made to be (re)programmed by the user after it has been manufactured.

Greenhouse gases (GHGs): Any gas that contributes to the greenhouse effect, by absorbing infrared radiation. For example, carbon dioxide, methane, water, etc.

Hyperscaler: Large-scale computing center specializing in delivering large amounts of computing power and storage capacity to organizations and individuals around the world.

Internet of Things (IoT) The interconnection between the Internet and physical objects, places and environments. Equipment connected to the Internet is also called connected objects.

Artificial Intelligence (AI): All techniques aimed at creating machines and computer programs capable of simulating human intelligence capabilities (creation, reasoning, learning, etc.).

Electricity mix: The electricity mix represents the composition of primary, renewable and non-renewable energy sources used in the production of electricity in a given geographical region.

Smartphone: A category of mobile phone that can perform many of the features of a computer, typically having a touchscreen interface, Internet access from Wi-Fi and mobile networks, a GPS connection, and an operating system (OS) that allows downloadable applications to run.

AI-configured server: A conventional server unit, prepared to accommodate GPU units and a large amount of memory, which are used intensively in specific processing for complex algorithms used in artificial intelligence techniques. This type of unit is also suitable to provide the higher power needed.

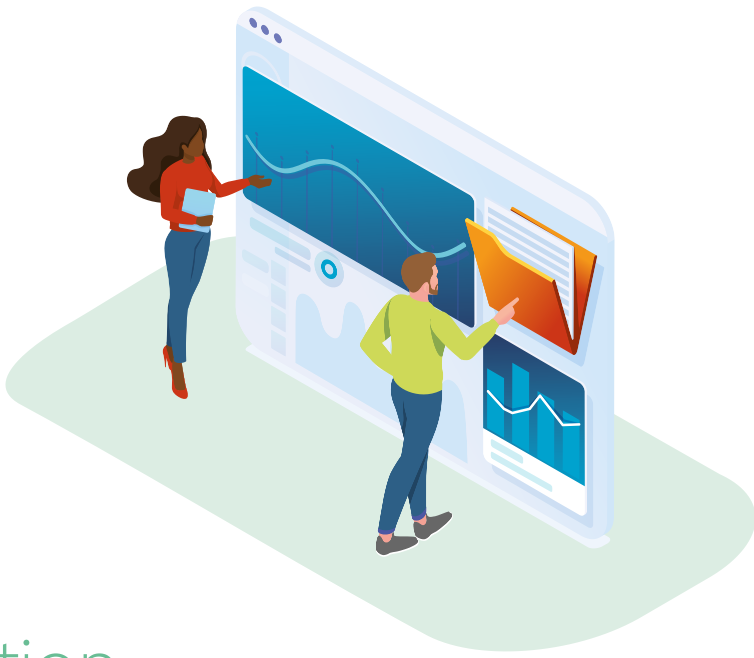
Tonne eq. CO_2: CO_2 equivalent emissions are the amount of carbon dioxide (CO_2) emitted that would cause the same integrated radiative forcing, for a given time horizon, as a quantity emitted of a single or more greenhouse gases. (source: IPCC)

ACRONYMES

Acronyme	Signification
ACV	Life Cycle Assessment
ADEME	Agency for Ecological Transition (France)
ADSL	Asymmetric Digital Subscriber Line
ASIC	Application Specific Integrated Circuit
FPGA	Field-Programmable Gate Array
FTTH	Fiber To The Home
GHG	Greenhouse Gases
GPU	Graphic Processor Unit
GSMA	Global System for Mobile Communications Association
AI	Artificial intelligence
ICV	Life Cycle Inventory
ICT	Information and Communication Technology
Iot	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
LCD	Liquid Crystal Display
OLED	Organic Light-Emitted Display / Organic Light-Emitting Diode
PEF	Product Environmental Footprint
Sim card	Subscriber Identity/Identification Module

Summary

Summary



1 Introduction

1.1 Preamble

This study was carried out voluntarily by the authors, as part of the **Green IT association**. This is the third edition of the "Global Digital Environmental Footprint" (EENM) study, published in its first version in 2010, and in its second edition in 2019.

The Green IT association provides the general public with quality studies allowing anyone to **better know and understand** the **environmental impacts of digital technology** and their **consequences**. To date, the 2019 Global Digital Environmental Footprint (EENM 2019) study and the 2025 Global Digital Environmental Impacts (EENM 2025) study are the only multi-criteria life cycle assessments (LCAs) to estimate the overall global digital footprint.

As the categories and impact factors are different between 2019 and 2023, we refrain from any direct comparison between the results of these two studies. Similarly, the sources used to estimate equipment stock may vary from study to study and limit comparability between the 2019 study and the 2025 study.

1.2 By the way

The Green IT association is a **non-profit association of general interest**, which works every day for better **knowledge, consideration and reduction of the environmental impacts of digital technology**.

To do this, the members of the association carry out awareness-raising activities for the general public, tools and repositories that are freely accessible and made available to all, advocacy with institutions in France and Europe, and carry out open access studies such as this one.

The members of the association are not legal persons but only natural persons. The association does not represent the interests of any professional organization, private or public, or economic or political actor.

Within the association, the **Study Group** brings together the most expert members in the assessment of the environmental impacts of digital technology, in order to carry out studies such as this one on a voluntary basis.

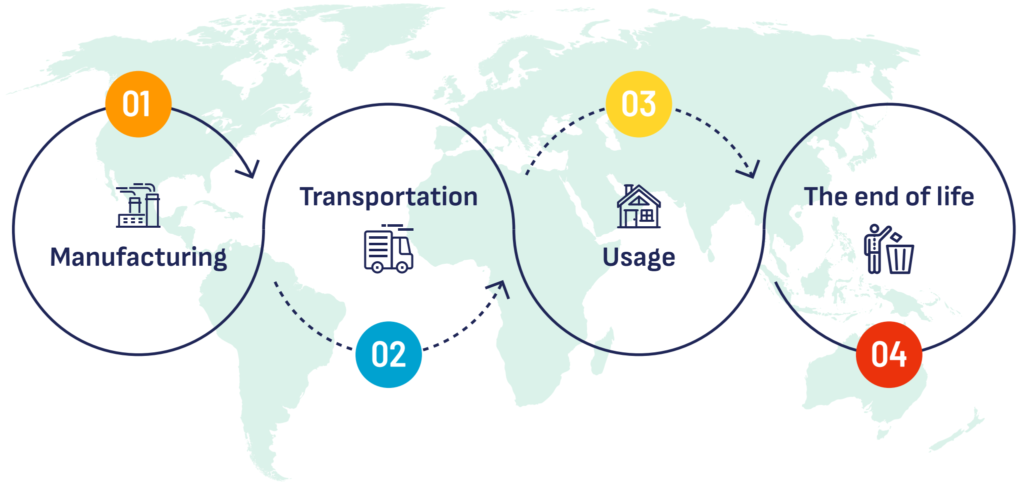
The Green IT association was created in March 2022 from the Green IT.fr collective, which has been in existence since 2004. The association is made up of volunteers and experts who act for a society where digital technology is used in a sustainable way.

To find out more about the association: https://greenit.eco/qui-sommes-nous/

1.3 Methodology

This assessment of the environmental impacts of digital technology on a global scale was carried out according to the **simplified** Life Cycle Assessment **(LCA) methodology**, as close as possible to the ISO 14040/44 standards[4] and the PEF/OEF methodology[5] of the European Commission.

Life Cycle Assessment is a method of measuring the **environmental impacts of products or services**. It is characterized by taking into account the impacts over the entire **life cycle**. The following steps are usually distinguished:



In addition, this LCA is a **multi-criteria analysis**, i.e. it takes into account several environmental impacts. The indicators considered in this study are listed in the next section.

The functional unit is the reference unit that quantifies the services or products studied. The function studied is the provision of digital services around the world, used by consumers, private and public organizations for one year. Due to this wide diversity of use, it is difficult, if not impossible, to classify the use of digital services worldwide into functional units.

In this case, the concept of functional unit is replaced by a declared unit:

« Equipment and systems related to global digital services for one year. »

And at the individual level:

« Equipment and systems related to global digital services for one year and reported to an Internet user. »

4 https://www.iso.org/standard/37456.html and https://www.iso.org/standard/38498.html

5 Product Environmental Footprint (PEF), https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html

The inventory of the quantities and uses of the equipment was carried out on the basis of the latest data available quantifying the **active stock in 2023**. In other words, all existing equipment and systems in 2023 are considered, not just purchases made in 2023.

The scope studied is the one defined in the second edition of the study: "All electronic equipment that uses binary data".

The classification usually used in the assessment of the environmental impacts of digital technology follows 3 "Tiers"[6]:

Tier I
User equipment
These are all the terminals that users use as an interface with the digital channel;

Tier II
Networks
These are all the networks, fixed, mobile and backbone (the backbone of the network) that allow digital data to circulate.

Tier III
Data centers
These are suitable and secure places for hosting computer equipment allowing the processing and storage of digital data.

The detailed methodology and assumptions made are available in section 5.2 in the appendix.

1.4 Environmental and flow indicators used

In this study, the 16 environmental indicators recommended in the PEF method[7] have been calculated. However, for the readability of the study, **7 environmental indicators** are selected. They are presented in Table 1. They correspond to at least 80 % of the total impacts, in accordance with the PEF standardization and weighting method for defining the environmental indicators. The **most important things to consider** with regard to the scope of the study. More details on the methodology for selecting these indicators are given in the 5.2.6.

Environmental Indicator Name	Acronym and unit	Weight in the footprint
Global warming potential	GWP (kg CO_2 eq.)	23,25 %
Resource Use, Minerals and Metals	EPDA (kg Sb eq.)	23,71 %
Resource Use, fossils	ADPf (MJ)	15,62 %
Eutrophication, freshwater	Epf (kg P eq.)	5,71 %
Particulate matter, human health	PM (Disease Occurrence)	5,82 %

6 *This notion of "Tier" is to be understood in the sense of "level", in English, like the bricks that make up the digital by communicating with each other, and not in the sense of "tiers" in the French sense of third party or 1/3 of a quantity.*

7 *https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html*

	Acidification	AP (mol H+ eq.)	5,42 %
	Ionising radiation, human health	IR (kBq U235 eq.)	5,52 %

Table 1: *List of environmental indicators included in the study and respective weight in the overall footprint*

These environmental indicators are supplemented by flow indicators. Unlike environmental indicators, which report on the effects on the environment, flow indicators quantify the quantities of material and energy used.

The flow indicator considered in this study is the **total primary energy consumption** (TPE), in MJ.

2 Presentation of the results

2.1 Digital in the world in 2023

Digital **technology** has now become **essential** in our daily lives and in our professional uses: whether it is payment systems, our means of communication or entertainment, digital technology is omnipresent. Contrary to what the terms "cloud" or "dematerialization" evoke, digital technology is **very material**, both in terms of the **quantity of equipment** and **the resources** needed to make it work and in terms of **the pollution** and other **effects generated** on the environment.

As with the rest of our activities, it is necessary to **reduce the impacts of digital technology** globally, in particular in order to meet the objectives of international agreements - such as the **Paris agreements**, the objective of which is to limit the increase in the global average temperature to 1.5°C above pre-industrial levels.[8] Similarly, the environmental impacts of digital technology are very visible when compared to **planetary boundaries**: these limits are broken down into an annual budget to be respected on various indicators so that the human species can continue to live. There is therefore a strong challenge in **knowing and reducing the environmental impacts of digital technology** in order to remain in a sustainable environment for human survival.

2.1.1 Quantities of equipment and number of Internet users

In 2023, the number of internet users is estimated at 5.35 billion people[9]. This value is considered to represent the number of digital users.

*In 2023, there were about **30.5 billion devices** used for **5.35 billion Internet users**, or **nearly 6 devices per Internet user**.*

8 The Paris Agreement | UNFCCC, https://unfccc.int/fr/a-propos-des-ndcs/l-accord-de-paris

9 2024 Global Digital Report, https://www.meltwater.com/en/global-digital-trends

This figure was estimated at 32 billion devices for 4.1 billion people with Internet access in 2019, or about 8 devices per Internet user. This difference in the number of devices per Internet user is mainly due to a difference in sources in the estimation of the number of connected objects (IoT) in the world. The estimate made for this study is based on 2 different but concordant sources, making the value relatively reliable. The quantity of IoT equipment was analysed for sensitivity at the 5.1.3 in the appendix.

Excluding IoT, there has been a 13.8% increase in the number of devices in 4 years (+3.3% annualized), while at the same time, the **number of Internet users has jumped** by more than 30%. This difference is explained by the fact that new Internet users, mainly located in Central Asian and African countries, own fewer devices than older Internet users. With the largest pool of new internet users in these regions of the world, we can expect this trend to continue: an **increase in the number of internet users and total loadouts**, accompanied by a **decline in the average gear rate per internet user**.

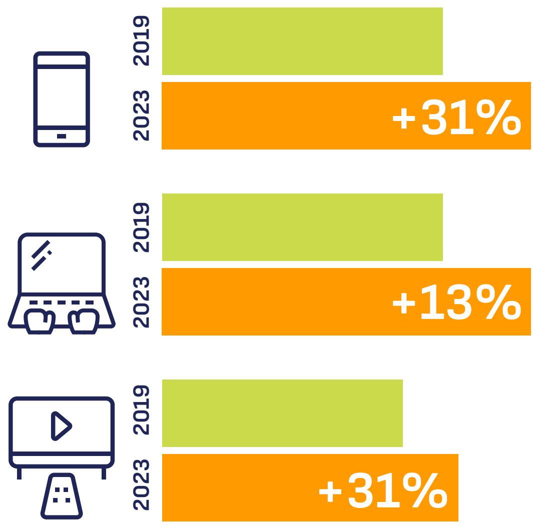
2.1.2 Most used devices by Internet users

*The **most widely used devices** in the world are **smartphones** (4.6 billion), **monitors** and **televisions** (2.4 billion), landline phones (1.7 billion) and feature phones (1 billion).*

In addition, there are about 15.7 billion connected objects (IoT) on Earth in 2023[10].

Overall, there has been very strong growth in the number of smartphones, with growth of more than 31% in 4 years (up 1.1 billion in 2023 compared to 3.5 billion in 2019). The number of televisions in service also increased in the same proportion, thanks in particular to the extension of their useful life and a temporary boost in sales during the Covid-19 period. As for computers, there was a slight increase of 5% in their total number between 2019 and 2023 (to reach 1.5 billion) but a clear increase in the share of laptops compared to desktop computers, from 56% in 2019 to 69% in 2023. This distinction is important to make because these two types of equipment do not have the same characteristics or the same lifespan and therefore not the same environmental impacts.

The evolution of the technical characteristics of the various equipment (increase in size, etc.) is analysed and discussed in section 2.5.



2.1.3 Networks

The **network** makes it possible to **connect digital equipment to each** other as well as to the data centers. A distinction is made between fixed networks (ADSL and fibre optics, for example) and mobile networks (2G / 3G / 4G / 5G). These are made up of many pieces of equipment that manage data exchanges.

The **number of fixed network subscriptions** is 1.5 billion, compared to 7 billion for the mobile network, i.e. about 4.7 times more. This difference is due to the fact that the same fixed network subscription allows several users to be served (typically one xDSL / FTTH subscription per household or office). In addition, a connection to mobile networks simply requires the acquisition of a SIM card and a connected terminal. Connecting to fixed networks requires connection to a wired installation and an internet box, which is more expensive and complex. This is particularly true in countries where electricity and telecoms infrastructures cover very partially the territory.

The 7 billion mobile subscriptions can be compared to the number of mobile phones: 5.6 billion (smartphones and feature phones). The differ-

10 *See Methodological appendix concerning the connected objects included in the scope of this study. Connected objects, our previous study, was estimated at 19 billion in 2019. This discrepancy is due to a difference in the inventory source identifying the number of IoT devices. The source used in this study estimates that there were 10 billion IoT devices in 2019.*

ence can be explained by the fact that several SIM cards can be installed in a single smartphone, for professional and personal aspects for example. In addition, other user equipment such as tablets, or certain connected equipment (cars for example), can be equipped with SIM cards.

Conversely, fixed networks have 3 times more **data exchanged** than mobile networks. The fixed network, in particular fibre, provides higher-speed internet access that allows for more energy-consuming uses[11] (professional connections, streaming, etc.).

The number of subscriptions and the amounts of data exchanged on the networks are summarized in the following table:

	Number of subscriptions in 2023	Amount of data exchanged in 2023 (GB)
Fixed network	1.5 billion	4500 billion
Mobile network	$7.0 billion	1500 billion

Table 2: *Number of subscriptions and amount of data exchanged on fixed and mobile networks in 2023*

The number of Internet users is 5.35 billion in 2023, for almost 6 billion TB (Tera, or 6,000 billion GB) of data transferred on fixed and mobile networks combined. This gives an average of 3,000 GB of data exchanged in one year per Internet user on the fixed network and 214 GB on the mobile network.

2.1.4 Data centres

Data **centres** store and calculate user-generated information. With the current rise of cloud services, blockchain-based systems, and more recently generative artificial intelligence, these centres are hosting increasingly large amounts of data, and their computing power is increasing considerably.

In 2023, all activities combined, there were approximately **79.5 million servers** accompanied by more than **8.2 million network equipment** dedicated to data centres. The electricity consumption of these centres is estimated at **506 TWh** per year, which is about as much as the consumption of a country like Germany[12]. Of these 506 TWh, nearly 190 TWh, or about 37%, are devoted to so-called "non-IT" equipment (batteries, inverters, thermal management systems here called "air conditioning", etc.).

11 Cisco Annual Internet Report (2018–2023) White Paper, https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

12 Total electricity consumption of 515.55 TWh in Germany in 2023: https://lowcarbonpower.org/fr/region/Allemagne

2.2 Environmental and health impacts

2.2.1 Globally

The environmental and health impacts of digital technology in the world over 1 year are presented in the following table:

Indicator Name	Acronym and unit	Global footprint in 2023
Global warming potential	GWP (kg CO_2 eq.)	1,832 billion
Resource Use, Minerals and Metals	EPDA (kg Sb eq.)	41 million
Resource use, fossils	ADPf (MJ)	24,995 billion
Eutrophication, freshwater	Epf (kg P eq.)	673 million
Particulate matter, human health	PM (Disease Occurrence)	79 111
Acidification	AP (mol H+ eq.)	9,947 million
Ionising radiation, human health	IR (kBq U_{235} eq.)	953 billion
Total Primary Energy	TPE (GM)	28,634 billion

Table 3: *Global digital footprint in 2023 on the selected environmental indicators*

Digital-related greenhouse gas (GHG) emissions are 1.8 billion tonnes of CO_2 eq. CO_2[13]. Thus, on the indicator concerning the potential for global warming, global digital technology is equivalent to about 3 times the emissions of South Korea, more than 2 times those of Canada or Saudi Arabia, or about 5.5 times those of France[14].

In 2023, global digital technology accounts for **3.4% of global GHG emissions**. Between 2019 and 2023, global GHG emissions across all sectors increased by more than 1.9%.[15] The global impact of digital has followed the same growth trend. This is why the share of digital technology in the global footprint seems to remain stable, despite an increase in impacts.

Some **Sensitivity analyses** are carried out (see section 5.1.3 in the appendix) to assess the uncertainty interval by varying certain parameters: they show that digital-related GHG emissions are between 1.692 and 1.962 billion tonnes of CO_2 eq. CO_2 The lifespans of screens and TVs as well as the power consumption of AI servers are the elements that have the most impact on this variation.

13 *As an indication, this figure amounted to 1.4 billion tonnes of CO_2 eq. CO_2 in 2019. However, a direct comparison is not appropriate, as the two figures are the result of different valuation methodologies*

14 *CO_2 and Greenhouse Gas Emissions - Our World in Data, https://ourworldindata.org/co₂-and-greenhouse-gas-emissions*

15 *Global GHG emissions increased by 52.80 billion tonnes of CO_2 eq. CO_2 in 2019 at 53.82 billion tonnes CO_2 eq. CO_2 in 2023. https://ourworldindata.org/co₂-and-greenhouse-gas-emissions*

2.2.2 At the individual level

By relating the overall impacts to the number of Internet users[16], we obtain the following impacts for an Internet user over 1 year:

Indicator Name		Acronym and unit	Global footprint in 2023
	Global warming potential	GWP (kg CO_2 eq.)	342,355
	Resource Use, Minerals and Metals	EPDA (kg Sb eq.)	0,008
	Resource use, fossils	ADPf (MJ)	4 671,940
	Eutrophication, freshwater	Epf (kg P eq.)	0,126
	Particulate matter, human health	PM (Disease Occurrence)	0,0015 %
	Acidification	AP (mol H+ eq.)	1,859
	Ionising radiation, human health	IR (kBq U_{235} eq.)	178,139
	Total Primary Energy	TPE (GM)	5 352,130

Table 4: *Digital footprint per Internet user in 2023 on the environmental indicators selected*

In comparison, this corresponds for each Internet user over 1 year, to:

- **For the use of resources, minerals and metals:**
  about 40 tons of excavated soil[17] or the equivalent of ores in 3 smartphones;
- **For the global warming potential:**
  about 3,500 km travelled by car[18] ;
- **For primary energy consumption:**
  1 radiator of 1,000 Watts, for about 20 days[19].

16 *5.35 billion, as identified above in section 2.1.3.*

17 *Using a clarke value of 2.00E-04 kg eq. Sb per ton of excavated soil.*

18 *With the assumption of an emission of 97 g of CO_2 per km travelled*

19 *Considering 1 1,000 Watt radiator on 24 hours a day and a ratio of 3 between 1kWh of primary energy and 1kWh of final energy.*

2.3 Comparison to planetary boundaries

2.3.1 Definition and methodology

There are nine **planetary boundaries**, eight of which have been quantified by researchers and six have already been crossed. The Figure below summarizes their status at the end of 2023. The dotted circle represents the estimate of the safe zone boundaries, and the coloured areas represent the estimate of their condition, with the orange or red colour each representing a greater exceedance.

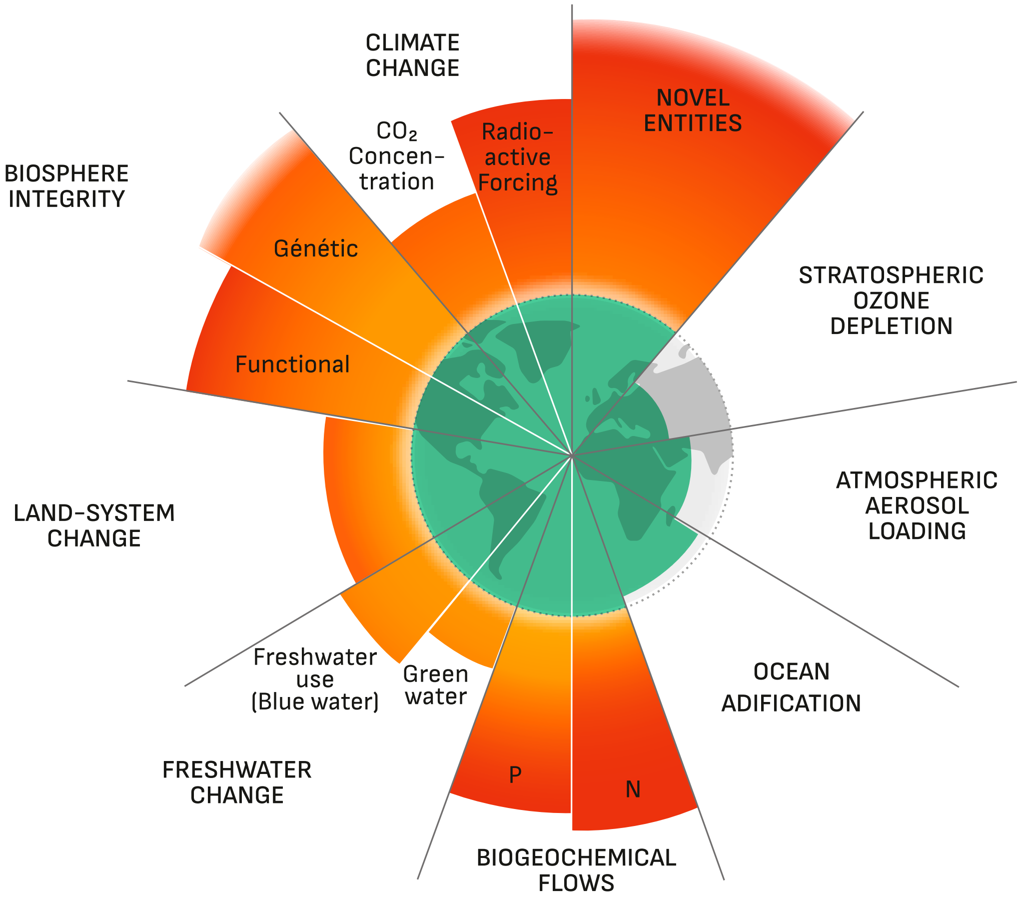


Figure 1: *Illustration of the Nine Planetary Boundaries and Their Level of Exceeding*[20]

Planetary **boundaries** are a concept that translates the limits that must be respected in order for the human species to continue to live on earth. The concept is now consensual ("Earth Overshoot Day"), however disagreements persist among scientists on the exact numerical values of these limits. Although the 16 PEF indicators do not correspond as such to the 9 planetary boundaries, a methodology is proposed by the Joint Research Center (JRC),[21] the European Union's science and knowledge service, to report the results of a multi-criteria PEF LCA to planetary boundaries[22]. It is applied below.

This approach makes it possible to compare the results of environmental impacts at planetary boundaries, to estimate the extent to which the pressure exerted by human activities on the environment respects the limits of a secure framework or greatly exceeds sustainable limits, posing a great risk to the

20 Earth beyond six of nine planetary boundaries | Science Advances, https://www.science.org/doi/10.1126/sciadv.adh2458

21 Joint Research Centre, https://commission.europa.eu/about/departments-and-executive-agencies/joint-research-centre_en

22 European Commission, Joint Research Centre, Castellani, V., Cerutti, A., Beylot, A., Sanyé-Mengual, E., et al., Consumption and consumer footprint: methodology and results: indicators and assessment of the environmental impact of European consumption, Publications Office, 2019, https://data.europa.eu/doi/10.2760/98570 § Figure 71, page 134 survival of the human species. To do this, an identical "sustainable budget" is allocated to each person, per year, for each environmental indicator.

In other words, comparing the results of a multi-criteria LCA at planetary boundaries makes it possible to realize **the proportion that the measured activity takes on the limited budget to be respected to allow humanity to live in sustainable conditions integrating all of our activities**.

2.3.2 On the scale of all humans

Le tableau ci-dessous donne le pourcentage des limites planétaires atteint avec les indicateurs environnementaux liés au numérique, pour chaque humain·e. Le budget est réparti à l'identique pour l'ensemble des êtres humains vivant en 2023 indifféremment de son usage du numérique :

Environmental Indicator Name	Acronym and unit	Global footprint	% limit per human
Global warming potential	GWP (kg CO_2 eq.)	1 831 601 700 281	26,9 %
Resource Use, Minerals and Metals	ADPe (kg Sb eq.)	40 917 068	18,7 %
Particulate matter, human health	PM (Disease Occurrence)	79 111	15,3 %
Eutrophication, freshwater	Epf (kg P eq.)	672 955 785	11,6 %
Resource use, fossils	ADPf (MJ)	24 994 879 417 990	11,2 %
Ecotoxicity, Freshwater	CTUe (CTUe)	12 597 943 615 723	9,6 %
Photochemical ozone formation, human health	POCP (kg NMVOC eq.)	5 430 140 022	1,3 %
Acidification	AP (mol H+ eq.)	9 947 464 423	1,0 %
Eutrophication, marine	Epm (kg N eq.)	1 889 122 942	0,9 %
Human toxicity, non-cancerous	CTUh-nc (CTUh)	20 717	0,5 %
Eutrophication, terrestrial	Ept (mol N eq.)	17 985 028 874	0,0 %
Human toxicity, cancerous	CTUh-c (CTUh)	2 108	0,0 %
Ionizing radiation, human health	IR (kBq U_{235} eq.)	953 044 536 804	0,0 %
Ozone depletion	ODP (kg CFC-11 eq.)	86 296	0,0 %

***Table 5:** Percentage of planetary limit per human reached with the environmental impacts of digital technology*

The comparison with planetary boundaries mainly highlights the following 6 indicators for the environmental impacts of digital technology at the global level:

1. Global warming potential
2. Resource Use, Minerals and Metals
3. Particulate Emissions
4. Eutrophication of freshwater
5. Resource use, fossils
6. Ecotoxicity on freshwater

In 2023, the world's digital sector alone consumes 27% of the annual planetary sustainable budget to stay below 1.5°C of global warming.

Similarly, the entire global digital sector consumes 18.7% of the annual global sustainable budget in terms of the use of mineral and metal resources, and 15.3% of the planetary sustainable budget in terms of fine particle emissions.

2.3.3 At the level of Internet users

However, it is possible to attribute the impacts of the activity analysed (in this case, the global digital world) only to its users and not to all living human beings. In the table below, the planetary boundaries are related to the total budget of the 5.35 billion Internet users,[23] i.e. without affecting the budget of non-Internet users:

Environmental Indicator Name	Acronym and unit	Global footprint	% limit per human
Global warming potential	GWP (kg CO_2 eq.)	1 831 601 700 281	40,3 %
Resource Use, Minerals and Metals	ADPe (kg Sb eq.)	40 917 068	28,0 %
Particulate matter, human health	PM (Disease Occurrence)	79 111	23,0 %
Eutrophication, freshwater	Epf (kg P eq.)	672 955 785	17,3 %
Resource use, fossils	ADPf (MJ)	24 994 879 417 990	16,7 %
Ecotoxicity, Freshwater	CTUe (CTUe)	12 597 943 615 723	14,4 %
Photochemical ozone formation, human health	POCP (kg NMVOC eq.)	5 430 140 022	2,0 %
Acidification	AP (mol H+ eq.)	9 947 464 423	1,5 %
Eutrophication, marine	Epm (kg N eq.)	1 889 122 942	1,4 %
Human toxicity, non-cancerous	CTUh-nc (CTUh)	20 717	0,8 %
Eutrophication, terrestrial	Ept (mol N eq.)	17 985 028 874	0,4 %
Human toxicity, cancerous	CTUh-c (CTUh)	2 108	0,3 %

23 5.35 billion Internet users in 2023

	Ionizing radiation, human health	IR (kBq U_{235} eq.)	953 044 536 804	0,3 %
	Ozone depletion	ODP (kg CFC-11 eq.)	86 296	0,0 %

***Table 6:** Percentage of planetary limit per Internet user reached with the environmental impacts of digital technology*

Thus, in 2023, the annual use of global digital technology consumes 40% of the annual sustainable GHG budget per Internet user to stay below 1.5°C of global warming.

Similarly, global digital technology consumes 28% of the annual sustainable budget per Internet user in terms of the depletion of mineral and metal resources. It should be noted that ecotoxicity on freshwater, an indicator that does not appear among the most relevant environmental indicators according to the PEF's weighting standardisation method, stands out at 14.4% of the sustainable budget per Internet user according to the planetary boundaries method, which is quite substantial.

The fact that digital technology alone consumes more than 40% of the sustainable GHG budget of Internet users demonstrates the enormous role that digital technology plays in our lives today, *and the flagrant disproportion between, on the one hand, the image of a «virtual» digital technology that has little or no impact on the environment, and on the other hand, the proportion of impacts in relation to a sustainable budget.*

2.4 Distribution of environmental and health impacts

2.4.1 Depending on the Tier

The environmental and health impacts related to digital technology are detailed according to the 3 tiers of the digital architecture:

1. Tier I: User devices
2. Tier II: Networks
3. Tier III: Data centers

The breakdown of impacts by Tier is shown in the following table:

	GWP (kg CO_2 eq.)	ADPe (kg Sb eq.)	ADPf (MJ)	Epf (kg P eq.)	PM (Disease Occur-rence)	AP (mol H^+ eq.)	IR (kBq U_{235} eq.)	TPE (GJ)
Tier I – User devices	**54 %**	**72%**	**53 %**	**48 %**	**52 %**	**55 %**	**71 %**	**53 %**
Tier II – Networks	23 %	15 %	24 %	26 %	25 %	23 %	21 %	25 %
Tier III – Data Centers	23%	13 %	22 %	26 %	23 %	22 %	8 %	21 %

***Table 7:** Distribution of the environmental impacts of digital technology for each of the 3 Tiers*

User devices is the main source of digital impacts worldwide, between 48 and 72% depending on the indicators. Networks account for between 15 and 26% of impacts, while data centers account for between 8 and 26% of impacts.

For most of the indicators, a very similar distribution can be observed on average around 57%, 23% and 20% for Tier I, II and III respectively. For two indicators, however, (the use of resources, minerals and metals and ionizing radiation), this distribution is much more uneven, with about 70% of the impacts coming from Tier I.

To better understand the distribution of these impacts, it is necessary to study it according to the life cycle, detailed in the next section.

User devices (Tier I) accounts for more than half of the environmental impacts of digital technology. The rest of the impacts are spread between networks (Tier II) and data centers (Tier III).

Two indicators sand out: the depletion of abiotic mineral and metal resources and ionizing radiation emissions. For these, Tier I concentrates even more impacts than the average (more than 70%).

2.4.2 Depending on the stage of the life cycle

The environmental impacts broken down by Tier, according to life cycle stages, are presented in Figure 2. The Table 14 In the appendix, this distribution is presented in numerical form.

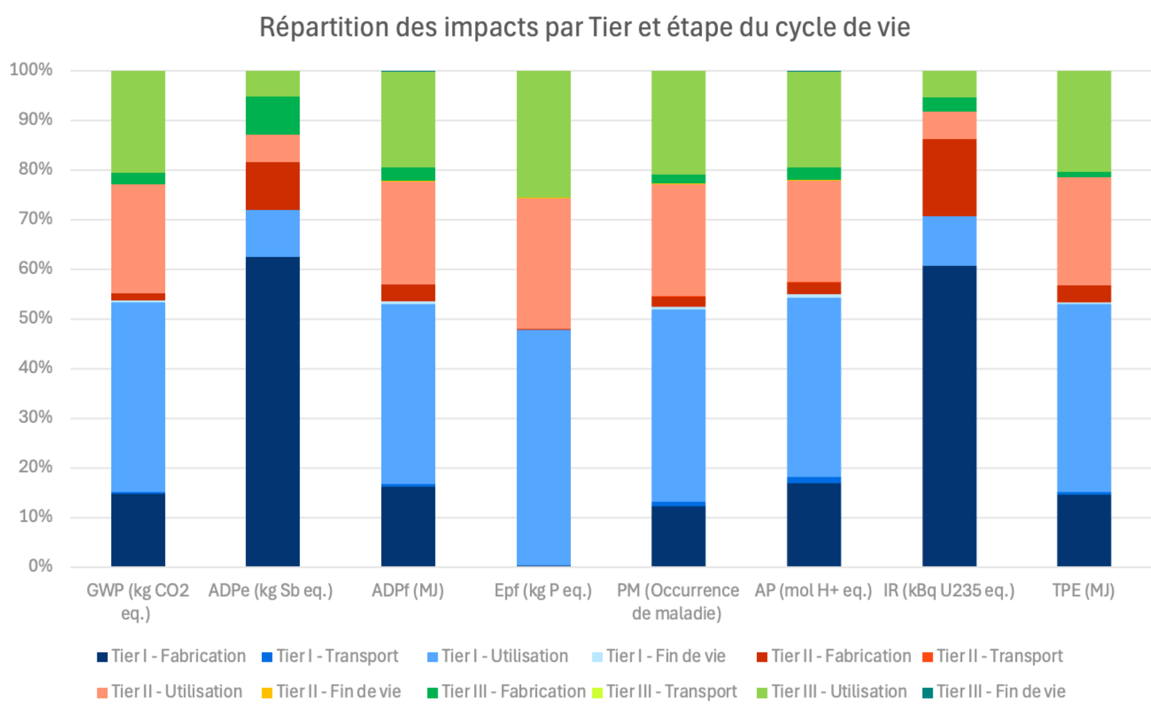


Figure 2: Distribution of the environmental impacts of digital technology by Tier and by stage of the life cycle

For **user devices**, the impacts are mainly divided between the **manufacturing and use phases**. For **networks and data centers**, the **use phase** concentrates the impacts. The difference in distribution between the Tiers is mainly explained by the **unit electricity consumption of the equipments**. Indeed, network or data center equipments have higher power than user devices and are often used 24 hours a day, unlike the majority of user devices (except IoT). In addition, the **global electricity mix** is still partly dependent on **fossil fuels**. **Thus, for Tier II and III, the share of impacts due to manufacturing is proportionally much lower than for use.**

This distribution of impacts differs for two environmental indicators, for which manufacturing represents proportionally a larger impact: the indicator of use of mineral and metal resources, and the indicator concerning ionizing radiation emissions.

Regarding the indicator of the use of mineral and metal resources, this is explained by the **extraction of the raw materials** necessary for the **manufacturing of equipments**, the overwhelming majority of which is part of Tier I. Indeed, the quantity of servers and network equipment is smaller compared to the quantity of user devices of all types: 30.5 billion user devices for 86 million computer devices in data centers, i.e. a proportion of 355 user devices for 1 computer equipment in data centers. Much of this impact in Tier I manufacturing comes from the manufacturing of televisions. A focus is made on the main contributing equipments in the next section.

The second indicator, the distribution of which varies, is that of the emission of ionizing radiation. In the same way, a large part of these impacts come from the manufacturing of user devices, and especially televisions.

The **distribution and end-of-life stages** represent, proportionally, a **negligible part** of the environmental impacts of digital technology, regardless of the Tier and the indicator observed.

Generally speaking, at the global level[24], the use phase is the main source of digital impacts.

Two indicators are exceptions in this respect: the use of mineral and metal resources and ionizing radiation emissions, for which the impact mainly takes place during the manufacturing phase.

24 *Mainly due to differences in the electricity mix, this general case valid at the global level is not the case at the European and French levels. See our Europe studies and the ADEME-ARCEP study for France.*

2.5 Detailed analysis

2.5.1 Focus on user equipment

User devices account for between 48 and 72% of total environmental impacts, depending on the indicator considered. The Figure 3 represents the distribution of Tier I impacts according to equipment categories. The Table 15 In the appendix, this distribution is presented in numerical form.

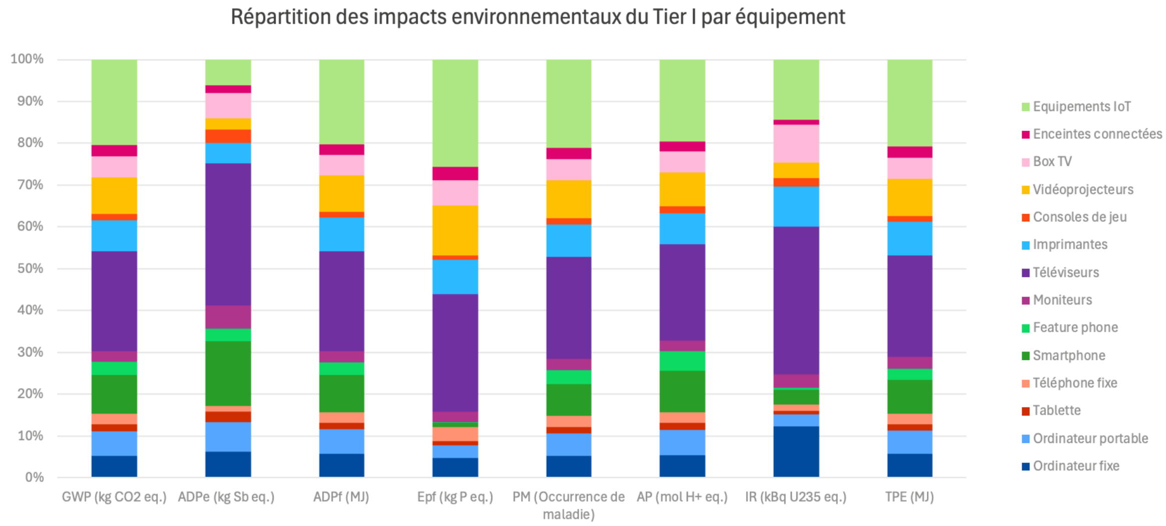


Figure 3: *Distribution of the environmental impacts of user devices (Tier I) by equipment category*

2.5.1.1 Televisions

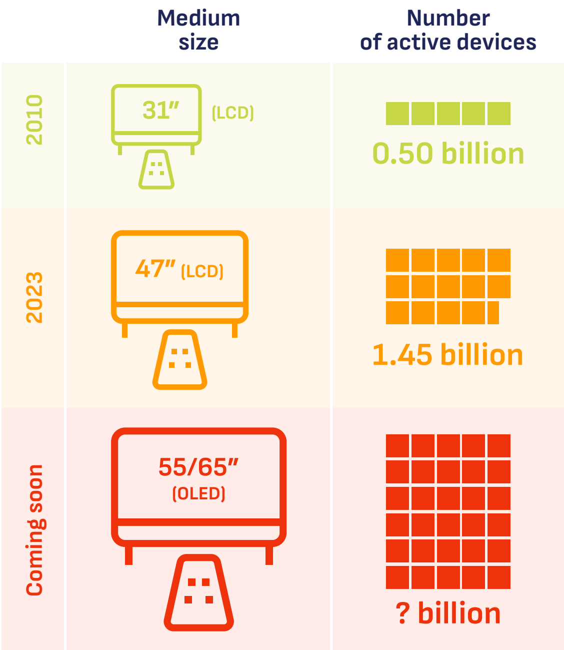
Televisions **(TVs)** and **TV boxes** are the **first category *of* user devices** with the **biggest impact**. They account for 16 to 31% of the world's environmental impacts, mainly on indicators of the use of mineral and metal resources and ionizing radiation emissions. This is mainly due to the conjunction of two factors: their number (1 TV for 3.6 Internet users or 1 TV for 5.3 people worldwide) and the continuous increase in the size of screens (diagonal of 47 inches on average for active stock, and even more so for screens currently sold).

Indeed, the environmental impacts of a television set increase in proportion to its size (screen area), during both the manufacturing and the use phases. The impact on use is multiplied by nearly 4 when the diagonal doubles[25].

Over the last 5 years, while the growth in the number of equipments was temporarily boosted during the COVID-19 period, sales now seem to be stabilizing or even decreasing in countries that are already well equipped. However, the growth of the fleet over nearly 15 years remains impressive. Increasing the size of screens, on the other hand, seems to be a trend that will continue in the coming years: the average size of LCD TV shipments exceeded 50 inches for the first time in mid-2023[26].

25 Modelling and assessment of the environmental impacts of consumer products and capital goods - La librairie ADEME, https://librairie.ademe.fr/industrie-et-production-durable/1189-modelisation-et-evaluation-des-impacts-environnementaux-de-produits-de-consommation-et-biens-d-equipement.html

26 Omdia: For the first time, LCD TV display weighted average size surpasses the 50-inch display size, https://www.prnewswire.com/apac/news-releases/omdia-for-the-first-time-lcd-tv-display-weighted-average-size-surpasses-the-50-inch-display-size-301883953.html



In addition, the emergence of OLED televisions, which are currently in small proportion of the fleet but whose sales are increasing year after year, will also drive up the environmental impacts, as their size is already higher on average (58 inches), as will their environmental impacts during the manufacturing phase. Finally, this provision by industry of ever-increasing sizes encourages the renewal of equipment and therefore technological obsolescence[27 28].

The lifespan of monitors and televisions is set at 7 years and has been approximated from old data. A sensitivity analysis was therefore performed on this parameter to assess its impact on the overall results. Details are given in the 5.1.3. It can be observed that this parameter is one of the main culprits of the uncertainty about the total impacts of digital technology.

2.5.1.2 Internet of Things - Iot

The **various connected objects** have become the **second category of user** devices with the **biggest impact**. Excluding connected speakers, they represent around **11% of the environmental impacts** of digital technology for all indicators, with the exception of the indicator on the use of mineral and metal resources (5%).

Connected objects have a different impact profile than most user equipment: contrary to popular belief, a large proportion of connected objects are **powered by the mains** and not by battery, with a standby mode having very little difference in its power consumption compared to the active mode. As there are so many of such devices , and for the most part rarely turned off (rather in active mode or standby mode), their **cumulative electricity consumption** is large enough to represent **10.6% of the electricity consumption of all digital technology**, i.e. 242 TWh, i.e. as much as 49% of the total electricity production in France in 2023[29].

The difference in the quantity of IoT equipments between the 2019 study and the present study led to a sensitivity analysis on the quantity of connected objects. Details are presented in the 5.1.3. The results show that this parameter is not very responsible for the uncertainty of the overall results.

2.5.1.3 Smartphones

Smartphones are the **third category of user devices** with the biggest environmental impacts of digital technology. They account for 11% of the use of digital mineral and metal resources, an indicator on which they have proportionally the most impact compared to other types of equipment. Regarding the potential for global warming, the quantity of smartphones makes them exceed the impacts of laptops (5% compared to 3% for laptops).

Smartphones are the **third category of user devices** with the biggest environmental impacts of digital technology. They account for 11% of the use of digital mineral and metal resources, an indicator on which they have proportionally the most impact compared to other types of equipment. Regarding the potential for global warming, the quantity of smartphones makes them exceed the impacts of laptops (5% compared to 3% for laptops).

27 Small screen, big waste: the obsolescence of televisions - HOP,
https://www.halteobsolescence.org/publication/rapport-obsolescence-televiseurs/

28 Omdia: For the first time, LCD TV display weighted average size surpasses the 50-inch display size,
https://www.prnewswire.com/apac/news-releases/omdia-for-the-first-time-lcd-tv-display-weighted-average-size-surpasses-the-50-inch-display-size-301883953.html

29 Production | EDF FR, https://www.edf.fr/groupe-edf/comprendre/production

The **number** of smartphones **has increased by 1 billion between 2019 and 2023**: the **use** of smartphones has become widely **democratized** in recent years around the world. At the same time, there has been a sharp **decrease in the number of feature phones**.

GSMA research[30] provides information on smartphone penetration by region of the world. We can see that the geographical distribution of smartphones is not homogeneous. The penetration rate is highest in North America, followed by Europe and Asia at 70 to 80%. Conversely, in Africa and the Middle East, the penetration rate ranges from 20 to 60%. In these areas, the study explains that now, the obstacles to the use of a smartphone are no longer network coverage, but mainly the cost of the device and the skills to be able to use it (including reading skills).

From the point of view of development trends, in a market that has been declining since the peak of 2021 in the context of the pandemic[31], sales seem to have picked up slightly in 2024, in particular due to the continued **deployment of 5G** in so-called "emerging" markets[32]. Recent news around the latest developments in AI technologies has been seized upon by manufacturers to develop and promote **new products** claiming computing capabilities dedicated to **AI**. These new products are seen as levers of "growth",[33] which **raises significant risks of psychological** (marketing) **and technical** (upgrading of Operating Systems)[34] obsolescence, with the impact of accelerating the renewal of devices, smartphones and laptops[35].

2.5.1.4 Video projectors

Video **projectors** account for 2 to 6% of the environmental and health impacts of digital technology, making them a category of equipment with a significant impact in Tier I.

Their impact is mainly due to the **electricity consumption during the use phase**. Indeed, the unit power of a piece of equipment is high and their usage time can also be high, especially in a school or professional setting.

However, inventory data on projector quantities was indirectly inferred from monitor and projector data. In addition, there are many types of video projectors: in companies, in schools, for individuals, etc. These different types of equipment and their various uses make it difficult to obtain a reliable figure. Thus, a sensitivity analysis was carried out to estimate the influence of the quantity of video projectors on the overall impacts of digital technology. Details are given in the 5.1.3. As a result, this is not the main source of uncertainty about the overall results.

2.5.1.5 Focus sur les réseaux

Fixed **and mobile networks** (Tier II) are overall responsible for **15 to 26% of the overall** environmental and health impacts of digital technology in 2023.

The Figure 4 represent the distribution of network impacts between fixed and mobile. The mobile network accounts for a slightly larger share of digital impacts than the fixed network for most indicators (60% to 40% distribution respectively). Only the use of resources, minerals and metals and ionizing radiation are slightly higher for the fixed network.

The unit impact of the mobile network for a subscriber is lower than for the fixed network. It is the number of subscribers to the mobile network (7 times greater than on the fixed network) that makes the total impact greater for the mobile network.

30 GSMA | The State of Mobile Internet Connectivity Report 2024 - Mobile for Development, https://www.gsma.com/r/somic/

31 Canalys Newsroom - Global smartphone market declined just 4% in 2023 amid signs of stabilization, https://www.canalys.com/newsroom/worldwide-smartphone-market-2023

32 Worldwide Smartphone Forecast Update, 2024–2028, https://www.idc.com/getdoc.jsp?containerId=US52314824

33 Global Smartphone Shipments Growth Forecast for 2024 Raised to 5%, https://www.counterpointresearch.com/insights/global-smartphone-forecast-2024/

34 Apple https://www.apple.com/newsroom/2024/06/introducing-apple-intelligence-for-iphone-ipad-and-mac/ and Microsoft https://blogs.windows.com/windowsexperience/2024/10/01/new-experiences-coming-to-copilot-pcs-and-windows-11/ Announcement

35 Global PC Shipments Dip Slightly Despite Recovery Economy, AI Integration Key to Future Market Success, According to IDC Tracker, https://www.idc.com/getdoc.jsp?containerId=prUS52644924

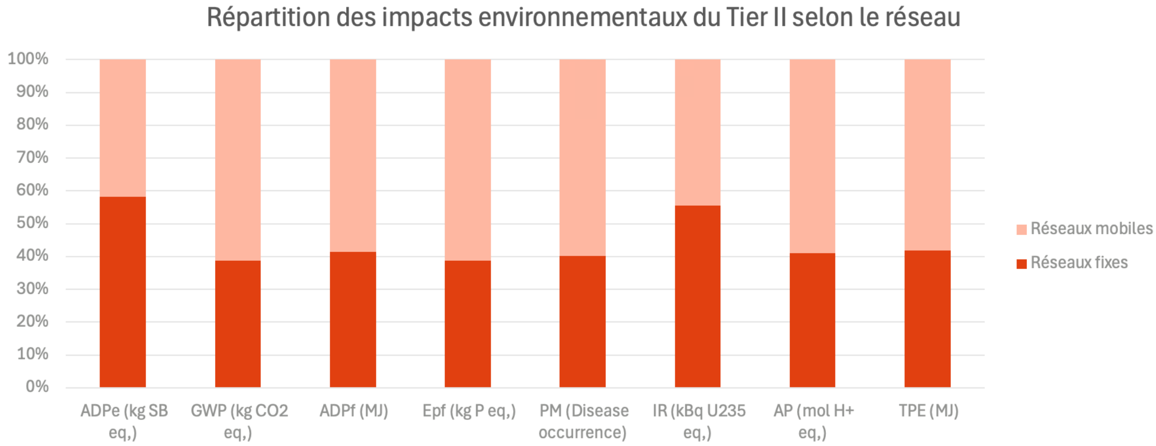


Figure 4: Distribution of the environmental impacts of networks (Tier II) between fixed and mobile networks

The Table 8 represents the percentages of impacts of the different networks in relation to the overall digital footprint. In the network, a distinction is made between a share of the impact due to the connection to the network and a part of the impact due to the amount of data consumed, according to the ADEME study method used[36] for network impact modelling:

	GWP (kg CO_2 eq.)	ADPe (kg Sb eq.)	ADPf (MJ)	Epf (kg P eq.)	PM (Disease Occurrence)	AP (mol H+ eq.)	IR (kBq U235 eq.)	TPE (MJ)
Fixed Network	**9,07 %**	**8,87 %**	**10,08 %**	**10,24 %**	**9,94 %**	**9,45 %**	**11,70 %**	**10,50 %**
Share due to the amount of data	*1,37 %*	*2,01 %*	*1,54 %*	*1,52 %*	*1,42 %*	*1,35 %*	*1,88 %*	*1,56 %*
Share due to the number of subscriptions	*7,70 %*	*6,85 %*	*8,55 %*	*8,72 %*	*8,52 %*	*8,10 %*	*9,82 %*	*8,95 %*
Mobile Network	**14,30 %**	**6,38 %**	**14,25 %**	**16,22 %**	**14,83 %**	**13,58 %**	**9,37 %**	**14,59 %**
Share due to the amount of data	*7,22 %*	*2,98 %*	*6,95 %*	*8,75 %*	*7,36 %*	*6,93 %*	*3,73 %*	*7,22 %*
Share due to the number of subscriptions	*7,08 %*	*3,39 %*	*7,30 %*	*7,48 %*	*7,47 %*	*6,65 %*	*5,64 %*	*7,36 %*
Total Tier II	**23,37 %**	**15,24 %**	**24,33 %**	**26,46 %**	**24,77 %**	**23,03 %**	**21,07 %**	**25,09 %**

Table 8: Distribution of the environmental impacts of networks according to the type as well as the share due to the subscription or the amount of data exchanged

It can be seen that for the fixed network, the share of impact due to the network connection is greater than the share of impact due to the amount of data consumed. Indeed, a significant part of the impacts takes place at the time of connection to the network: the installation of the fiber optic cable above or below ground to connect the internet box for example. Once this connection has been made, the amount of data that is exchanged only slightly increases the consumption of the installed equipment and therefore the total impact.

36 Evaluation of the environmental footprint of the provision of internet access in France - La librairie ADEME, https://librairie.ademe.fr/industrie-et-production-durable/6789-evaluation-de-l-empreinte-environnementale-de-la-fourniture-d-acces-a-internet-en-france.html

For the mobile network, on the other hand, the distribution of impacts is more evenly shared between the connection and data consumption. Indeed, unlike the fixed network, the exchange of more data will require significant electricity consumption for the equipments (antennas, amplifiers, etc.).

According to the ADEME study used to model the impacts of the network, the core network (called the backbone) and the transport network account for about 10 to 25% of the network's impacts, depending on the indicators. It is particularly pooled and optimized, which reduces its impact, especially during the use phase. On the other hand, the access network is much more diffuse, to connect each subscriber to the rest of the network. Its impact is the majority with about 75 to 90% of the total. In addition, two aspects of networks were excluded from the study: telecommunication satellites and undersea cables. More details on the scope taken into account are given in the section 5.2.5.

2.5.2 Focus on data centers

In 2023, **Data centers** are responsible for **13 to 26% of the environmental and health impacts of digital technology worldwide**, depending on the indicators. The figure below details the distribution of environmental impacts according to equipment categories, as well as the Table 9.

Within data centers, electricity consumption is by far the largest source of impact, except for the indicator of use of mineral and metal resources, which is mainly linked in order of importance to the manufacturing phase of servers and batteries.

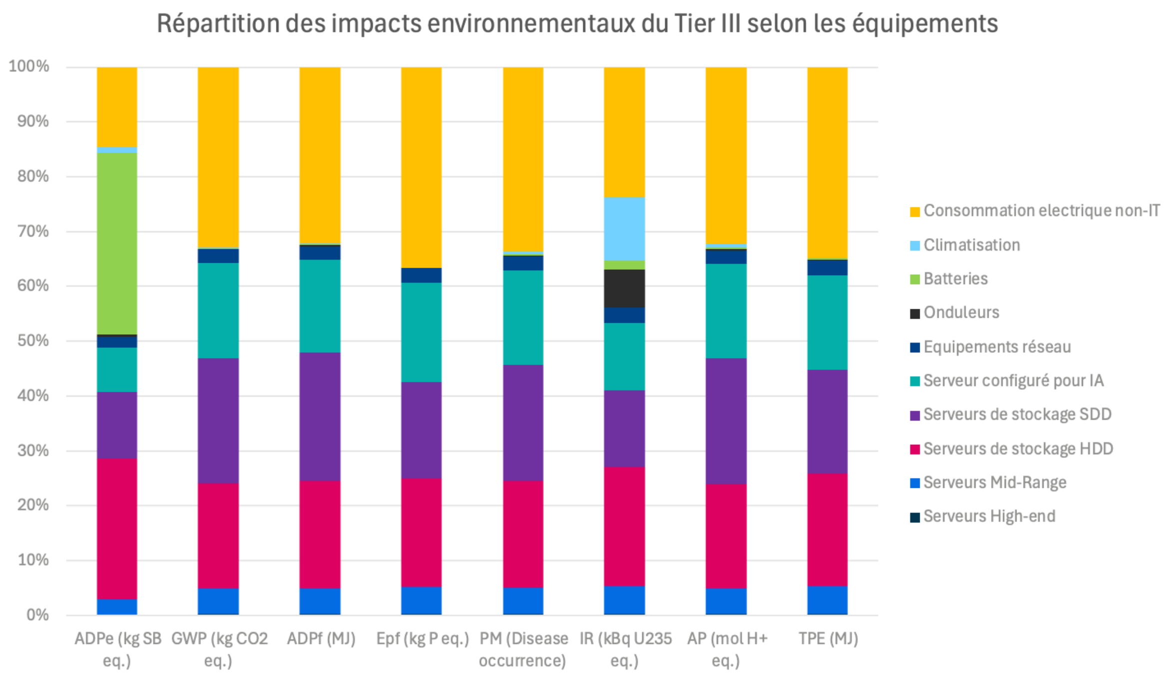


Figure 5: *Distribution of the environmental impacts of data centers (Tier III) according to equipment*

	GWP (kg CO_2 eq.)	ADPe (kg Sb eq.)	ADPf (MJ)	Epf (kg P eq.)	PM (Disease Occurrence)	AP (mol H+ eq.)	IR (kBq U235 eq.)	TPE (MJ)
Compute Servers - High-end	0,07 %	0,02 %	0,07 %	0,08 %	0,07 %	0,07 %	0,02 %	0,07 %
Compute Servers - Mid-range	1,06 %	0,35 %	1,02 %	1,27 %	1,07 %	1,01 %	0,41 %	1,09 %
Storage Servers - HDDs	**4,34 %**	**3,27 %**	**4,37 %**	**5,05 %**	**4,43 %**	**4,17 %**	1,79 %	**4,41 %**
Storage Servers - SDDs	**5,22 %**	1,55 %	**5,17 %**	**4,49 %**	**4,81 %**	**5,06 %**	1,15 %	**4,05 %**
AI-Configured Servers	**3,95 %**	1,05 %	**3,76 %**	**4,64 %**	**3,95 %**	**3,76 %**	1,01 %	**3,69 %**
Network equipment	0,57 %	0,24 %	0,55 %	0,69 %	0,58 %	0,55 %	0,24 %	0,59 %
Inverters	0,02 %	0,07 %	0,05 %	0,00 %	0,04 %	0,05 %	0,57 %	0,04 %
Batteries	0,03 %	4,22 %	0,05 %	0,00 %	0,07 %	0,09 %	0,14 %	0,04 %
Air conditioning	0,02 %	0,14 %	0,02 %	0,00 %	0,10 %	0,11 %	0,95 %	0,02 %
Non-IT Power Consumption	**7,51 %**	1,86 %	**7,14 %**	**9,39 %**	**7,64 %**	**7,10 %**	1,95 %	**7,47 %**
Total Tier III	**22,80 %**	**12,77 %**	**22,18 %**	**25,61 %**	**22,75 %**	**21,97 %**	**8,22 %**	**21,46 %**

Table 9: *Distribution of the environmental impacts of data centres (Tier III) in relation to the total digital impacts*

The lines specific to non-IT equipment (inverters, batteries, air conditioning) are to be understood as indicating the impacts excluding electricity consumption during the use phase of those equipments. This power consumption is accounted in the line "non-IT power consumption".

2.5.2.1 Servers for AI

In 2023, servers dedicated to Artificial Intelligence (AI) already account for 1 to 5% of the environmental impacts of data centers dependingding on the indicators, despite their small number in proportion to other servers[37]. **AI-configured servers already emit nearly 4% of digital GHG emissions, which is already more than all laptops combined.** In view of the future growth projections of the use of AI technologies, the proportion of impacts of AI servers is set to increase even faster in the coming years, with the corresponding environmental consequences.

However, it is already noted that servers configured for AI consume more than 18% of the electricity in data centers, while they represent only 2% of the number of servers.

	Allocation
Compute Servers - High-end	0,31 %
Compute Servers - Mid-range	4,95 %
Storage Servers - HDDs	19,71 %
Storage Servers - SDDs	17,48 %
AI-Configured Servers	18,13 %
Network equipment	2,70 %
Non-IT Power Consumption	36,71 %

Table 10: *Tier III electricity consumption allocation*

37 AI servers represent, in our 2023 inventory, only 2% of servers, less than mid-range servers.

It is important to remember that this distribution is a 2023 representation in a sector that is still very young and in full evolution. As a result, this distribution is likely to quickly become obsolete and is likely to be still incomplete and therefore underestimated. Indeed, computing units dedicated to AI, especially in their model training phase, are specially designed for these uses (FPGA, ASIC or GPU type server)[38]. In 2023, this type of unit accounted for about 30% of deliveries, and 44% planned for 2024[39]. However, these specialized units have an increasingly high electricity consumption. To take into account this degree of uncertainty and the associated impacts, a sensitivity analysis was conducted and detailed in the appendix section 5.1.3.2. It highlights the potential variations in the impacts of digital technology in relation to the power consumption related to servers configured for AI.

In addition, **the rise of generative AI is an additional use that does not replace other uses but adds to them**. The same applies to server-type equipment, which is added to existing stocks. Computing processes requiring additional components and in much larger quantities (GPU, RAM, storage). In 2023, the lifespan of these non-AI servers is currently tending to be slightly extended to 7 years, to free up capital for the acquisition of AI servers, which are expensive and in a context of a sluggish global economy[40].

2.5.2.2 Non-IT equipment

The distribution of electricity consumption, as shown in the above table, shows the large share of non-IT equipment. It should be noted that our model on 2023 data does not yet take into account the gradual reconfiguration currently beginning, driven by the rise of generative AI, which generates a much higher thermal density and therefore increased cooling needs and the gradual emergence of new cooling methods (door cooling, immersion cooling)[37].

2.5.2.3 torage Servers

Storage **servers** are the equipment with the most impact in data centers: **this is linked to their large number in proportion to the computing servers, although unitedly, a computing server is much more energy-intensive in use**.[41]

2.5.2.4 Synthèse

Migration to the cloud, the rise of generative AI, and cryptocurrencies are the 3 main vectors of the ongoing reconfiguration of the impacts of data centers. All three are leading to a significant increase in demand, with strong growth in the number of data center projects around the world, with the United States leading the way. For the first time in February 2024, the International Energy Agency warned of the jump in electricity consumption of the sector since 2022, announcing projections of doubling the electricity consumption of data centers between 2022 and 2026[42].

The rapid development of AI technologies is also generating profound upheavals in the management of existing data centers: in 2023, their managers favour extending the lifespan of existing servers and investing in optimizing energy management and increasing capacity. These 2 points aim to support the development of their offer in specialized computing capacity for AI[43].

38 Global AI Server Demand Surge Expected to Drive 2024 Market Value to US$187 Billion; Represents 65% of Server Market, Says TrendForce, , https://www.trendforce.com/presscenter/news/20240717-12227.html

39 Global annual AI server shipments, 2023-2024, https://www.digitimes.com/reports/item.asp?id=20240711RS400

40 Omdia: Servers for AI processing are big sellers | Network World, https://www.networkworld.com/article/1312785/omdia-servers-with-ai-processing-are-big-sellers.html

41 Our inventory counts a ratio of 15.5 storage servers (HDD or SDD) for 1 compute server (high-end, mid-range, or AI).

42 Electricity 2024 – Analysis - IEA, https://www.iea.org/reports/electricity-2024 § License: CC BY 4.0, page 31

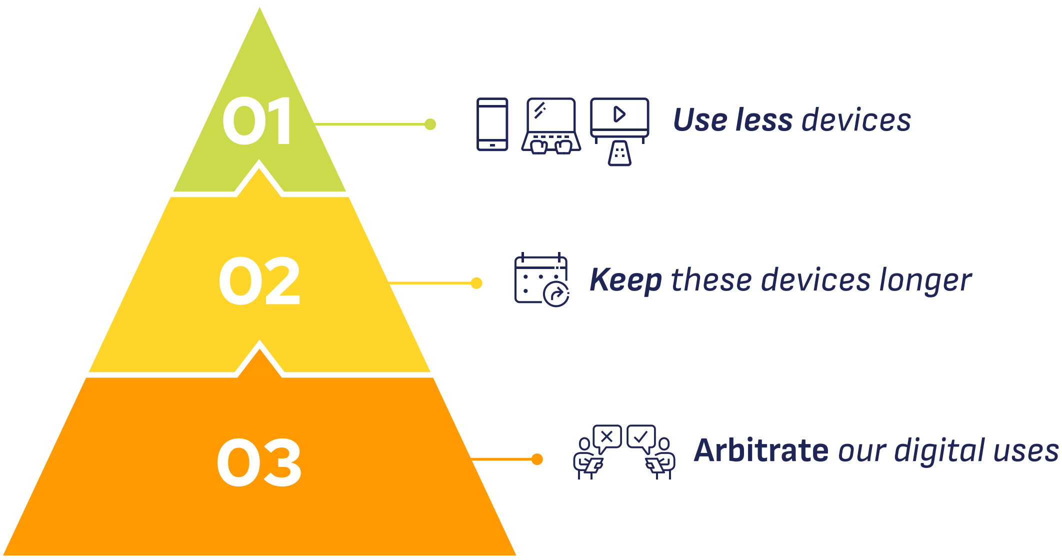
43 Omdia: AI boosts server spending but unit sales still plunge | Network World, https://www.networkworld.com/article/1251147/omdia-ai-boosts-server-spending-but-unit-sales-still-plunge.html

3 Recommandations

In this study, we were able to see that digital technology already consumes more than 40% of the GHG budget per Internet user to stay below 1.5°C of global warming. If digital technology were to take a **place proportional to its contribution to GHG emissions** (3.4%) while respecting the sustainable budget to stay within planetary limits, then digital emissions would have to **be reduced by a factor of 12**.

Given the significant environmental and health impacts of digital technology, what can be done to reduce its footprint?

The general idea could be summarized in 3 general recommendations:



Pour que chacun·e puisse s'emparer concrètement des enjeux à sa portée, nous avons structuré les **recommandations** selon **3 profils (citoyen, entreprise, pouvoirs publics)** et listé les recommandations par **priorité**.

Une **réduction** d'une telle **ampleur** appelle à considérer tout exercice de recommandation avec humilité et à **réévaluer régulièrement les ambitions** de réduction à la hausse, par palier. En effet, si pour certains internautes, réduire ses impacts environnementaux du numérique peut être de ne pas posséder de téléviseur, d'ordinateur ou de smartphone, pour d'autres, de telles contraintes peuvent paraitre inaccessibles tant le numérique imprègne nos quotidiens personnels, administratifs et professionnels. Mieux vaut, dans ce dernier cas, **se concentrer sur la ou les actions ayant le plus de potentiel de réduction des impacts** tout en combinant une **dose d'effort réaliste au regard de ses contraintes**. Pour des utilisateur·rices ayant déjà un usage sobre du numérique, l'effort contributif supplémentaire pourrait être de partager leur expérience de sobriété et de réparabilité du numérique pour accompagner d'autres sur cette voie.

A ce titre, il est aussi nécessaire de rappeler que bien que les équipements utilisateur·rices **représentent la majorité des impacts**, l'effort **ne peut reposer uniquement sur les actions individuelles** : les **actions collectives et citoyennes**, la règlementation et une véritable stratégie de sobriété numérique sont nécessaires pour **réduire efficacement** les impacts environnementaux et sanitaires du numérique. Par ailleurs, demander un effort identique aux pays en voie de développement en comparaison aux pays développés ne tiendrait pas compte de la dette des émissions passées des pays développés, ni des **inégalités persistantes** actuellement en matière d'accès au numérique et de taux d'équipement.

D'après les résultats de la présente étude, il apparaît clairement que :

1. **To reduce the environmental and health impacts of digital technology,** it is necessary to act as a priority on the equipment and life cycle phases that concentrate the most impacts, therefore
    a. At Tier I level **– User equipment:**
        i. Reduce the **number** and **size** of **monitors** and **TVs**
        ii. Reduce the number of **connected objects**
        iii. Reduce the number of **smartphoness**
        iv. **Make** all these devices last longer
        v. **Reduce the time spent** using monitors, TVs, smartphones and projectors
        vi. Improve the **energy efficiency** of new devices
    b. At Tier II – **Networks:**
        i. Size networks as accurately as possible and limiting the deployment of new infrastructures
        ii. **Favoure** the use of existing fixed networks
        iii. **Reduce the amount of data** transferred over mobile networks
        iv. Improve the **energy efficiency** of new network equipment
    c. At Tier III – **Data Centers:**
        i. **Size** data centers as accurately as possible and limit the deployment of new infrastructures, and therefore associated digital services,
        ii. **Less strain on** data centers (calculations and storage)
        iii. **Slow down the spread of new uses** (AI in particular)
        iv. Improve the **energy efficiency of new equipment**
2. **To get back below the threshold of planetary boundaries,** the above actions must be carried out with the ambition of reducing the environmental and health impacts of digital technology by a factor of 12. To do this, **all stakeholders have a role to play**. Here are our recommendations for public authorities, companies and organisations, and individual consumers/citizens.

Public authorities

Action 1: Limit the growth of digital technology, regulate uses	In particular, the use of digital technology for public services and the management of the commons. Create the conditions to **promote the extension of the lifespan of digital equipment** (e.g. promote the repair and reuse sector, limit advertising in public spaces, extend the warranty period to 5 years, separate security and comfort updates, regulate the use of dark patterns, etc.). **Regulate the uses of AI** by taking into account its environmental impacts.
Action 2: Inform and consult citizens	Raise awareness among the general public about the environmental impacts of digital technology in general, and more particularly about the equipment and uses that concentrate the most impacts. Open the debate and **involve citizens to collectively define what digital technology is desirable** for today and tomorrow. Provide exhaustive information on projects qualified as «of major public interest» in AI or digital transition.
Action 3: Encouraging transparency	Frame the assessment and claims practices on the environmental impacts of digital equipment and services (multi-criteria LCA PEF), and to encourage stakeholders to implement these practices. **Extend the repairability and durability indexes at European and international level.**

__Table 11:__ Recommendations for action by the public authorities to reduce the impacts of digital technology

Companies and Organizations

Action 4: Reduce the environmental impacts of digital equipment and services	Generalize eco-design practices for digital equipment and services. **Systematically question** the needs and new uses envisaged.
Action 5: Be transparent about the environmental impacts of their facilities and services	Especially for manufacturers and service providers (Cloud/Hyperscalers), **assess the environmental impacts of their equipment and services using the multi-criteria LCA method, communicate detailed and auditable results.**
Action 6: Innovate in terms of business model to be compatible with planetary boundaries	**Change the business models of companies in the digital sector** to slow down the production of new digital equipment. Slow down the deployment of new infrastructure and its use. Adopt regenerative business models.

__Table 12:__ Recommendations for action by companies and organizations to reduce the impacts of digital technology

Citizens

Action 7: Limit the number of your devices	Equip yourself with the bare essentials, first and foremost for **monitors, televisions, connected objects, smartphones and video projectors,** but also all other digital equipment (computers, printers, etc.). and small equipment such as headphones, headphones, external hard drives, etc.). Choose sustainable and energy-efficient appliances.
Action 8: Resist fashions / question uses	**Reduce your screen time in general.** Reduce your data-intensive use on mobile networks (e.g. video streaming, video calls). Only renew your devices when they become unusable (and not when a new model is released). Use AI systems, generative in particular, only very sparingly. Publicize your sufficiency choices to stimulate the engagement of other Internet users, industry players and public authorities.
Action 9: Extend the lifespan	**Protect your devices and take care of them** to avoid premature breakage. Adopt maintenance and cleaning practices (hardware and software) to extend the life of your devices. Prefer the refurbished equipment sector for the purchase and resale of your devices.

Table 13: *Proposals for good practices by individuals to reduce the impacts of digital technology*

4 Conclusion

This study highlights that the environmental impacts of digital technology are anything but intangible, with around **30.5 billion active user devices in 2023**. Thus, if digital technology were a country, it would emit as much Greenhouse Gases as **3 times South Korea** or **5.5 times France**.

Among the indicators that stand out in particular, the **contribution of digital technology to the depletion of mineral and metal resources stands out**, exceeding the global warming potential indicator for the first time, despite a weighting method that is much more favourable to highlighting the global warming potential.[44] Thus, the indicator of the use of mineral and metal resources reminds us that **digital technology contributes to tensions on resources and does not exist without these minerals and metals, which are finite resources, on which other sectors** such as health, energy infrastructure and defence also depend. Making excessive use of digital technology thus contributes to jeopardizing resources for future generations.[45]

The example of the contribution of digital technology to the depletion of mineral and metal resources, as well as the indicators relating to **water resources** (such as **eutrophication** and **ecotoxicity on fresh water**), show how important it is to have an overview of the environmental and health impacts of digital technology, hence the usefulness of a multi-criteria LCA. In addition, depending on the stages of the life cycle and the type of digital equipment analysed, the impacts differ, as we have seen throughout this study, reinforcing the need to use a multi-criteria analysis, which thus makes it possible to **avoid causing pollution transfers due to a lack of consideration of an indicator in decision-making**. Hopefully, social impacts, such as human exploitation, can also one day be considered for these assessments.

It should be noted that at the global level, unlike the European and French scales, the use phase has proportionally more impact than the manufacturing phase, except for the contribution to the depletion of mineral and metal resources and ionizing radiation emissions, indicators for which the manufacturing phase remains more impactful.

44 *See the results of the weighting standardization and the weighting factors of the European Commission in the PEF methodology, dealt with in the appendix.*

45 *See the https://www.mineralinfo.fr/fr/substances?title=&field_usages_target_id=151&sort_by=field_criticite_a_plat_value, or the USGS data. To take an example on which many sectors such as digital technology depend: if nickel production in 2023 remained the same every year, there would be 36 years of nickel left before the known global reserves are depleted (calculated from https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-nickel.pdf).*

This study also highlights the relationship between GHG emissions from digital technology and the sustainable budget of planetary limits to be respected to stay below 1.5°C of global warming. Indeed, although it represents 3.4% of global GHG emissions, **digital technology nevertheless consumes 40% of an Internet user's sustainable annual budget to stay below 1.5°C of global warming**, in accordance with the Paris Agreement.[46]

In the light of the data collected during our inventory, we have been able to see that the current trajectory for digital technology tends strongly towards a **systemic increase in the number of equipment, uses, and the number of users, at the expense of environmental consequences**. This is particularly noteworthy when it comes to user devices, **televisions**, **smartphones**, and **connected objects**. Similarly, the boom of **generative AI** in a short period of time is already visible in the environmental impacts of digital technology, totalling, **just for servers configured for AI, between 1 and 5% of the impacts of digital technology depending on the indicators** (4% for GHG emissions).

On a global scale, there has been no significant decline in any category of equipment. Thus, new uses and equipment are added to the previous ones with an overall trajectory of increase in the impacts of digital technology. This increase in the impacts of digital technology is combined with the increase in the impacts of other sectors, which demonstrates the emptiness of the promises of greening that digital technology could bring to other sectors.

Faced with these observations, our recommendations concerning the reduction of environmental impacts focus on **digital sufficiency** and the mechanisms to implement it, both on the reduction of impacts related to manufacturing and related to the use of digital equipment and services: **less equipment, which last longer, and reassess and limit our uses.** These recommendations are the subject of a dedicated section, intended for public authorities, organisations and citizens. **However, this study and these recommendations are nothing without your individual and collective commitment to actively reduce our impacts.**

46 The Paris Agreement | UNFCCC, https://unfccc.int/fr/a-propos-des-ndcs/l-accord-de-paris

5 Annexes

5.1 Additional results

5.1.1 Detailed results tables

The sum of the totals does not always equal 100% due to rounding.

			Tier I	Tier II	Tier III	Total
	GWP (kg CO_2 eq.)	Manufacture	15 %	1 %	2 %	**18 %**
		Transport	1 %	0 %	0 %	**1 %**
		Usage	38 %	22 %	20 %	**81 %**
		End of life	0 %	0 %	0 %	**1 %**
	ADPe (kg Sb eq.)	Manufacture	62 %	10 %	8 %	**80 %**
		Transport	0 %	0 %	0 %	**0 %**
		Usage	9 %	6 %	5 %	**20 %**
		End of life	0 %	0 %	0 %	**0 %**
	ADPf (MJ)	Manufacture	16 %	3 %	3 %	**22 %**
		Transport	1 %	0 %	0 %	**1 %**
		Usage	36 %	21 %	19 %	**77 %**
		End of life	0 %	0 %	0 %	**1 %**
	Epf (kg P eq.)	Manufacture	0 %	0 %	0 %	**0 %**
		Transport	0 %	0 %	0 %	**0 %**
		Usage	48 %	26 %	26 %	**100 %**
		End of life	0 %	0 %	0 %	**0 %**

			Tier I	Tier II	Tier III	Total
	PM (Disease Occurence)	Manufacture	12 %	2 %	2 %	**16 %**
		Transport	1 %	0 %	0 %	**1 %**
		Usage	39 %	23 %	21 %	**82 %**
		End of life	1 %	0 %	0 %	**1 %**
	AP (mol H^+ eq.)	Manufacture	17 %	2 %	3 %	**22 %**
		Transport	1 %	0 %	0 %	**1 %**
		Usage	36 %	20 %	19 %	**76 %**
		End of life	1 %	0 %	0 %	**1 %**
	IR (kBq U_{235} eq.)	Manufacture	61 %	16 %	3 %	**79 %**
		Transport	0 %	0 %	0 %	**0 %**
		Usage	10 %	5 %	5 %	**21 %**
		End of life	0 %	0 %	0 %	**0 %**
	TPE (MJ)	Manufacture	15 %	3 %	1 %	**19 %**
		Transport	0 %	0 %	0 %	**0 %**
		Usage	38 %	22 %	20 %	**80 %**
		End of life	0%	0%	0%	**0%**

Table 14: Distribution of the environmental impacts of digital technology by Tier and by stage of the life cycle

	GWP (kg CO_2 eq.)	ADPe (kg Sb eq.)	ADPf (MJ)	Epf (kg P eq.)	PM (Disease Oc-curence)	AP (mol H^+ eq.)	IR (kBq U_{235} eq.)	TPE (MJ)
Desktop computer	3 %	4 %	3 %	2 %	3 %	3 %	9 %	3 %
Laptop	3 %	5 %	3 %	1 %	3 %	3 %	2 %	3 %
Tablet	1 %	2 %	1 %	0 %	1 %	1 %	1 %	1 %
Landline	1 %	1 %	1 %	2 %	1 %	1 %	1 %	1 %
Smartphone	5 %	**11 %**	5 %	1 %	4 %	6 %	3 %	4 %
Feature phone	0 %	2 %	0 %	0 %	0 %	0 %	0 %	0 %
Monitors	1 %	4 %	2 %	1 %	1 %	1 %	2 %	1 %
Televisions	**13 %**	**25 %**	**13 %**	**14 %**	**13 %**	**13 %**	**25 %**	**13 %**
Printers	4 %	4 %	4 %	4 %	4 %	4 %	7 %	4 %
Game Consoles	1 %	2 %	1 %	0 %	1 %	1 %	1 %	1 %
Video projectors	5 %	2 %	5 %	6 %	5 %	5 %	3 %	5 %
Box TV	3 %	4 %	3 %	3 %	3 %	3 %	6 %	3 %
Smart speakers	1 %	1 %	1 %	2 %	1 %	1 %	1 %	1 %
IoT Devices	**11 %**	5 %	**11 %**	**12 %**	**11 %**	**11 %**	**10 %**	**11 %**
Total Tier I	**54 %**	**72 %**	**53 %**	**48 %**	**52 %**	**55 %**	**71 %**	**53 %**

Table 15: Distribution of the environmental impacts of user equipment (Tier I) by equipment category as a proportion of the total environmental impacts of digital technology in the world over the 3 Tiers

Totals may not always add up due to rounding.

	GWP (kg CO_2 eq.)	ADPe (kg Sb eq.)	ADPf (MJ)	Epf (kg P eq.)	PM (Disease Oc-curence)	AP (mol H^+ eq.)	IR (kBq U_{235} eq.)	TPE (MJ)
Fixed Network	**9 %**	**9 %**	**10 %**	**10 %**	**10 %**	**10 %**	**12 %**	**11 %**
Share due to the amount of data	1 %	2 %	2 %	2 %	1 %	1 %	2 %	2 %
Share due to the number of subscriptions	8 %	7 %	9 %	9 %	9 %	8 %	10 %	9 %
Mobile Network	**14 %**	**6 %**	**14 %**	**16 %**	**15 %**	**14 %**	**9 %**	**15 %**
Share due to the amount of data	7 %	3 %	7 %	9 %	7 %	7 %	4 %	7 %
Share due to the number of subscriptions	7 %	3 %	7 %	7 %	7 %	7 %	6 %	7 %
Total Tier II	**23 %**	**15 %**	**24 %**	**26 %**	**24 %**	**23 %**	**21 %**	**25 %**

Table 16: *Distribution of the environmental impacts of networks (Tier II) according to the type and share due to the subscription or the amount of data exchanged, in proportion to the total environmental impacts of digital technology in the world on the 3 Tiers*

	GWP (kg CO_2 eq.)	ADPe (kg Sb eq.)	ADPf (MJ)	Epf (kg P eq.)	PM (Disease Oc-curence)	AP (mol H^+ eq.)	IR (kBq U_{235} eq.)	TPE (MJ)
Compute Servers - High-end	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Compute Servers - Mid-range	1 %	0 %	1 %	1 %	1 %	1 %	0 %	1 %
Storage Servers - HDDs	**4 %**	**3 %**	**4 %**	**5 %**	**4 %**	**4 %**	2 %	**4 %**
Storage Servers - SDDs	**5 %**	**2 %**	**5 %**	**4 %**	**5 %**	**5 %**	1 %	**4 %**
AI-Configured Servers	**4 %**	1 %	**4 %**	**5 %**	**4 %**	**4 %**	1 %	**4 %**
Network equipment	1 %	0 %	1 %	1 %	1 %	1 %	0 %	1 %
Inverters	0 %	0 %	0 %	0 %	0 %	0 %	1 %	0 %
Batteries	0 %	4 %	0 %	0 %	0 %	0 %	0 %	0 %
Air conditioning	0 %	0 %	0 %	0 %	0 %	0 %	1 %	0 %
Non-IT Power Consumption	**8 %**	2 %	**7 %**	**10 %**	**8 %**	**7 %**	2 %	**7 %**
Total Tier III	**23 %**	**13 %**	**22 %**	**26 %**	**23 %**	**22 %**	**8 %**	**21 %**

Table 17: *Distribution of the environmental impacts of data centers (Tier III), as a proportion of the total environmental impacts of digital technology in the world over the 3 Thirds*

5.1.2 Comparison with the literature

The results can be compared with the **existing scientific literature** to **identify differences and similarities**. There have been several studies identifying the environmental impacts of digital technology around the world in recent years. The results obtained in the present study are therefore compared with the results of these other studies to compare the relevance of orders of magnitude or to identify potential differences.

However, **no study used the same methodology**. Therefore, **the results should** be compared **with caution**. There is a need to understand how differences in results between different studies are explained.

The main study used (Freitag et al., 2021[47]) is a **literature review**, which analyzes three scientific articles published **between 2015 and 2021**, on the environmental impacts of digital technology around the world:

- Andrae and Edler (2015);[48]
- Belkhir and Elmeligi (2018);[49]
- Malmodin and Lundén (2018).[50]

These are the most recent studies on the subject. In addition to these three studies, another article by Malmodin published in 2024[51] is added. It contains updates from the 2018 Malmodin and Lundén study.

All these studies focus solely on the indicator of **global warming potential**. The comparison is therefore made only on this indicator. In addition, they all include the **three Third Parties:** data centers, networks, and user equipment. The elements taken into account in the different Third Parties vary and are detailed below.

In the study by Andrae and Edler and Belkhir and Elmeligi, the method used is the estimation of the electrical consumption of the equipment for the 3 Thirds, during the use phase and manufacturing. This amount of electricity is then converted into greenhouse gas emissions with an electricity mix. The study by Malmodin et al. uses a similar life-cycle approach to the present study. It is therefore the closest methodologically to the present study. It is also the one that is based on the most recent data. The comparison with this study is therefore preferred.

The Table 16 summarizes the main inclusions and exclusions within the scope of the studies considered.

	Tier I		Tier II		Tier III	
	Inclusive	**Excluded**	**Inclusive**	**Excluded**	**Inclusive**	**Excluded**
Andrae and Edler	Desktop and laptop computers, monitors, mobile phones, tablets, TVs, DVD players	Printers, IoT	Based on the amount of data transferred	Satellites	Based on the amount of data transferred	-

47 *Freitag et al., The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations - ScienceDirect, 2021, https://linkinghub.elsevier.com/retrieve/pii/S2666389921001884*

48 *On Global Electricity Usage of Communication Technology: Trends to 2030, ttps://www.mdpi.com/2078-1547/6/1/117*

49 *Assessing ICT global emissions footprint: Trends to 2040 & recommendations - ScienceDirect, https://www.sciencedirect.com/science/article/abs/pii/S095965261733233X*

50 *The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015, https://www.mdpi.com/2071-1050/10/9/3027*

51 *Malmodin et al., ICT sector electricity consumption and greenhouse gas emissions – 2020 outcome - ScienceDirect, 2024, https://www.sciencedirect.com/science/article/abs/pii/S0308596123002124*

	Tier I		Tier II		Tier III	
	Inclusive	**Excluded**	**Inclusive**	**Excluded**	**Inclusive**	**Excluded**
Belkhir and Elmeligi	Computers, laptops, LCD and CRT screens, tablets, smart-phones	TVs, TV box-es, printers, IoT	Internet box, profes-sional and operator networks, technical environ-ment	Satellites	Compute and storage servers, network equipment, cooling, power sup-ply	Buildings
Malmodin et al.	Computers, laptops, screens, tablets, smart-phones, in-ternet box-es, payment terminals, connected speakers, headphones, IoT	TVs, print-ers, game consoles	Fixed and mobile net-work, WAN and LAN in companies, Satellites	Internet box	Servers, storage equipment, commu-nication equipment, technical environ-ment	-

Table 18: *Main inclusions and exclusions in the scope of the 3 scientific studies compared to this one*

Several notable differences can already be identified:

- This study gives the digital impacts for the year 2023, the other scientific studies concern the year 2020. In addition, two of them were carried out upstream on the basis of projections. An underestimation of the results from the scientific literature is therefore expected compared to the results of the present study.
- The first two studies are based solely on electricity consumption. Impacts on the global warming potential from other processes or raw materials are therefore not taken into account. An underestimation of the results from these studies is therefore expected compared to the results of the present study.
- The differences in boundaries detailed in the Table above may lead to under- or over-estimates compared to the present study.

The Table 17 summarizes the results by Tier of the various scientific studies, in comparison with the present study.

	GWP Tier I impact (G tonnes CO_2 eq. CO_2)	GWP Tier II impact (G tonnes CO_2 eq.) CO_2)	GWP Tier III impact (G tonnes CO_2 eq.) CO_2)	Total GWP impact (G tonnes eq. CO_2)	Percentage of total result of this study
Current study (year 2023)	0,99	0,43	0,42	1,83	**100 %**
Andrae and Edler (year 2020, expected case scenario)	0,97	0,46	0,43	1,86	**102 %**
Belkhir and Elmeligi (year 2020, "average" scenario)	0,45	0,27	0,49	1,21	**75 %**
Malmodin and Lundén (year 2020)	0,43	0,20	0,12	0,76	**58 %**

Table 19: *Comparison of the results of the present study with three scientific studies*

Regarding Tier I, the present study is the closest to the results of Andrea and Edler. The difference with the other studies is mainly explained by the fact that they do not take into account televisions in the scope. If we remove the televisions from our study to have the same perimeter, we obtain 0.65 Gt eq. CO_2, reducing the gap with Malmodin's results to around 30%. The remaining difference is likely due to IoT modelling. Indeed, Malmodin et al. estimate 13 Mt eq. CO_2 for IoT, whereas the present study gives 207 Mt CO_2 eq. CO_2, or about 16 times more. Indeed, the present study uses a quantity of 15 billion connected objects compared to 6 billion for Malmodin et al. Also, the estimated power consumption for IoT is 3 times higher. However, the value of 15 billion connected objects is retained in the present study because it is considered sufficiently reliable. Indeed, two recent sources (Transforma Insights[52] and Ericsson[53]) giving consistent results for 2023 were found. A sensitivity analysis was carried out on the quantity of connected objects (variation between 12 and 18 billion), and it results that the variation induced on the overall results is +/-5% on the Tier I results.

The same is true for Tier II: the present study is the closest to the results of Andrea and Edler. The results of the other two studies are much lower; the results of Malmodin et al. indicate a half the impact of the present study. The results show that the majority of the impacts of the global warming potential come from the use phase and therefore from the electricity consumed. Looking at electricity consumption, we find that Malmodin et al. estimate a total of 272 TWh of electricity for the networks, compared to 513 TWh in the present study. It should be noted, however, that in the study by Malmodin et al., internet boxes are taken into account in Tier I and not in Tier II. On a like-for-like basis, excluding Tier II boxes, this study gives 410 TWh. In addition, the IEA[54] indicates that the electricity consumption of the grids world-wide will be between 260 and 360 TWh in 2022. Despite a slight overestimate, the value resulting from the study is therefore in the same order of magnitude. There is a high degree of uncertainty in the Tier II modelling, as detailed in section 6.13.3. Indeed, the impacts were obtained from an extrapolation of a study carried out in France and is therefore not representative of the plurality of network infrastructures that can be observed in the world.

For Tier III, the results presented in this study are higher than the estimates of previous studies. As with Tier II, the majority of impacts come from the electricity consumed. Malmodin et al. are based on a value of 223 TWh in 2020, while the present study is based on 506 TWh in 2023. However, in previous studies, the impact of AI was not taken into account because it had not yet experienced the "boom" it has experienced in recent years. This probably explains part of the discrepancies between the two electricity consumption values. In addition, the value of 506 TWh is consistent with an IEA report[55] estimating

52 *Current IoT Forecast Highlights - Transforma Insights https://transformainsights.com/research/forecast/highlights*

53 *Wide-area and short-range IoT devices worldwide 2029 | Statista, https://www.statista.com/statistics/1016276/wide-area-and-short-range-iot-device-installed-base-worldwide/*

54 *Data centres & networks - IEA, https://www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks*

55 *Electricity 2024 - Analysis and forecast to 2026, https://iea.blob.core.windows.net/assets/6b2fd954-2017-408e-bf08-952fd-d62118a/Electricity2024-Analysisandforecastto2026.pdf*

the electricity consumption of data centers in 2022 at 460 TWh worldwide, which validates the order of magnitude. There is still uncertainty about the unit power consumption of servers, especially those dedicated to AI. A sensitivity analysis is conducted in section 3.2 on this topic.

5.1.3 Sensitivity analysis

Several **sensitivity analysis** were carried out on elements with a strong impact on the overall result and based on data with a high uncertainty. Indeed, a sensitivity analysis makes it possible to study how the variation of an input parameter influences the final result.

The 4 analyses carried out in this study focus on:

- The quantities of video projectors;
- The power consumption of servers dedicated to AI;
- The lifespan of monitors and televisions;
- The quantities of IoT equipment.

5.1.3.1 Sensitivity analysis of projector quantities worldwide

Video **projectors** have a relatively large impact on the impacts of Tier I. However, the inventory data was indirectly inferred from aggregated data on the sales of monitors and projectors. In addition, there are many types of video projectors: in companies, in schools, for individuals, etc. These different types of equipment and their various uses make it difficult to obtain a reliable figure.

To perform this sensitivity analysis, a 30% increase and decrease in the **amount of equipment** is simulated.

Indicator	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
-30% difference	98 %	99 %	98 %	98 %	98 %	98 %	99 %
Variance of +30%	101 %	100 %	101 %	101 %	101 %	101 %	100 %

Table 20: *Overall results of the sensitivity analysis on the quantity of video projectors as a proportion of the total impacts*

Of the total, the change in impact is 1 to 3% of the global footprint on most indicators. On the other hand, if we look more closely at the relative impact on Tier I, the difference is more significant with up to 7% difference between the high and low value.

Indicator	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
-30% difference	97 %	99 %	97 %	96 %	97 %	97 %	99 %
Variance of +30%	103 %	101 %	103 %	104 %	103 %	103 %	101 %

Table 21: *Tier I results of the sensitivity analysis on the quantity of video projectors in proportion to the impacts of Tier I*

5.1.3.2 Sensitivity analysis on the power consumption of AI servers

The deployment of infrastructures dedicated to artificial intelligence (AI) has accelerated sharply since the end of 2022. As the phenomenon is recent, it is still poorly documented in the scientific literature, whether it is the quantity of equipment, its electricity consumption or environmental data. Indeed, beyond the servers dedicated to AI, many "classic" servers have been augmented with GPUs, and it seems difficult to make an accurate inventory of them. These very powerful machines significantly increase electricity consumption per unit, and their exponential multiplication has strong repercussions on the impact of digital technology. Thus, the uncertainty about the quantities of servers and their power consumption is very high.

To perform this sensitivity analysis, a 30% increase and decrease in the power consumption of servers dedicated to AI is simulated..

Indicator	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
-30% difference	98 %	99 %	98 %	97 %	98 %	98 %	99 %
Variance of +30%	101 %	100 %	101 %	102 %	101 %	101 %	100 %

Table 22: *Overall results of the sensitivity analysis on the power consumption of servers dedicated to AI in proportion to the total impacts*

The variation in overall results ranged from -3% to +2% across all indicators. Looking more closely at Tier III, the difference in environmental indicators is 7 to 17 points between the high and low value.

Indicateur	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
-30% difference	92 %	95 %	92 %	91 %	92 %	92 %	93 %
Variance of +30%	108 %	105 %	108 %	109 %	108 %	108 %	107 %

Table 23: *Tier III results of the sensitivity analysis on the power consumption of servers dedicated to AI in proportion to the impacts of Tier III*

5.1.3.3 Sensitivity analysis on the lifespan of monitors and TVs

Monitors and TVs account for about 18% of the overall digital footprint. However, their lifespan, set at 7 years, has been approximated from old data. A sensitivity analysis was therefore carried out by reducing their lifespan by 20% or increasing their lifespan by 40%. This corresponds to varying the lifespan from 5.6 years to 9.8 years. The total equipment stocks have been replenished accordingly.

Indicator	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
-20% difference	97 %	99 %	97 %	96 %	97 %	97 %	99 %
Difference of +40%	105 %	102 %	105 %	106 %	105 %	105 %	102 %

Table 24: Overall results of the sensitivity analysis over the lifetime of monitors and televisions as a proportion of total impacts

On the total impacts, the variation ranges from -4% points to +6% of the global footprint on all indicators.

This variation is due to the use of the inventory method[56]. Consequently, **this simulation does not take into account the second-order effects that would result from the increase in the lifespan of this equipment in terms of postponement of purchases of equipment to replace the previous one.** And conversely, this simulation does not take into account the second-order effects that would result from the reduction in the lifespan of the equipment in terms of an increase in the purchase of equipment to replace the previous one.

A closer analysis of Tier I reveals discrepancies ranging from 4 to 20% between the high and low values.

Indicator	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
-20% difference	95 %	98 %	95 %	93 %	95 %	96 %	98 %
Difference of +40%	110 %	103 %	109 %	114 %	110 %	109 %	103 %

Table 25: Tier I results of the sensitivity analysis over the lifetime of monitors and televisions as a proportion of total impact

5.1.3.4 Sensitivity analysis on IoT equipment quantities

IoT devices represent 15 billion connected objects worldwide. In the study carried out in 2019, the inventory estimated the quantity of connected objects at 19 billion, due to a difference in source, which leads to a **decrease in** the quantity of equipment **between these two studies**. This decrease led to a **sensitivity analysis by estimating** a variation of +/- 20% in the **quantity of connected objects** (i.e. a variation of 12 to 18 billion devices).

56 *The amount of equipment in use in the year under study is estimated by adding sales over a time interval corresponding to the life of the equipment. Thus, increasing the lifespan of equipment means taking into account older equipment in an additional way and therefore increases the quantities of equipment as well as the associated impacts, while cushioning the impacts specifically related to the manufacture of this equipment over a longer period.*

Indicator	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
-20% difference	98 %	99 %	98 %	98 %	98 %	98 %	98 %
Difference of +20%	102 %	101 %	102 %	103 %	102 %	102 %	102 %

Table 26: *Overall results of the sensitivity analysis on the quantities of IoT equipment as a proportion of the total impacts*

On the overall results of the study, the **variation observed is +/- 2%** due to this variation in the quantity of connected objects, which remains small. A closer analysis of Tier I reveals a variability of 3 to 10% between high and low values

Indicator	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
-20% difference	97 %	99 %	97 %	96 %	96 %	97 %	97 %
Difference of +20%	105 %	102 %	105 %	106 %	105 %	105 %	103 %

Table 27: *Tier I results of the sensitivity analysis on the quantities of IoT equipment as a proportion of the total impacts*

5.1.3.5 Cumulative sensitivity analysis

Sensitivity analyses were then aggregated to determine the maximum and minimum magnitude of possible variations around the impacts assessed in this study.

Indicator	GWP	ADPe	ADPf	Epf	PM	AP	IR
Base case	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Minimum Deviation	94 %	98 %	94 %	92 %	94 %	94 %	97 %
Maximum Deviation	108 %	103 %	108 %	110 %	108 %	108 %	103 %

Table 28: *Overall results of the sensitivity analysis on all cumulative scenarios*

Finally, we obtain an interval of -8% to +10% around the baseline value - on the Freshwater Eutrophication (Epf) indicator, which is the indicator most sensitive to variations. The **majority of this uncertainty** is due to uncertainty related to the **lifespans of monitors and televisions** and then to the **power consumption of AI servers**.

5.2 Detailed study methodology

5.2.1 General principles of LCA

Life Cycle Assessment (LCA) is a method used to assess the environmental impact of products, services or organizations.

There are other methods of environmental impact assessment, such as **carbon footprint** or **impact assessments**. LCA has specific characteristics that make its holistic approach unique. Indeed, used since the late 1990s and standardized in the ISO 14040:2006[57] and ISO 14044:2006[58] standards, this method aims to establish the environmental impact of a product or service according to several key concepts:

- A **multi-criteria approach:** Several environmental indicators are systematically taken into account, including global warming potential, depletion of abiotic resources, photochemical ozone creation, water, air and soil pollution, human ecotoxicity and biodiversity. The list of indicators is not fixed but depends on the sector of activity.
- A **life-cycle perspective:** Taking into account the impacts generated at all stages of the life cycle of equipment or services, from the extraction of resources that are often difficult to access to the production of waste, including installation processes, energy consumption during the use phase, etc.
- A **quantitative approach:** Each indicator is described quantitatively in order to place all external aspects of a product or service on the same scale and to make objective decisions.
- A **functional approach:** The object of study is defined by the function it fulfills in order to compare different technical solutions.

When carrying out an LCA, it is necessary to define a **functional unit:** the reference unit used to relate inputs and outputs as well as the environmental performance of one or more systems that quantify the services or products studied.

A functional unit can be:

- **Attributional:** This describes the potential environmental impacts that can be attributed to a system (e.g. a product) throughout its lifecycle, i.e. upstream along the supply chain and downstream following the value chain of the system's use and end-of-life. It focuses on the direct effects of a system.
- **Consequential:** This involves identifying the consequences that a decision made in the foreground system has on other processes and systems in the economy, both in the back-end system of the system being analyzed and in other systems. It models the system analyzed on these consequences. It includes the indirect effects of a system.

In the digital sector, LCA was initially applied mainly in the field of products, but its scope has expanded in recent years, first thanks to the ETSI 203 19918 standard and now thanks to the extensive work carried out by professional organisations in the telecommunications sector, such as the ITU[59], the NegaOctet consortium[60] for digital services or the eco-design cluster[61] for services in general.

The transition from a product to a service implies maintaining the multi-criteria and functional perspective but moving from a circular approach ("cradle to grave" i.e. from extraction to landfill throughout the life cycle) to a matrix approach encompassing the life cycle of all the equipment making up the three entities (user equipment, networks, data centres) that make up the digital service and enable it to operate.

This method of environmental diagnosis makes it possible to identify the stages and **avoid the transfer of impacts from one to another** but also **from one Tier to another**. For example, when moving from an on-premises solution to a SaaS solution in the cloud, the lifecycle analysis will ensure that the avoided impacts on users' endpoints will not be offset by additional impacts on the network.

57 *ISO 14040:2006 - Environmental management — Life cycle assessment — Principles and framework, https://www.iso.org/standard/37456.html*

58 *ISO 14044:2006 - Environmental management — Life cycle assessment — Requirements and guidelines, https://www.iso.org/standard/38498.html*

59 *ITU, https://www.itu.int/fr/Pages/default.aspx#/fr*

60 *NegaOctet, https://negaoctet.org/*

61 *Eco-design division, https://www.eco-conception.fr/*

5.2.2 Methodological approach to LCA

5.2.2.1 The different phases of an LCA

As presented in ISO 14040:2006, an LCA study consists of 4 interrelated phases:

1. **Definition of the objective and scope of action**
2. **Life Cycle Inventory (LCI) Analysis**
3. **Life Cycle Impact Assessment (LIIA)**
4. **Interpreting lifecycle results**

LCA is an iterative technique in which each phase uses the results of the others, thus contributing to the integrity and consistency of the study and its results. This is a holistic approach and transparency of use is therefore crucial to ensure proper interpretation of the results obtained.

Note: LCA deals with potential environmental impacts and therefore does not predict actual or absolute environmental impacts.

5.2.2.2 Definition of the objective and scope of action

The definition of the purpose of the study should describe the purpose of the study and the decision-making process for which it will support environmental decision-making. The purpose of an LCA should determine the intended application, the reasons for which the study is being conducted, the intended audience, i.e., the people to whom the results of the study are intended to be communicated, and whether the results are intended to be used in comparative statements that will be disclosed to the public.

The scope of an LCA (including system limitations, level of detail, data quality, assumptions made, study limitations, etc.) depends on the topic and the intended use of the study. The depth and breadth of a scope of action can vary greatly depending on the specific objective being pursued.

An LCA takes a structured, functional and/or declared unit approach. All subsequent analyses therefore relate to these units. If a comparison is necessary (only of goods or services performing the same function), it is necessary to choose a functional unit with reference to the function that the goods or services in question perform.

5.2.2.3 Life Cycle Inventory (LCI) Analysis

Data collection

This phase consists of the collection of data and calculation procedures to quantify the relevant inputs and output products of the system studied. The data to be included in the inventory must be collected for each unit process considered within the limits of the system studied.

Inventory of elementary flows

In an LCI, elementary fluxes must be accounted for within the boundaries of the system, i.e. flows of materials and energy from the environment without prior transformation by humans (e.g. consumption of oil, coal, etc.) or that enter nature directly (e.g. atmospheric emissions of CO_2, SO_2, etc.) without further transformation. Elemental fluxes include resource use, air emissions, and releases to water and land associated with the system.

The data collected, whether measured, calculated or estimated, makes it possible to quantify all the inputs and outputs of matter and energy from the various processes.

Allocation and assignment rules

In reality, few industrial processes produce a single result: industrial processes usually produce more than one product and/or intermediate products, or their waste is recycled. In this case, criteria must be applied to assign the environmental burden to the individual products, as is the case in the study carried out.

Data quality assessment

LCA and LCI data for digital services and equipment remain difficult to obtain. Most LCA-inspired studies use single-criteria data (such as energy or global warming), or heterogeneous datasets.

5.2.2.4 Life Cycle Impact Assessment (LCIA)

Selection, classification and characterization of impacts

This phase aims to assess the significance of the potential environmental impacts based on the results of the inventory. This process involves the selection of impact categories (e.g., climate change) and the assignment of inventory data to these impact categories with impact category indicators (e.g., climate change in 100 years according to the CML impact model) by means of a characterization factor. This phase provides information for the interpretation phase.

Normalization and weighting

The numerical results of the indicators can also be ordered, normalized, grouped and weighted. This approach facilitates interpretation, but there is no scientific consensus on a sound method for conducting such an assessment.

5.2.2.5 Interpreting lifecycle results

Interpretation is the final phase of LCA. These are the results of the inventory or evaluation, or both, that are summarized and discussed in a comprehensible way. This section is used by the study recipients as a basis for conclusions, recommendations and decision-making in accordance with the established objective and scope.

Sensitivity and uncertainty analysis

Some of the data is collected from the literature, which means that the model is based on secondary and therefore possibly uncertain data. In order to determine the order of magnitude of the variations in the results, sensitivity and uncertainty analyses must be performed.

5.2.3 Definition of the objective and scope of actio

5.2.3.1 Objective of the study

Generally speaking, carrying out a life cycle analysis of a sector of activity (in this case, digital activities) means putting it in relation to its real physical and environmental context. It is relevant to apply this method to:

- Establish a quantitative diagnosis of the direct environmental impacts of digital activities at the global level;
- Identify key contributors to impacts;
- Identify the most significant levers for improvement;
- To allow monitoring of environmental performance in the following years;
- Communicate objectively on environmental performance and opportunities for improvement;
- Fuelling a responsible digital strategy focused on environmental performance.

This study therefore aims to **measure the environmental impacts of digital technologies and infrastructures around the world** in order to shed light on the environmental impacts of digital technology in order to **inform the general public and generalize collective awareness** and **empower citizens and strategic actors**.

5.2.3.2 Framework

This work is a **Simplified Life Cycle Assessment**.

To the extent possible and depending on our context, the methodological choice will refer to ISO 14040:2006 and 14044:2006, as well as complementary standards such as:

- PEF Guidelines[62] and PEFCR (Product Environmental Footprint Category Rules Guidance) relative to IT equipment
- ITU L1410[63] - Methodology for environmental life cycle assessments of information and communication technology goods, networks and services

5.2.3.3 Conduct of the study

The study was organized according to the following phases:

- **A scoping phase** to define the scope of the study and encompass the complexity of the system;
- **A data collection phase** covering all the equipment and uses included in our scope. This phase consisted of an in-depth literature search, workshops with experts, etc.;
- **A development phase of a tailor-made tool** to calculate the environmental impacts of digitalization at a global level using the methodology of life cycle assessment;
- **Inventory and** life cycle impact analysis;
- **Interpretation** of the results.

5.2.3.4 Intended audience

The target audience is mainly the **general public**.

The final study and the final data generated are licensed under a **Creative Commons license (CC-By-NC-ND)** to allow wide access and use of the results for the common good.

The results are not intended to be used in comparative assertions intended for public disclosure.

5.2.4 Validity of the results

The results are valid only for the situation defined by the assumptions described in this report.

The conclusions may change if these conditions differ. The suitability and reliability of use by Third Parties or for purposes other than those mentioned in this report can therefore not be guaranteed by LCA practitioners. It is therefore the sole responsibility of the sponsor.

Scope of the study

As part of our study, the aim is to provide the latest knowledge (2023) on the environmental impacts of digital technologies using the LCA method described above, on a global scale.

Only **direct impacts are taken into account**. Indirect, positive and negative impacts (such as direct or indirect rebound effects, substitution, structural changes, etc.) are not taken into account. This constitutes an **attributional LCA**.

The following paragraphs provide details on the scope of the study, namely:

- Functional Unit;
- Limitations of the system: inclusion, exclusion, cut-off criteria;
- Geographical, temporal and technological representativeness;
- Life cycle phases considered;
- Quantification of environmental impact, characterization methods;
- Types and sources of data;
- Data quality requirements.

62 *PEF METHOD - European Commission, https://green-business.ec.europa.eu/environmental-footprint-methods/pef-method_en*

63 *ITU-T L.1410 - Methodology for environmental life cycle assessments of information and communication technology goods, networks and services | GlobalSpec, https://standards.globalspec.com/std/9953730/itu-t-l-1410*

5.2.5 Product System to Study

5.2.5.1 Technological boundaries

This study focuses on **digital services on a global scale**. The definition of digital used to account for what is or is not part of the digital perimeter in this study is as follows: All electronic equipment that uses binary data.

The scope of digital services covered three categories also known as "Third Parties":

- **Tier I: User devices**: These are all the terminals that users use as an interface with the digital channel;
- **Tier II: Networks**: These are all the networks, fixed, mobile and backbone (the backbone of the network) that allow digital data to circulate;
- **Tier III: Data centers**: These are suitable and secure places for hosting computer equipment allowing the processing and storage of digital data.

5.2.5.2 Function and functional unit

The functional unit is the reference unit used to relate inputs and outputs as well as the environmental performance of one or more product systems.

The function studied is the **provision of digital services around the world**, used by consumers, private and public organizations for one year. Due to this wide diversity of use, it is difficult, if not impossible, to classify the use of digital services worldwide into functional units.

In this case, the concept of functional unit is replaced by a **declared unit:**

« Equipment and systems related to global digital services for one year. »

And at the individual level:

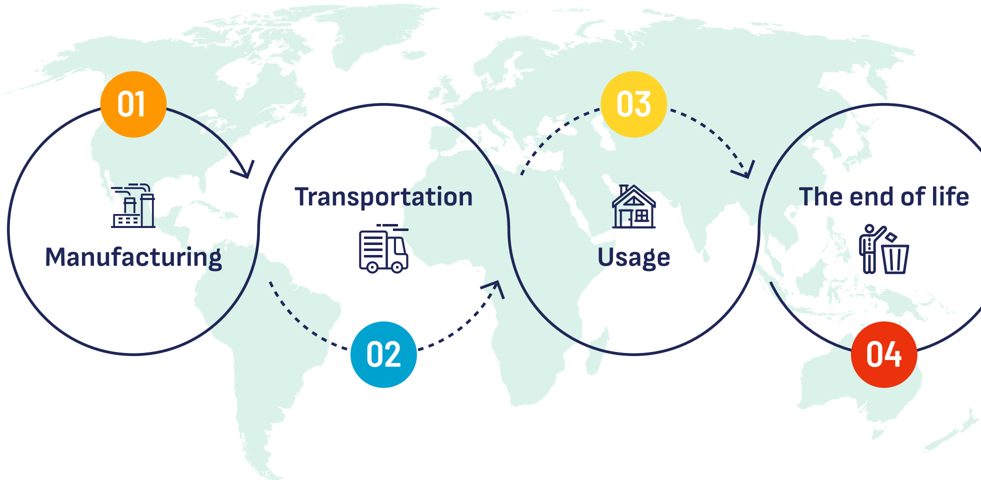
« Equipment and systems related to global digital services for one year and reported to an Internet user. »

5.2.5.3 System Limitations

Life Cycle Stages Studied

During this study, we looked at the following stages of the life cycle:

1. **Manufacturing stage:** Includes raw material extraction, upstream transportation, and manufacturing processes.
2. **Transportation Stage:** Includes transportation between the manufacturer and the installation site.
3. **Stage of use:** Includes at least the electricity used by the computer equipment.
4. **End-of-Life Stage:** Includes end-of-life processing of IT equipment.



Temporal limits

This study covers all digital services worldwide in **2023**. Therefore, the selected data are as representative as possible of the year 2023. If any data are missing, they have been replaced and extrapolated as much as possible with the most recent data possible. Where applicable, this is specified in the methodology. The oldest data used is from 2018.

Geographical boundaries

The geographical scope considered in this study covers IT equipment located worldwide.

Inclusions and exclusions

As presented earlier, the study covers digital service infrastructures and devices located around the world across the three Tiers. The Figure 6 represents the division of digital technology according to the 3 Thirds.

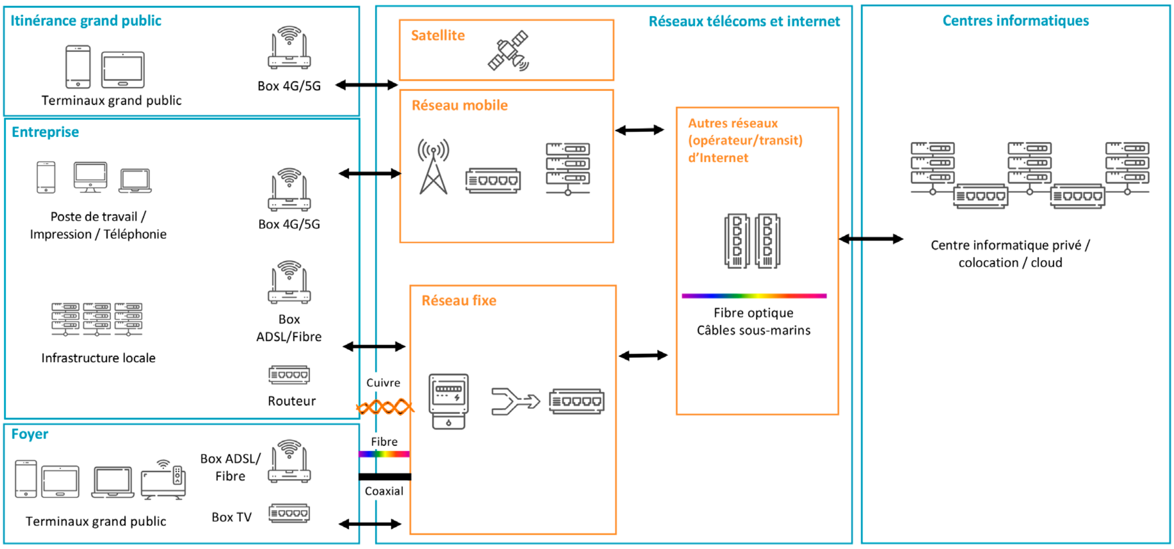


Figure 6: Modeling Digital Services in 3 Tiers

The list of equipment covered or excluded by the study is presented below:

1. Tier I — User equipment:

Included: Desktop, Laptop, Tablet, Mobile Phone, Standard Mobile Phone (GSM), Landline Phone, Screen, TV, Smart TV, Projector, TV Box, Game Console, Printer, IoT Equipment (Automotive, Security, Sensor, Building).

Excluded: packaging, charger and power supply, peripherals (keyboard, mouse, controller, etc.), satellite phone, smartwatch, 3D printer, docking station, DVD / Blu-ray / Ultra HD player, interactive whiteboard, MP3 player, stand-alone home audio equipment, ATM, cash register and payment terminal, public WLAN access point, security camera, camera and the connected part of vehicles.

The above items are excluded due to a lack of available data.

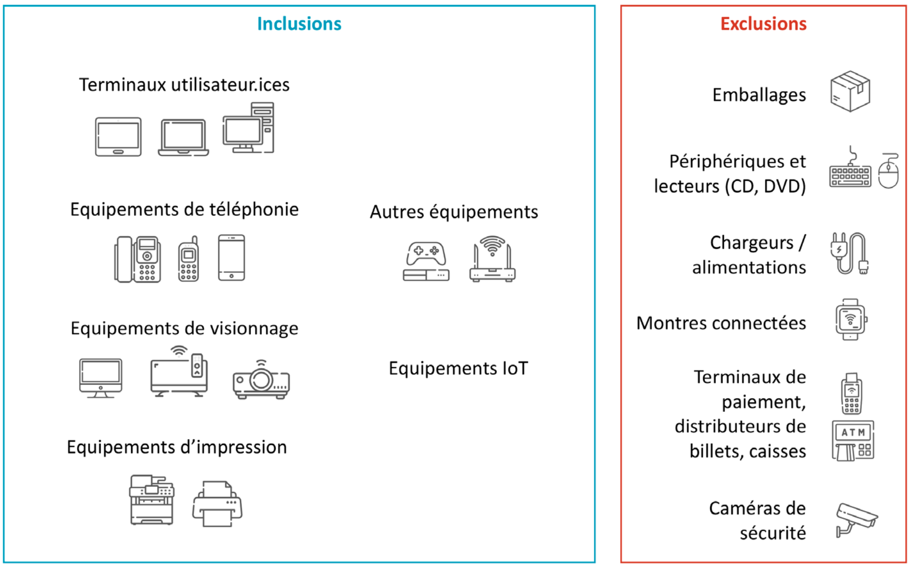


Figure 7: Diagram of the main inclusions and exclusions concerning the scope of Tier I

2. Tier II – Networks: The modelling is based on the study on the assessment of the environmental footprint of the provision of internet access in France by ADEME[64].

The list of equipment taken into account in this study is given below:

- **Fixed network:** Router/backhaul switch, ADSL and fiber box, ONT, copper cable, fiber optics, copper and fiber local loops (copper cables, fiber optics, poles, trenches), DSLAM, OLT, aggregation router, WDM aggregation loop equipment, WDM backbone equipment, peering router, hosting site;
- **Mobile Network:** Multi-band passive antenna, radio amplifiers, BBU 2G/3G/4G/5G, active antenna, radio site collection router, 4G/5G security gateway, aggregation router, WDM aggregation loop equipment, WDM backbone equipment, peering router, MME/SGSN, HSS/HLR, SP-GW/GGSN, PCRF, Gi LAN, FW roaming, fiber optic, site hosting.

Conversely, the main exclusions are the following: TV boxes (taken into account in Tier I), Wi-Fi repeaters, RU amplifiers, microwave links, fixed and mobile DNS, sub-distributor, sharing point, connection point, fixed wireless access (FWA) connections.

In addition, satellite internet access, the international backbone and submarine cables are excluded from the study.

The exhaustive and justified list of inclusions and exclusions can be found in the ADEME study directly.

3. Tier III – Data Centers:

Included: computing server, storage server, dedicated AI server, network equipment, UPS, battery, air conditioning, power consumption of the technical environment (cooling and power supply of IT equipment).

Excluded: manufacture, distribution and end-of-life of electrical power systems (transformers, generators, etc.), refrigerant leakage, small IT and non-IT equipment, and buildings.

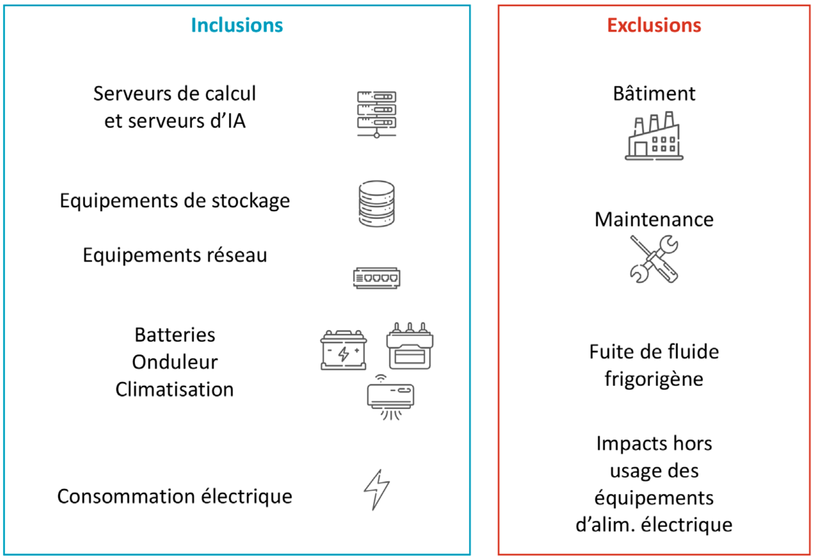


Figure 8: Diagram of the main inclusions and exclusions concerning the scope of Tier III

64 *Evaluation of the environmental footprint of the provision of internet access in France - The ADEME bookstore, https://librairie.ademe.fr/industrie-et-production-durable/6789-evaluation-de-l-empreinte-environnementale-de-la-fourniture-d-acces-a-internet-en-france.html*

In addition, the following flows were excluded from the study because they were considered to be outside the scope:

- The design and research and development work for each piece of equipment.

The following flows were excluded from the study as they were considered negligible:

- Input peripheral equipment (keyboard, mouse, graphics tablet, etc.), charging or power devices;
- Software and hardware upgrade of equipment during its life;
- The equipment and tools necessary for the installation and maintenance of equipment and infrastructure.

The following flows have been excluded from the study due to the lack of homogeneous data on all third parties

- Lighting, heating, cleaning of equipment production facilities;
- The construction and maintenance of equipment production infrastructure.

Cut-off criteria

In general, environmental modelling should cover a defined percentage (greater than or equal to 95%) of equipment or systems:

- The mass of intermediate flows not taken into account must be less than or equal to 5 % of the mass of the elements of the reference product corresponding to the functional unit,
- The energy flows not taken into account shall be less than or equal to 5 % of the total primary energy used during the life cycle of the reference product corresponding to the functional unit.

In the specific context of the study, no flows were explicitly excluded by the cut-off criterion rule. However, the databases used apply the above cut-off criterion. Thus, for example, flows such as certain packaging or upstream transport could be excluded by this cut-off criterion, during the creation of life cycle impact data. The environmental scan reveals the parts of the service under consideration that have the most impact and will be subject to a sensitivity analysis.

5.2.6 Allocation procedures

The only allocations made directly in this study are the **temporal allocations** to reduce the impacts of equipment and infrastructure to a period of one year.

Specific allocation procedures were carried out in the source study[65] from which the results on Tier 2 - Network were derived. For more details, consult the source study directly.

5.2.7 The AICV methodology and types of impacts

5.2.7.1 Selection, classification and characterization of impacts

The analysis is based on the 16 indicators proposed by the European Commission in the framework of the Product Environmental Footprint (PEF) project[66], using the PEF 3.1 version.

In order to make these indicators as comprehensible as possible and to focus recommendations on key topics, the set of indicators is usually reduced to an appropriate selection. This is done using the normalization and weighting approach. The following indicators were selected, representing more than 80% of the overall weighted results:

65 https://librairie.ademe.fr/industrie-et-production-durable/6789-evaluation-de-l-empreinte-environnementale-de-la-fourniture-d-acces-a-internet-en-france.html

66 Environmental Footprint Methods - European Commission, https://green-business.ec.europa.eu/environmental-footprint-methods_en

	Environmental Indicator Name	Acronym and unit	Weight in the total footprint
	Resources Use, minerals and metals	ADPe (kg Sb eq.)	**23,71 %**
	Global warming potential	GWP (kg CO_2 eq.)	**23,25 %**
	Resource Use, fossils	ADPf (MJ)	**15,62 %**
	Particulate Matter	PM (Disease Occurence)	5,82 %
	Eutrophication, freshwater	Epf (kg P eq.)	5,71 %
	Ionizing radiation, human health	IR (kBq U_{235} eq.)	5,52 %
	Acidification	AP (mol H^+ eq.)	5,42 %

Table 29: *List of environmental indicators representing 85% of the overall footprint according to the PEF standardisation and weighting method*

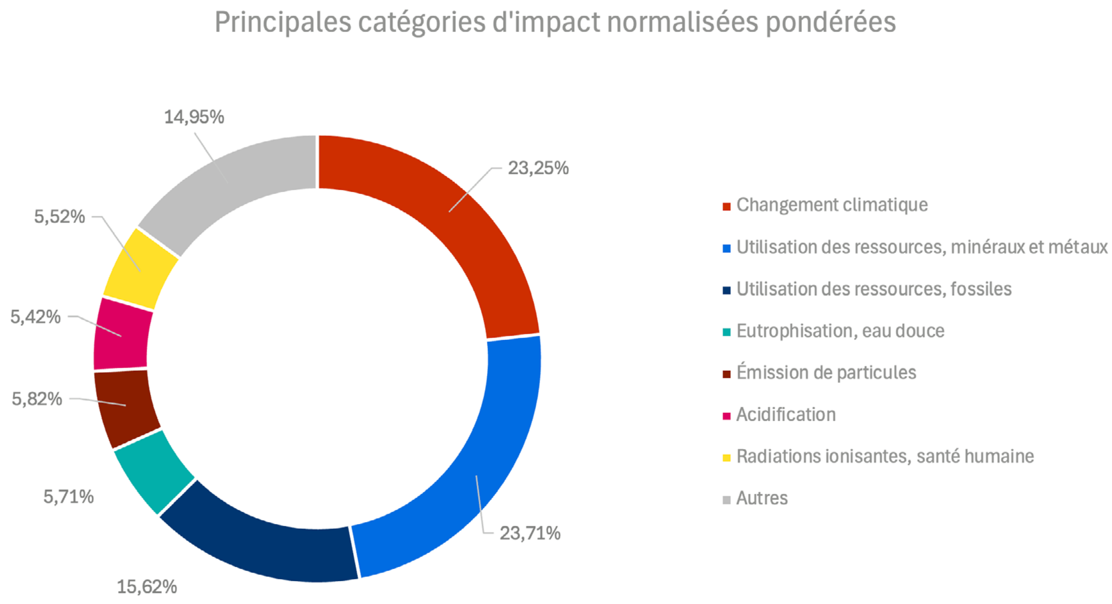


Figure 9: *Weighted Standardized Major Impact Categories*

The use of mineral and metal resources, greenhouse gas emissions, and the use of fossil resources together account for 62.6% of the impacts, according to the PEF method. This is followed by eutrophication of fresh water, the emission of fine particles and ionising radiation emissions, for a total of 79.6% of the impacts. With acidification, the total of the indicators presented reaches a representation of 85.1% according to the PEF method.

The indicators Land use and water use could not be included in this study due to problems related to the allocation of flows concerning them, making their results inconsistent.

Note: Despite a particularly favourable weighting coefficient for the indicator related to global warming potential, the indicator that comes in first place is the indicator of use of minerals and metals resources67. Indeed, for the digital field, a large part of the impacts come from the use of ores and metals in the manufacture of digital equipment. For example, the manufacture of a smartphone requires more than 50 different metals[68].

These environmental indicators are complemented by a flow indicator: total **primary energy consumption** (TPE), in MJ. Unlike environmental indicators, which report on the effects on the environment, flow indicators quantify the quantities of material and energy used. These indicators cannot be standardized and weighted but provide an additional understanding of environmental impacts.

5.2.7.2 Normalization and weighting

The numerical results of the indicators can also be ordered, normalized, grouped and weighted. This approach facilitates interpretation, but there is no scientific consensus on a robust way to conduct such an assessment.

In this study, we used the normalization and weighting factors provided by the JRC in the PEF/OEF METHOD (EF 3.1), published on 20 November 2019. Table 27 lists the normalization factors and Table 28 lists the weighting factors used.

		Acronym and unit	Normalization value
	Acidification	AP (mol H^+ eq. /person)	5,56E+01
	Global warming potential	GWP (kg CO_2 eq. /person)	7,55E+03
	Ecotoxicity, Freshwater	Ecotox (CTUe / person)	5,67E+04
	Particulate Matter	PM (Disease Occurence) / person)	5,95E-04
	Eutrophication, freshwater	Epf (kg P eq. / person)	1,61E+00
	Eutrophication, marine	Epm (kg N eq. / person)	1,95E+01
	Eutrophication, terrestrial	Ept (mol N eq. / person)	1,77E+02
	Human Toxicity, cancer	CTUh-c (CTUh / person)	1,73E-05
	Human Toxicity, non-cancer	CTUh-nc (CTUh / person)	1,29E-04
	Ionizing radiation, human health	IR (kBq U_{235} eq. / person)	4,22E+01
	Land use	LU (pt / person)	8,19E+05

67 See Table 29.

68 ISF SystExt - Smartphone 2017, https://www.systext.org/sites/all/animationreveal/mtxsmp/#/7

		Acronym and unit	Normalization value
	Ozone depletion	ODP (kg CFC-11 eq. / person)	5,23E-02
	Photochemical ozone formation, human health	POF (kg NMVOC eq. / person)	4,09E+01
	Resource use, fossils	ADPf (MJ / person)	6,50E+04
	Resource Use, Minerals and Metals	ADPe (kg Sb eq. / person)	6,36E-02
	Water use	WU (m^3 eq. / person)	1,15E+04

Table 30: List of environmental indicators and their standardisation factors proposed by the JRC

Environmental Indicator Name		Weighting factor [%]
	Acidification	6,20 %
	Global warming potential	21,06 %
	Ecotoxicity, Freshwater	1,92 %
	Particulate Matter	8,96 %
	Eutrophication, freshwater	2,80 %
	Eutrophication, marine	2,96 %
	Eutrophication, terrestrial	3,71 %
	Human toxicity, cancer	1,84 %
	Human toxicity, non-cancer	2,13 %
	Ionizing radiation, human health	5,01 %
	Land use	7,94 %
	Ozone depletion	6,31 %
	Photochemical ozone formation, human health	4,78 %

	Environmental Indicator Name	Weighting factor [%]
	Resource use, fossils	8,32 %
	Resource Use, Minerals and Metals	7,55 %
	Water use	8,51 %

Table 31: List of environmental indicators and their weighting factors proposed by the JRC

5.2.8 Data type and source

An LCA calculation requires two different types of information:

- **Data related to the physical characteristics** of the system studied (such as the number of smartphones used worldwide, and the amount of electricity consumed by smartphones). For this project, these data are aggregated from various studies, reports and assumptions made.
- **Data relating to the life cycle impacts** of the IT equipment or energy flows that enter the system under study. This data comes from the NegaOctet database.

5.2.8.1 Physical Characteristics Data

The collection of data relating to the quantities and physical characteristics (lifespan, electricity consumption, duration of use, technical configuration, etc.) of digital equipment is based on **various bibliographic resources** (institutional reports, scientific studies, market studies, etc.) and **hypotheses made**.

5.2.8.2 Life cycle impact data

Data related to the lifecycle impacts of IT equipment or energy flows are classified into the following categories: primary data and secondary data.

Primary **data** is site-specific data. Examples include data collected in the manufacturing plant where product-specific processes are carried out or data on materials or electricity supplied by a contracted supplier capable of providing data on the services actually provided, transport carried out on the basis of actual fuel consumption and associated emissions, etc.

Secondary data is divided into:

- **Specific data:** data from commonly available data sources that meet the prescribed data quality characteristics, i.e. accuracy, completeness and representativeness,
- **Surrogate data:** data from commonly available data sources that do not meet all the quality characteristics of the "selected secondary data".

Most of the lifecycle data was extracted from the NegaOctet database. For mobile and fixed network modelling (Tier II), lifecycle data are secondary data from a previous study.

In this project, the NegaOctet database (published in December 2021) is used. The NegaOctet database is a three-year project, co-funded by the French Environment Agency (ADEME). This database has undergone a critical review process by a scientific research institute. For this reason, the environmental impact database was excluded from the scope of the critical review of this study. This choice of database is explained by the fact that it is the only homogeneous LCI database for digital equipment to date in the world, allowing the calculation of PEF/OEF impact indicators (EF 3.1).

5.2.9 Data quality requirements

In accordance with the objectives and limitations of the system, the required quality of the data collected follows the rules described below:

- **Technology representativeness:** Representative of technologies between 2018 and 2023.
- **Geographical representativeness:** Specific data corresponding to equipment related to digital services worldwide during their use. If data are missing, assumptions are warranted where possible.
- **Representativeness over time:** Data from 2018-2023. Where data are more than four years old (prior to 2018), they have been extrapolated with assumptions and justified where possible.
- **Comprehensiveness:** The application of the cut-off criteria is complex given the quantity of equipment and processes. The study includes all identified flows, unless otherwise specified.
- **Parameter uncertainty:** For most data, only one source was available, resulting in a high degree of uncertainty. Where possible, the data were cross-checked with additional sources.
- **Methodological relevance and consistency:** The methodology used is based on ISO 14040/44 standards. A consistent data collection methodology for all components studied was applied.

5.2.10 LCA Modeling Tool

The evaluation of all global digital services for one year was carried out by compiling all the data related to equipment, environmental data and making the allocations in an **Excel spreadsheet-type tool**.

5.2.11 Critical Review Considerations

The critical review is a procedure to certify that the Life Cycle Assessment (LCA) complies **with international standards** (ISO 14040/44) and complementary national standards to meet the objectives of the study. It is carried out mainly when the results are intended to be communicated to the public or when they are comparative claims. Its objective is to **limit the risks** in terms of:

- **Inconsistency** between the purpose, data collection, and results of the study;
- Disclosure of **unfounded findings**.

In our context, critical review also aims to:

- Identify the important elements and **limitations** of the study so that it is not distorted and in order to avoid biases in communication;
- Ensure the **relevance** and **reliability** of the information given.

An external critical review was conducted between September and November 2024, by:

- Augustin Wattiez, PhD student at the Catholic University of Louvain;

The critical review was carried out in the following steps:

- Sending the methodology and inventory data;
- Sending remarks and comments from the critical review panel.
- Consideration of remarks and comments in the conduct and drafting of the study.

5.3 Data used in the LCA model

5.3.1 Summary

Tier	Parameters	Unit	Quantity in 2023	Lifetime (year)
–	Population	unit	8 009 000 000	–
–	Number of Internet users	unit	5 350 000 000	–
–	Number of mobile phone users	unit	5 610 000 000	–
I	Desktop – Basic	unit	92 950 000	6
I	Desktop – Family	unit	92 950 000	6
I	Desktop – Gaming	unit	139 425 000	6
I	Desktop – Power Gaming	unit	46 475 000	6
I	Desktop – Power User	unit	92 950 000	6
I	Laptop – Type Chromebook	unit	419 816 000	5
I	Laptop – Office Type	unit	524 770 000	5
I	Laptop – Gaming Type	unit	104 954 000	5
I	Tablet – Entry-level (mini < 9 inches)	unit	91 980 000	3
I	Tablet – Standard (9 to 11 inches)	unit	275 940 000	3
I	Tablet – Premium (10 to 13 inches)	unit	91 980 000	3
I	Landline	unit	1 750 600 000	8
I	Smartphone – LCD	unit	2 363 136 000	3
I	Smartphone – OLED	unit	2 270 464 000	3
I	Feature phone	unit	950 800 000	4
I	Monitor – 24 inches, LCD	unit	906 165 240	7
I	Monitor – 39 inches, OLED	unit	634 760	7
I	TV – 45 inches, LCD	unit	1 445 794 000	7
I	TV – 53 inches, OLED	unit	14 753 000	7
I	TV – 68 inches, OLED	unit	14 753 000	7
I	Multifunction printer	unit	584 770 000	6
I	Game Console – Living Room	unit	153 624 008	6,5
I	Game Console – Portable	unit	140 055 992	6,5
I	Video projector	unit	567 000 000	5
I	Box TV	unit	773 080 312	5
I	Smart speaker	unit	717 800 000	5
I	IoT Security – Video	unit	448 751 832	9
I	IoT Security – Control	unit	747 904 014	5
I	IoT Auto – Water heating	unit	448 736 126	12

Tier	Parameters	Unit	Quantity in 2023	Lifetime (year)
I	IoT Auto - Street lights	unit	448 736 126	10
I	IoT Auto - Space	unit	448 751 832	12
I	IoT Auto - Lighting	unit	1 196 640 140	7
I	IoT Auto - Cooking	unit	448 736 126	15
I	IoT Auto - Audio	unit	1 495 808 028	4
I	IoT Auto - Appliances	unit	598 320 070	12
I	IoT Smart meters	unit	1 869 783 594	12
I	IoT Sensors - Res-WiFi	unit	74 791 972	5
I	IoT Sensors - Res-LE	unit	388 911 972	5
I	IoT Sensors - Industry	unit	673 112 042	5
I	IoT Sensors - Health	unit	987 232 042	5
I	IoT Gateway - Bus	unit	82 268 028	7
I	IoT Gateway - LE to WiFi	unit	74 791 972	7
I	IoT Comm building control	unit	5 235 328 098	12
I	IoT Blinds + windows	unit	37 395 986	5
II	Amount of data exchanged on the fixed network	Go	4 490 000 000 000	-
II	Number of fixed network subscribers	unit	1 495 600 000	-
II	Amount of data exchanged on the mobile network	Go	1 505 447 000 000	-
II	Number of mobile network subscribers	unit	7 029 800 000	-
III	Server - High-end (2 high-end CPUs, 3072 GB, 8 TB SSD, 1 GPU)	unit	116 550	5,5
III	Server - Mid-Range (2 high-end CPUs, 128 GB, 8 TB SSD)	unit	2 913 750	5,5
III	Storage Server — HDD, 48 Drives	unit	39 572 610	5,5
III	Storage Servers — SDD, 48 Drives, TLC, 1024 GB Per Drive	unit	35 097 090	5,5
III	AI-configured server	unit	1 779 816	5,5
III	Data center network equipment	unit	8 229 473	5
III	Inverter	unit	899 030	10
III	Battery	unit	58 548 400	10
III	Air conditioning	unit	225 686	15
III	Non-IT Power Consumption	kWh	185 913 473 654	1
III	Average PUE	-	1,58	-

***Table 32:** Summary of Inventory Data*

5.3.2 Tier I – Internet equipment

5.3.2.1 General information

For each Tier I piece of equipment, we give:

- The definition;
- The number of units in the number in 2023;
- The average annual final electricity consumption for equipment representative of this category;
- The frequency of use, i.e. the average duration of "active" use[69] of a device per Internet user;
- The average lifespan for a representative piece of equipment in this category;
- The market penetration rate, i.e. the rate (0-100%) measuring the market coverage of the equipment in question. This value is not directly used in the calculations, but it allows when available to check the consistency of the number of units obtained.
- Technical characteristics, i.e. the definition of one or more categories of equipment with their technical characteristics (screen size, storage capacity, etc.) It makes it possible to model environmental impacts more precisely.

5.3.2.2 Phones

5.3.2.2.1 Mobile phones

5.3.2.2.1.1 Smartphones

- ***Definition***

A **smartphone** is a mobile phone that performs many of the features of a computer, typically having a touchscreen interface, internet access from Wi-Fi and mobile networks, a GPS connection, and an operating system (OS) capable of running downloaded applications[70].

- ***Number of units worldwide in 2023***

4.6 billion units

This figure is estimated from Counterpoint Research's market research[71]. This data is consistent with other sources such as those from Gartner[72] and IDC[73]. The data was constructed from annual data on global shipments and consolidated according to an estimated average lifespan of 3 years (see below).

According to smartphone market statistics[74], the share of reused and refurbished smartphones continues to increase. Thus, 845 million smartphones have been added to the 3.79 billion new units shipped in the last 3 years.

69 For always-on user devices, such as smartphones, the frequency of use is defined as the duration of use with the screen on.

70 VHK and Viegand Maagøe for the European Commission, ICT Impact Study, Assistance to the European Commission – ICT Impact study – FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p.108

71 Global Smartphone Market Share: Quarterly, https://www.counterpointresearch.com/insights/global-smartphone-share/

72 Gartner Forecasts Worldwide Device Shipments to Decline 4% in 2023, https://www.gartner.com/en/newsroom/press-releases/2023-01-31-gartner-forecasts-worldwide-device-shipments-to-decline-four-percent-in-2023

73 IDC, Closed Source, https://www.idc.com/getdoc.jsp?containerId=prUS50604823

74 Worldwide Market for Used Smartphones Is Forecast to Surpass 430 Million Units with a Market Value of $109.7 Billion in 2027, According to IDC, https://www.idc.com/getdoc.jsp?containerId=prUS51804924

- ***Power consumption***

3.9 kWh /year /equipment[75]

- ***Frequency of use***

4h37 of use /day[76]

Data vary from country to country. This data is a global average data, dating from 2023.

- ***Average Lifespan***

3 years

The working life is estimated here at 3 years[77] on the basis of the ecosmartphone Task 2 §4.1.2 study[78] cross-checked by other studies.[79]

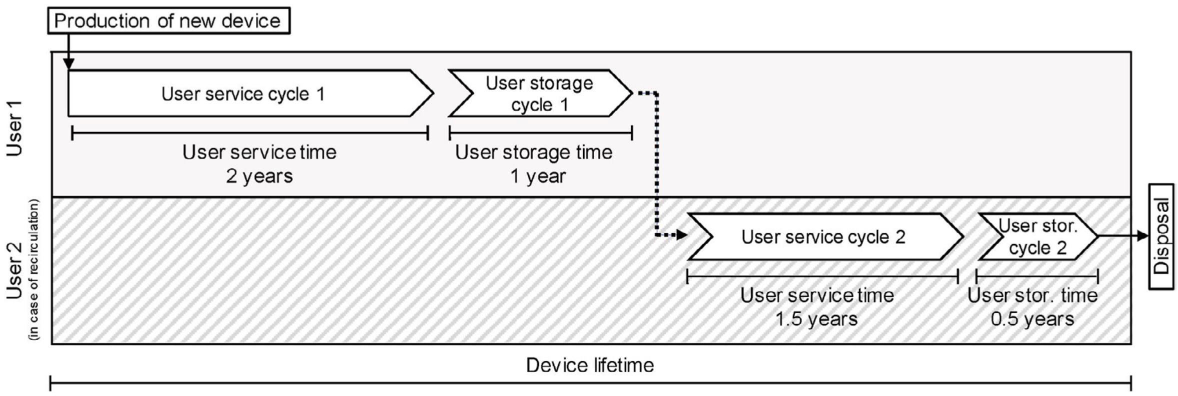


Figure 10 : *Representation of the life cycle of a smartphone*[80]

- ***Market penetration rate***

In 2023, 78.1% (5.228 billion) of people aged 10 and over own a mobile phone.[81] In addition, in 2023 there were 7.01385 billion active subscriptions to mobile broadband telephony, however these subscriptions listed by the ITU do not distinguish between subscriptions linked to a smartphone and subscriptions linked to connected equipment (SIM cards embedded in cars, and in other types of connected equipment with subscription).[82]

75 VHK and Viegand Maagøe for the European Commission, ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 120

76 Time Spent Using Smartphones (2024 Statistics), https://explodingtopics.com/blog/smartphone-usage-stats

77 European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Schischke, K., Clemm, C., Berwald, A. et al., Ecodesign preparatory study on mobile phones, smartphones and tablets — Publications Office of the European Union, 2021, https://data.europa.eu/doi/10.2873/175802

78 European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Schischke, K., Clemm, C., Berwald, A. et al., Ecodesign preparatory study on mobile phones, smartphones and tablets — Publications Office of the European Union, 2021, https://data.europa.eu/doi/10.2873/175802

79 FANGEAT Erwann, ADEME, Laurent ESKENAZI, Eric FOURBOUL, Hubblo, Julie ORGELET DELMAS, DDemain, Etienne LEES PERASSO, Firmin DOMON, LCIE Bureau Veritas, Evaluation de l'impact environnemental d'un ensemble de produits reconditionnés — rapport final, 2022, https://librairie.ademe.fr/ged/6720/ademe_impact_environnemental_reconditionnement_rapport.pdf § p. 28

80 Jan C.T. Bieser, Yann Blumer, Linda Burkhalter, René Itten, Marilou Jobin, Lorenz M. Hilty, Consumer-oriented interventions to extend smartphones' service lifetime - ScienceDirect, Volume 7,2022,100074,ISSN 2666-7843, https://www.sciencedirect.com/science/article/pii/S2666784322000286?via%3Dihub#fig1

81 Facts and Figures 2023 - Mobile phone ownership, https://www.itu.int/itu-d/reports/statistics/2023/10/10/ff23-mobile-phone-ownership/

82 ITU DataHub - Fixed and mobile subscriptions: https://datahub.itu.int/dashboards/?id=2, indicates 87.4% of mobile broadband

- ***Technical characteristics***

	Entry-level	Mid-range
Display Technology	Touch LCD	Touch OLED
Screen size (inch)	6,6	6,6
Distribution (%)	51 %	49 %

Table 33: *Technical characteristics of the smartphone ranges used in the model*

According to a study by Counterpoint Research[83], 49% of smartphones sold in early 2023 now had an OLED display. So, we considered 49% OLED smartphones and 51% LCD smartphones in this study.

- ***Bounds***

Data on **dormant stock**, i.e. equipment that is not used but is not sent to an end-of-life channel, is difficult to obtain[84]. This stock is supposed to be non-negligible for smartphones in particular. This creates uncertainty about the quantity of smartphones, which is therefore underestimated. This does not impact the amount of electricity consumed because this equipment is not used.

5.3.2.2.1.2 Feature phones

- ***Definition***

A **feature phone** is a type of mobile phone that has more functions than a standard mobile phone for calls and text messages but is not equivalent to a smartphone. Feature phones can make and receive calls, send text messages, and offer some of the advanced features found on a smartphone[85].

- ***Number of units worldwide in 2023***

950.8 million units

According to feature phone market statistics[86], more than 200 million units are shipped every year. The quantity data used was constructed from annual global shipment data and consolidated according to an estimated average shelf life of 4 years (see below).

- ***Power consumption***

0.6 kWh /year /equipment

Feature phones consume significantly less than smartphones, according to the Borderstep study[87].

- ***Frequency of use***

No data available.

subscriptions worldwide in 2023. With 8.025 billion people on earth in 2023, this makes a total of 7.01385 billion active mobile broadband subscriptions worldwide in 2023.

83 Share of OLED Smartphones at Record High, https://www.counterpointresearch.com/insights/smartphone-oled-penetration-q1-2023/

84 GSMA —Methodology Estimating the number of dormant phones worldwide, https://www.gsma.com/betterfuture/wp-content/uploads/2023/06/Research-Methodology-2023.pdf & https://www.ecosmartphones.info/documents/ task 2 §4.1.2

85 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 108

86 Global: feature phone market volume 2019-2029 | Statista, https://www.statista.com/forecasts/1401833/worldwide-feature-phone-market-volume

87 BMWK - Entwicklung des IKT-bedingten Strombedarfs in Deutschland - Abschlussbericht , https://www.bmwk.de/Redaktion/DE/Downloads/E/entwicklung-des-ikt-bedingten-strombedarfs-in-deutschland-abschlussbericht.html § p. 168

- ***Average Lifespan***

4 years

According to a study by the Borderstep Institute[88], the lifespan of feature phones is significantly longer than smartphones and is around 4 years.

- ***Penetration rate***

No data available.

- ***Technical characteristics***

No data available.

- ***Bounds***

The lack of precise data on the technical configuration as well as on the frequency of use creates uncertainty about the environmental impacts.

5.3.2.2.1.3 Landline Phones

- ***Definition***

A **landline phone** is a phone that is connected to a landline. This can be a landline, cable-connected phone, or a cordless handset (usually a DECT phone) that needs to be charged on a carrier, which can also act as the base for connecting the handset to the landline[89].

- ***Number of units worldwide in 2023***

1.7 billion units

The quantity data used was constructed from annual global shipment data[90] and consolidated according to an estimated average lifespan of 8 years (see below).

- ***Power consumption***

18 kWh /year /equipment[91]

- ***Frequency of use***

No data available.

- ***Average Lifespan***

8 years

According to the study by the Borderstep Institute[92], the lifespan of landline phones is estimated at 8 years.

- ***Penetration rate***

No data available.

88 BMWK – Entwicklung des IKT-bedingten Strombedarfs in Deutschland – Abschlussbericht , https://www.bmwk.de/Redaktion/DE/Downloads/E/entwicklung-des-ikt-bedingten-strombedarfs-in-deutschland-abschlussbericht.html § p. 169

89 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission – ICT Impact study – FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p.109

90 Landline Phones – Worldwide | Statista Market Forecast, https://www.statista.com/outlook/cmo/consumer-electronics/telephony/landline-phones/worldwide#volume

91 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission – ICT Impact study – FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p.120

92 BMWK – Entwicklung des IKT-bedingten Strombedarfs in Deutschland – Abschlussbericht , https://www.bmwk.de/Redaktion/DE/Downloads/E/entwicklung-des-ikt-bedingten-strombedarfs-in-deutschland-abschlussbericht.html § p. 169

- ***Technical characteristics***

No data available.

- ***Bounds***

The lack of precise data on technical characteristics and frequency of use creates uncertainty about environmental impacts.

5.3.2.3 Tablets

- ***Definition***

A **tablet** is a product that is a type of laptop that includes both a touchscreen and can be equipped with a physical keyboard.[93]

- ***Number of units worldwide in 2023***

459.9 million units

This value is determined from quarterly sales of tablets worldwide between 2011 and 2022. The data is aggregated by Statista and sourced from iSuppli, IHS, and IDC[94]. Values up to 2020 can be compared with the global tablet sales quantities by operating system from 2010 to 2020[95] and are consistent with this second source. No data for 2023 could be found.

- ***Power consumption***

19.4 kWh /year /equipment

This value comes from a study carried out in Europe and obtained from data from the ICT Impact Study[96] from 2020. No more recent data could be found. The uncertainty about this value is therefore high.

- ***Frequency of use***

3h15 /day[97]

This source does not distinguish between tablets and laptops. In addition, this data dates from 2020. No more recent data could be found. The uncertainty about this lifetime value is therefore high.

- ***Average Lifespan***

3 years

The lifespan here is estimated at 3 years. This value is consistent between the ADEME study on refurbished goods[98] in 2022 and the ICT impact study[99] in 2020.

93 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission – ICT Impact study – FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p.108

94 IHS; iSuppli; IDC. Période de sondage : 2011 à 2022, PC monitor unit shipments by quarter 2024 | Statista, février 2023, https://www.statista.com/statistics/352891/global-pc-monitor-shipments-by-quarter/

95 Strategy Analytics. Période de sondage : 2010 à 2022, Global tablet shipments by OS 2022 | Statista, juillet 2022, https://www.statista.com/statistics/273268/worldwide-tablet-sales-by-operating-system-since-2nd-quarter-2010/

96 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission – ICT Impact study – FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p.109

97 GlobalWebIndex's flagship report on device ownership and usage | bluesyemre, 2020, https://bluesyemre.files.wordpress.com/2020/05/globalwebindexe28099s-flagship-report-on-device-ownership-and-usage.pdf § p.10

98 FANGEAT Erwann, ADEME, Laurent ESKENAZI, Eric FOURBOUL, Hubblo, Julie ORGELET DELMAS, DDemain, Etienne LEES PERASSO, Firmin DOMON, LCIE Bureau Veritas, Environmental Impact Assessment of a Set of Refurbished Products — Final Report, https://librairie.ademe.fr/ged/6720/ademe_impact_environnemental_reconditionnement_rapport.pdf § p. 28

99 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission – ICT Impact study – FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p.109

- ***Penetration rate***

No data available.

- ***Technical characteristics***

We consider 3 models. The entry-level, mid-range and high-end, whose configurations vary as shown in the table below

	Entry-level (<300€)	Mid-range (>300€, <900€)	High-end (>900€)
Display Technology	Touch LCD	Touch LCD	Touch LCD
Screen size (inch)	10,2	10,3	11,1
Distribution[100] (%)	20 %	60 %	20 %

Table 34: *Technical characteristics of the ranges of tablets used in the model*

- ***Bounds***

The lack of more recent data than 2020 or 2022 for the various parameters (quantities, lifespan, electricity consumption, etc.) leads to a likely underestimation of the environmental impacts of tablets.

5.3.2.4 Laptops

- ***Definition***

A **laptop is** a computer designed specifically for portability and to be used for extended periods of time, with or without a direct connection to an AC power source. It has a built-in display.

- ***Number of units worldwide in 2023***

1.05 billion units

This data was calculated from 2 sources: Canalys and Trendforce. The average quantity sold reported by each test was calculated[101].

- ***Power consumption***

27.59 kWh /year /equipment

In the study on the impacts of digital technology in Europe[102], the annual consumption per device was established at 30.96 kWh. However, this value was based on a consumption for an average use of 3 hours and 50 minutes per day, and for this study we established a consumption of 3 hours and 15 minutes per day, which gives us an estimated updated consumption of 27.59 kWh/year/device for 3 hours and 15 minutes of daily activity.

For a total of 1,049,540,000 active devices in 2023, this corresponds to an annual consumption of 28,957 TWh/year.

- ***Frequency of use***

3h15 /day[103]

100 Distribution assumption based on a Gaussian curve, considering that the majority of purchases are made in the mid-range.

101 From Statista. Sources: Canalys Global PC Market data (2020-2024) and Trendforce (2025 to 2023 report published in 2023)

102 Bordage, F., de Montenay, L., Benqassem, S., Delmas-Orgelet, J., Domon, F., Prunel, D., Vateau, C. and Lees Perasso, E. GreenIT.fr, Digital in Europe: an approach to environmental impacts through life cycle assessment (NumEU) - Green IT, 2021, https://www.greenit.fr/NumEU/

103 GlobalWebIndex's flagship report on device ownership and usage | bluesyemre, 2020, https://bluesyemre.files.wordpress.com/2020/05/globalwebindexe28099s-flagship-report-on-device-ownership-and-usage.pdf § p. 10

This source does not distinguish between tablets and laptops. In addition, this data dates from 2020. No more recent data could be found. The uncertainty about this value is therefore high.

- ***Average Lifespan***

5 years[104]

- ***Penetration rate***

No data available.

- ***Technical characteristics***

Not all laptops have the same configurations. The ICT impact study report, for the European Commission[105], identifies the following categories, ranging from the most basic laptop to the most powerful computers: 0, I1, I2, I3, D1, D2. Categories with relatively similar configurations have been grouped here, namely categories I0 and I1 (Notebook), categories I2 and I3 (Office Automation), and categories D1 and D2 (Gaming).

In the absence of additional sources, we have made an assumption of the distribution of equipment by category, at the global level.

Medium Configurations	Notebook	Office automation	Gaming
Distribution assumption	40 %	50 %	10 %
Equipment Mass (kg)	1,5	1,54	2,3
Screen size (inch)	14,5	14,5	15,6
Display Technology	LCD	LCD	LED
Processor Name	AMD Ryzen 5	Intel Core i5	8th Gen Intel Core i7
RAM Capacity (GB)	13	8	16
SSD Storage Capacity (GB)	427	564	512
HDD Storage Capacity (GB)	0	0	0
PCB area (cm^2)	52,93	62,03	88,22
Graphics card name	Integrated	Integrated	NVIDIA Ampere Ge-Force RTX 2060 6GB
Battery Mass (g)	330	165	287
Power Supply Mass (g)	245	211	208

Table 35: *Technical characteristics of the typical configurations of laptops used in the model*

104 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 112 table 68

105 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 131

- ***Bounds***

The lack of data to more accurately determine the typical configurations and proportions of different categories of laptops on the market is a significant factor of uncertainty. We have tried to limit it by establishing transparent hypotheses, on the basis of a pre-existing categorisation which, to our knowledge, has not, to our knowledge, been called into question.

5.3.2.5 Desktop computers

- ***Definition***

A **desktop computer** is a computer whose main unit is intended to be placed in a permanent location and is not designed to be transported. It is only operational with external equipment such as the monitor, keyboard and mouse.

- ***Number of units worldwide in 2023***

464.75 million units

This data was estimated from IDC studies of annual desktop sales for the periods prior to 2022[106], and an interpolation between the 2022 estimate of the IDC 2022 study and the 2024 estimate of the IDC 2024 study[107], giving a result of 76.48 million units, in an order of magnitude quite close to the 2023 estimate of the IDC 2022 study, which estimated 2023 sales of desktop computers at 75.39 million. Another source, Canalys[108], gave a systematically lower estimate, in the order of 15 to 25 million units depending on the year, with much more marked downward effects and slightly more marked upward effects, but systematically corroborating the annual trend of the CDI.

- ***Power consumption***

95.8 kWh /year /equipment

For 464,750,000 pieces of equipment, this represents 49.29 TWh of electricity per year. This value comes from data from the ICT Impact Study[109] from 2020. No more recent data could be found. The uncertainty about this value is therefore high.

- ***Frequency of use***

3 hours 15 minutes /day[110]

This source does not distinguish between tablets and computers. In addition, this data dates from 2020. No more recent data could be found. The uncertainty about this lifetime value is therefore high.

- ***Average Lifespan***

6 years[111]

Two sources make it possible to identify the average lifespan of desktop computers, estimated at between 5 and 7 years on average for the other. For this equipment, whose components are among the

106 *Desktop PC shipments worldwide 2024-2028 | Statista, (version available in May 2023), https://www.statista.com/statistics/269044/worldwide-desktop-pc-shipments-forecast/*

107 *Desktop PC shipments worldwide 2024-2028 | Statista, (version available in November 2024), https://www.statista.com/statistics/269044/worldwide-desktop-pc-shipments-forecast/*

108 *Canalys Global PC Market (2020-2024)*

109 *VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 109*

110 *GlobalWebIndex's flagship report on device ownership and usage | bluesyemre, 2020, https://bluesyemre.files.wordpress.com/2020/05/globalwebindexe28099s-flagship-report-on-device-ownership-and-usage.pdf § P. 10*

111 *VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 112 table 68*
What is the Average Lifespan of a Computer?, https://www.hungerford.tech/blog/what-is-the-average-lifespan-of-a-computer/#:~:text=Even%20if%20you%20take%20pristine,to%20five%20years%20for%20laptops

most easily replaceable in the event of a breakdown or to improve its performance, it would be interesting to study what proportion of equipment on the market is subject to the occasional replacement of some of its components rather than being replaced as a whole. No studies on this topic were found.

- ***Penetration rate***

No data available.

- ***Technical characteristics***

Not all desktops have the same configurations. The ICT impact study report, for the European Commission, identifies the following categories, ranging from the lowest-end computer to the most powerful computers: 0, I1, I2, I3, D1, D2. The Type 0 and I1 categories of computers have been grouped into a single category, with their configurations being quite similar.

In the absence of additional sources, we have made an assumption of the distribution of equipment by category, at the global level.

Medium Configurations	Categories 0 and I1 (Basic)	Category I2 (Family)	Category I3 (Gaming)	Category D1 (Power Gaming)	Category D2 (Power User)
Distribution assumption	20 %	20 %	30 %	10 %	20 %
Equipment Mass (kg)	2,2	2,4	4,8	6,8	10,5
Feed mass (kg)	0,34	1,2	3,27	1,7	1,66
PCB area (cm²)	289	359,1	590,49	686,25	686,25
Processor Name	Intel Celeron G3930	Intel Pentium G4560	AMD Ryzen 5 1500X	AMD Ryzen 5 1600	AMD Ryzen 7 1700X
RAM Capacity (GB)	4	8	8	16	16
Graphics card name	Integrated	MSI GeForce GTX 1050 2GT LP	Sapphire Radeon RX 570 Nitro+ 4Go	Ge-ForceRTX2080	Ge-ForceRTX2080
SSD Storage Capacity (GB)	250	250	250	500	1000
HDD Storage Capacity (GB)	0	1 000	1 000	2 000	2 000
DVD drive mass (kg)	0,7	0,7	0,7	0,7	0,7

Table 36: *Technical characteristics of the typical desktop configurations used in the model*

- ***Bounds***

The lack of data to more accurately determine the typical configurations and proportions of different categories of desktop computers on the market is a significant factor of uncertainty. We have tried to limit it by establishing transparent hypotheses, on the basis of a pre-existing categorisation which, to our knowledge, has not, to our knowledge, been called into question.

5.3.2.6 Video projectors

- ***Definition***

A **projector** is an optical device designed to process analog or digital video information, in any broadcast, storage, or networking format, in order to modulate a light source and project the resulting image onto an external screen. Audio information, in analogue or digital format, can be processed as an optional function of the projector.[112]

Projectors can be grouped by technology categories: DLP (digital light processing), LCD (liquid crystal display), LCOS (liquid crystal on silicon), LED and others. Their main uses are at home (home cinema), at school (education), at the office (company), or on the move (laptop).

- ***Number of units worldwide in 2023***

567 million units

This figure is estimated from the sales volume data of PC screens and projectors from 2018 to 2028[113]. The projector-only market volume is obtained by subtracting the volume of screens-only from a second source[114], aggregated by Statista. This data is finally consolidated according to an estimated average lifespan of 5 years (see below).

- ***Power consumption***

200 kWh /year /equipment[115]

- ***Frequency of use***

The frequency of use varies according to the context of use: 3 hours/day in a school setting, 1.5 hours/day in a professional setting and 0.5 hours/day in a personal setting.[Art. 38]

- ***Average Lifespan***

5 years[116]

- ***Penetration rate***

No data available

- ***Technical characteristics***

No data on environmental impacts and quantities available by technology. Thus, no differentiation according to technologies is taken into account.

- ***Bounds***

There is a great deal of uncertainty about the quantity of projectors because it is calculated on the basis of other equipment. In addition, the data obtained are limited to projectors used with computers and exclude projectors used as televisions. Finally, additional uncertainty is introduced by the impossibility of distinguishing between the different projector technologies. Also, a sensitivity analysis is carried out on the quantity of projectors to take this uncertainty into account (see section 4).

112 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 85 table, 5.2.1

113 Global: PC monitors & projectors volume 2019-2029 | Statista, 2024, https://www.statista.com/forecasts/1256931/volume-global-pc-monitor-projector-market

114 IDC, PC monitor unit shipments by quarter 2024 | Statista, 2022, https://www.statista.com/statistics/352891/global-pc-monitor-shipments-by-quarter/

115 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 88

116 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 86 table, 5.2

5.3.2.7 Printers

- ***Definition***

The product group of printing equipment that is considered here includes the following categories[117]

Product Category	Description
Monochrome Laser Printer (Multifunction Printer)	A multifunctional printer, capable of copying, scanning and printing, that uses laser marking technology (sometimes called electro-photography) to print in a single colour only.
Color Laser Multifunction Printer	A multifunctional printer capable of copying, scanning and printing, which uses laser marking technology (sometimes called electro-photographic) to print in multiple colours.
Monochrome Laser Printer	A printer that uses laser marking technology (sometimes called electro-photography) to print in a single color.
Color Laser Printer	A printer that uses laser marking technology (sometimes called electro-photography) to print in multiple colors.
Colour inkjet multifunction printer	Multifunction printer that can copy, scan, and print and uses inkjet marking technology to print in multiple colors.
Color inkjet printer	Printer that uses inkjet marking technology to print in multiple colors.
Professional printer and multifunction device	Professional printer or multifunction device that supports a grammage greater than 141 g/m2; A3 compatible; if printing only in monochrome, the IPM[118] is equal to or greater than 86; if printing in colour, the IPM is greater than or equal to 50; print resolution of 600x600 dpi or more; weight of the base model greater than 180 kg and several other features such as hole punching and ring binding.
Scanner	A product whose primary function is to convert paper originals into electronic images that can be stored, edited, converted, etc.
Copier	A commercially available imaging product whose sole function is to produce hard copies from graphic documents.

Table 37: *Description of printer categories*

- ***Number of units worldwide in 2023***

584.77 million units

Considering the estimates provided by Statista Research Department[119] and, after cross-referencing IDC's figures for the year 2022 and 2023[120], the number of printer units worldwide is estimated at 584.77 million.

Note that the 2 sources do not consider the same scope (For IDC: restricted to single-function printers, multifunction systems (MFPs) and single-function digital copiers (SF DC)).

As a result, IDC's figures are lower, but consistent across scope.

- ***Power consumption***

133 kWh /year /equipment

117 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 123 table, 7.1

118 IPM: Print speed in pages per minute

119 Global: printers & copiers volume 2019-2029 | Statista, https://www.statista.com/forecasts/1247400/worldwide-printer-and-copier-market-volume

120 Worldwide Quarterly Hardcopy Peripherals Tracker, https://www.idc.com/getdoc.jsp?containerId=IDC_P4437

Power consumption varies greatly from one type of appliance to another:

- **Minimum:** 2 kWh /year /device for an inkjet printer;
- **Maximum:** 664 kWh /year /device for a professional multifunction printer.

On average, we obtain a consumption of 133 kWh /year per equipment. These values are estimated to have been stable since 2018. They are based on data from the ICT Impact Study[121] from 2020. No more recent data could be found. The uncertainty about this value is therefore high.

- ***Frequency of use***

No data available.

- ***Average Lifespan***

6 years

Based on various sources (ICT Impact Study[122], ADEME, GreenIT.fr), the average lifespan of this type of equipment is estimated here at 6 years.

- ***Penetration rate***

No data available.

- ***Technical characteristics***

Printing equipment is a category of equipment that can be very different from each other. Due to the lack of more comprehensive environmental data as well as precise quantitative data on the different types of equipment, all equipment in this category has been modelled as networked laser multifunction printers.

- ***Bounds***

The ICT Impact Study[123] (source of the definitions for this category of equipment) also provides information about fax machines and 3D printers that we have excluded from our scope for three reasons:

- These devices are at the limit of what can or cannot be considered part of digital.
- They represent a limited stock of equipment (270,000 3D printers) or have a limited impact (fax machines)
- Lack of information on the environmental impacts of these devices to include them in our scope.

The modeling of all equipment in this category by networked laser multifunction printers as described leads to uncertainty in the environmental impacts of this category of equipment. It is not possible to say whether this uncertainty leads to an under- or over-estimation of the impacts.

121 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 125-128

122 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 124

123 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 124

5.3.2.8 Screens

- *Définition*

Un **écran** est composé d'un écran d'affichage et les composants électroniques associés qui, en tant que fonction principale, affichent des informations visuelles à partir d'une image ou d'une vidéo. Sa fonction principale est d'afficher des informations visuelles provenant de sources câblées ou sans fil".[124]

N'ont pas été pris en compte ici de manière spécifique les écrans destinés uniquement à des fins publicitaires, par manque d'information fiable permettant d'estimer leur quantité au niveau mondial.

- *Les catégories d'écrans*

Product category	Scope
Monitor	Computer monitor (for desktops, thin clients, or external second displays of laptops)
Television set	Regular TV, hospitality TV (hotel rooms and other accommodation, hospital beds, etc.)

Table 38: *Description of Screen Categories*

5.3.2.8.1 Monitors

- *Number of units worldwide in 2023*

906.8 million

The source used is IDC (International Data Corporation), which reports on global sales of personal computer (PC) monitors from 2012 to 2022, by quarter.[125] Linear interpolations were applied to obtain the values for the missing quarters.

- *Power consumption*

25 kWh /year /equipment for a 24-inch screen

50 kWh /year / equipment for a 35-inch screen

This data comes from a study by ADEME dating from 2018[126] to obtain the power in active mode and using the duration of use below. No more recent data were found. The uncertainty associated with this value is therefore high.

- *Frequency of use*

3 hours 15 minutes /day[127]

The daily usage time is considered similar to a computer since a monitor is always used in conjunction with a computer. Durée de vie moyenne

- *Average Lifespan*

7 years

124 European Commission, Commission Regulation (EU) 2019/2021 of 1 October 2019 laying down ecodesign requirements for electronic displays pursuant to Directive 2009/125/EC of the European Parliament and of the Council, amending Commission Regulation (EC) No 1275/2008 and repealing Commission Regulation (EC) No 642/2009 (Text with EEA relevance.), 2019, https://op.europa.eu/en/publication-detail/-/publication/648e809d-1729-11ea-8c1f-01aa75ed71a1/language-en/format-

125 Worldwide Quarterly PC Monitor Tracker, https://www.idc.com/getdoc.jsp?containerId=IDC_P7132

126 Modelling and evaluation of the environmental impacts of consumer products and capital goods - La librairie ADEME, https://librairie.ademe.fr/consommer-autrement/1189-modelisation-et-evaluation-des-impacts-environnementaux-de-produits-de-consommation-et-biens-d-equipement.html § p. 51

127 GlobalWebIndex's flagship report on device ownership and usage | bluesyemre, https://bluesyemre.files.wordpress.com/2020/05/globalwebindexe28099s-flagship-report-on-device-ownership-and-usage.pdf § p. 10

This value is obtained on the basis of an average between 2 sources: the GreenIT 2022 benchmark[128] and a Swedish study[129] dating from 2015. Given the lack of recent sources, this parameter will be subject to a sensitivity analysis (see Section 4).

- ***Penetration rate***

No data available.

- ***Technical characteristics***

	Configuration 1	Configuration 2
Display Technology	LCD	OLED
Screen size (inch)	24	35
Distribution[130] (%)	99,93 %	0,07 %

Table 39: *Characteristics of the monitor configurations used in the model*

Breakdown between technologies:

In 2023, 500,000 OLED monitors were sold, i.e. 0.5% of the market that same year (120,000 sales in 2022).[131] Taking into account the age of the current fleet, the share of OLED monitors falls to **0.07%** as it stands. Overall, this share remains marginal compared to LCD technologies, but this proportion will grow significantly in the coming years (+300% sales expected in 2024).

Average size:

The average screen sizes of the different technologies are as follows:

- **24-inch** for **LCD displays**, based on the following:
  1. The average size retained in Europe by ICT in 2020, 24 inches[132]
  2. Globally, the average height in 2016 was 22.1 inches [133], with a linear increase in height over the previous 5 years.
  3. In 2023, the manufacturer BenQ indicates that more than 50% of its sales are made in 24-inch vehicles. The 27-inch represents 30%.[134]
- **35-inch** OLED displays, based on the breakdown provided in Table 38, by Trendforce[135] for 2023 full-year sales (from best-selling to worst-selling size).

Screen size (inch)	27'	34'	49'	45'	Other (Not considered)
Sales volume (%)	32 %	37 %	14 %	10 %	7 %

Table 40: *Distribution of the quantities of monitors according to their size*

128 BENCHMARK GREEN IT 2022, https://club.greenit.fr/doc/2022-09-Benchmark_Green_IT-2022-rapport.0.5_FR.pdf

129 Yuliya Kalmykova, João Patrício, Leonardo Rosado, P. EO Berg, Out with the old, out with the new — The effect of transitions in TVs and monitors technology on consumption and WEEE generation in Sweden 1996–2014, Waste Management, Volume 46, 2015

130 Distribution assumption based on a Gaussian curve, considering that the majority of purchases are made in the mid-range

131 OLED Monitor Shipments Predicted to Soar by 323% in 2023; 2024 Shipments Expected to Surpass One Million Units, Says TrendForce, https://www.trendforce.com/presscenter/news/20231012-11875.html

132 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Electronic Displays, p. 77

133 PC monitor display size, https://www.pcmatic.com/blog/pc-monitor-display-size/

134 Out-of-Home: Bigger Screens Are Coming Away - EDI Magazine, https://www.edi-mag.fr/affichage-numerique/les-ecrans-plus-grands-simposent/

135 OLED Monitor Shipments Predicted to Soar by 323% in 2023; 2024 Shipments Expected to Surpass One Million Units, Says TrendForce, https://www.trendforce.com/presscenter/news/20231012-11875.html

- ***Bounds***

The lack of recent sources concerning the electricity consumption and lifespan of monitors generates a fairly high uncertainty about the environmental impacts of this category of equipment.

5.3.2.8.2 Televisions (TV)

- ***Number of units worldwide in 2023***

1.475 billion units

The source used is a Statista aggregation[136] of data consolidated annually by Trendforce[137], which reports on global TV sales from 2015 to 2024.

- ***Power consumption***

179 kWh /year /equipment[138]

This is data from 2020. No more recent data were found.

- ***Frequency of use***

3 hours 20 minutes /day[139]

This source is from 2022 and is specific to TVs.

- ***Average Lifespan***

7 years

The lifespan is estimated here at 7 years, based on the average of the sources used: professional benchmark GreenIT.fr[140] and report assessing the environmental impact of digital technology in France and prospective analysis by Ademe/Arcep[141].

- ***Penetration rate***

No data available.

136 Global TV shipments 2015-2024 | Statista, https://www.statista.com/statistics/276238/television-shipments-worldwide-forecast/

137 Global TV Shipments to Fall Below 197 Million Units for the First Time in 2023, Slight Growth of 0.2% Expected in 2024, Says TrendForce, https://www.trendforce.com/presscenter/news/20231128-11931.html
Global TV Shipments Are Projected to Drop by 3.9% YoY to Decade Low of Just 202 Million Units for 2022, Says TrendForce, https://www.trendforce.com/presscenter/news/20221221-11509.html

138 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf

139 Digital 2022: Global Overview Report — DataReportal – Global Digital Insights, https://datareportal.com/reports/digital-2022-global-overview-report

140 BENCHMARK GREEN IT 2022, https://club.greenit.fr/doc/2022-09-Benchmark_Green_IT-2022-rapport.0.5_FR.pdf

141 Assessment of the environmental impact of digital technology in France and prospective analysis, 2022, https://www.arcep.fr/uploads/tx_gspublication/etude-prospective-2030-2050_mars2023.pdf § p. 40

- ***Technical characteristics***

The characteristics considered are the following:

	Configuration 1	Configuration 2
Display Technology	LCD	OLED
Screen size (inches)	46,9	58,7
Distribution (%)	98%	2%

***Table 41:** Features of the TV configurations used in the model*

Average LCD TV size: Estimate of 46.9 inches from the average LCD[142] TV screen sizes worldwide from 2015 to 2021 (in inches) aggregated by Statista. These are forecasts for the period 2018 to 2021 and linear interpolation for the year 2022. These values are averaged by weighting according to the quantities sold worldwide each year to obtain an average size of TVs used worldwide in 2022. The values of the TV screen sizes provided by Statista are consistent with those provided by Omdia[143].

Average size of OLED TVs: Estimate of 58.7 inches from average sizes of OLED TV screens between 2016 and 2020, aggregated by Statista[144].

LCD vs OLED Proportion: Estimated at 98% LCD and 2% OLED. These values are obtained from the total quantities of TVs sold between 2015 and 2023, compared with the quantity of OLED TVs sold between 2016 and 2023[145].

5.3.2.9 Smart box TV

- ***Definition***

It is an external box connected to the TV allowing the use of multiple sources: cable or terrestrial wave, satellite, or internet (IPTV). Since the emergence of multiple video platforms via the Internet (Netflix, Prime, Disney+, etc.), the most recent boxes allow the integration of these channels from a single point, as well as "smart" services (AppleTV, AndroidTV) and can be coupled with voice assistants ("OTT" - "Over the top" boxes).[146]

- ***Number of units worldwide in 2023***

773 million units

This quantity is estimated based on the global sales volumes of smart home devices[147]. Among these smart home devices, the equipment considered is video entertainment, from which we subtract smart TVs (which are already counted elsewhere in the study, within the TV category).

142 Data source: GfK; gfu, Global average TV screen size 2015-2021 | Statista, Survey date: 2015 to 2017, https://www.statista.com/statistics/760288/average-tv-screen-size-worldwide

143 Omdia: For the first time, LCD TV display weighted average size surpasses the 50-inch display size, https://www.prnewswire.com/apac/news-releases/omdia-for-the-first-time-lcd-tv-display-weighted-average-size-surpasses-the-50-inch-display-size-301883953.html

144 Global OLED TV shipments by screen size 2016-2020 | Statista, https://www.statista.com/statistics/991181/worldwide-oled-tv-shipments-screen-size

145 Global OLED TV shipments 2016-2023 | Statista, https://www.statista.com/statistics/260316/global-oled-tv-shipments/

146 Definition inspired by the study Environmental assessment of digital equipment and infrastructures in France, ADEME, https://librairie.ademe.fr/ged/6700/impact-environnemental-numerique-rapport2.pdf § p. 54
Set Top Box Market Size, Share And Growth Report, 2030, https://www.grandviewresearch.com/industry-analysis/the-global-set-top-box-market
Set-Top Box Market Research | Industry Analysis, Size & Forecast Report, https://www.mordorintelligence.com/industry-reports/set-top-box-market

147 Worldwide Quarterly Smart Home Device Tracker, and associated press releases, reproduced in other media, https://www.idc.com/getdoc.jsp?containerId=IDC_P37480

• ***Power consumption***

73 kWh /year /equipment[148]

• ***Frequency of use***

No data available.

• ***Average Lifespan***

5 years

In the absence of available data, the assumption of a lifespan of 5 years is used. A similar hypothesis is made in the ADEME-Arcep study on the Environmental Impact Assessment of Digital Technology in France and prospective analysis for 2022.

• ***Penetration rate***

Globally, the distribution of smart box use was 88.1% in residential use in 2022[149]. Commercial uses come in particular from hotel and restaurant services and hospitals[150].

• ***Technical characteristics***

No data available.

• ***Trends***

In particular, smart TV boxes have been used to extend existing television while accessing new services provided via the internet, which are sometimes more widely available than other video distribution channels.

The use of smart TV boxes became widespread over the period 2020-2021, during the lockdowns linked to the COVID-19 pandemic. Today, the waves of equipment or equipment renewal are linked to technological releases (4G/5G, trend of migration from "SD" to "HD" and "4K" streams, etc.), which are growing, especially in Europe and the United States.

• ***Bounds***

Estimating the quantity of TV boxes from the quantities of other equipment (connected home equipment and smart TVs) generates a great deal of uncertainty.

5.3.2.10 Smart speakers

• ***Definition***

The so-called "connected" speakers are divided into 2 categories: wireless speakers (Bluetooth, wifi), with features for consuming "streaming" services (Spotify, Deezer, etc.), and voice/virtual assistants integrating the use of voice commands. Overall, assistants represent 82.4% of the entire smart speaker market in 2023[151].

• ***Number of units worldwide in 2023***

717.8 million units

This quantity is based on global sales volumes[152] and the average shelf life shown below.

148 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § p. 105-106

149 Set Top Box Market Size, Share And Growth Report, 2030, https://www.grandviewresearch.com/industry-analysis/the-global-set-top-box-market

150 Set-Top Box Market Size & Share, Growth Analysis 2024-2032, https://www.gminsights.com/industry-analysis/set-top-box-market

151 Smart Speaker Market Size, Share & Industry Trends [2032], https://www.fortunebusinessinsights.com/smart-speaker-market-106297

152 Global smart speaker shipments by vendor 2022 | Statista, https://www.statista.com/statistics/792598/worldwide-smart-

- ***Power consumption***

43.8 kWh /year /equipment

A 2019 report[153], carried out for the Senate, indicates an annual consumption of 43.8 kWh per equipment in its central hypothesis.

- ***Frequency of use***

No data available.

- ***Average Lifespan***

5 years

In the absence of precise data available, the average lifespan of 5 years was assumed to be used, as these devices are equipped with batteries.

- ***Tendency***

New products include a display device (screen), to offer video content and the integration of social networks, video on demand, etc. This trend is indicated as a "driver" of growth in the sector, implying increasing impacts, both in terms of manufacturing (addition of a screen), as well as in terms of electricity consumption and the demand on network infrastructures (data volume). The growing integration of AI technologies is also a factor tending to accelerate this growth in impacts.[154]

- ***Technical characteristics***

The modeling is based on a unique connected speaker configuration. Its mass is 820g.

- ***Bounds***

For this equipment, the main limitations are the assumption on the service life as well as the unique configuration for the technical characteristics. These approximations create uncertainty about the results.

5.3.2.11 Game Consoles

- ***Définition***

According to the SRI[155], cited in the ICT Impact Study,[156] "a game console is a computer device whose main function is to play video games. Game consoles share many of the features and components of the hardware architecture found in general personal computers (e.g., central processing unit(s), system memory, video architecture, optical drives and/or hard drives or other forms of internal memory). The game consoles covered by this SRI are those that:

- use dedicated handheld controllers or other interactive controllers designed to allow games to be played (rather than the mouse and keyboard used by individual players) (rather than the mouse and keyboard used by personal computers); and

speaker-unit-shipment/; https://omdia.tech.informa.com/pr/2022/aug/omdia-global-installed-base-of-smart-home-devices-exceeds-2bn-devices-in-2022
IDC, Closed Source, https://www.idc.com/getdoc.jsp?containerId=prUS49982122
Worldwide Shipments of Smart Home Devices Continue to Decline in 2023, Slump Expected to Last into 2024, According to IDC, https://www.idc.com/getdoc.jsp?containerId=prUS50994923

153 STUDY ON THE EVALUATION OF PUBLIC POLICIES TO REDUCE THE CARBON FOOTPRINT OF DIGITAL TECHNOLOGY, 2020, https://www.senat.fr/fileadmin/Fichiers/Images/commission/Developpement_durable/MI_empreinte_environnementale/r19-555-annexe.pdf § p. 112

154 Smart Speaker Market Size, Share & Industry Trends [2032], https://www.fortunebusinessinsights.com/smart-speaker-market-106297

155 In the EU, video games consoles are subject to a Self-Regulatory Initiative (SRI) under the Eco-design Directive (ENTR lot 3). Signatories are the three mainproducers: Microsoft (Xbox), Sony (PlayStation) and Nintendo. The most recent version is SRI 2.6.3 (2018) and the latest compliance report by the IndependentInspector (Intertek) was released in October 2019 (Intertek, Independent Inspector Annual Compliance Report — Games Consoles Self-Regulatory Initiative,Reporting Period 2018, Oct. 2019). All information on the SRI is available on a dedicated website www.efficientgaming.eu.

156 VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf

- are equipped with audio-visual outputs for use with external TVs as the main display; and
- use console-specific operating systems (rather than a traditional PC operating system)
- may include other secondary features such as optical disc drive, digital video and image viewing, digital music playback, etc.
- are mains-powered devices that consume more than 20 watts in active play mode with either stock sale[157]

- ***Number of units worldwide in 2023***

293.68 million units.

The game console stock was calculated using the annual sales between 2016 and 2022 reported by VG-ChartZ for the world[158] and based on the average lifespan of 6.5 years for game consoles.

- ***Power consumption***

55.88 kWh /year /equipment for a desktop game console

5.15 kWh /year /equipment for a mobile game console

The consoles' power consumption is based on the 2020 ICT Impact Study[159], adapted to VGChartZ's figures above, and using the Global Web Index Q3 figures presented by Hootsuite and reported in the ICT Impact Study[160].

- ***Frequency of use***

1 h 02 / day[161]

- ***Average Lifespan***

6.5 years

In France, the lifespan of new equipment is estimated at 5 years, and the lifespan of refurbished equipment is 3 years[162]. The study on the environmental impacts of digital technology in 2021[163] was based on an average lifespan of 6.5 years, with a good degree of certainty.

Based on these two sources and given the homogeneity of the market on a global scale, we estimate the global average lifespan of game consoles to be 6.5 years.

- ***Penetration rate***

No data available.

157 *VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 108*

158 *Yearly Hardware Comparisons - Global - VGChartz, https://www.vgchartz.com/tools/hw_date.php?reg=Global&ending=Yearly*

159 *VHK and Viegand Maagøe for the European Commission., ICT Impact Study, Assistance to the European Commission - ICT Impact study - FINAL REPORT. European Commission, 2020, https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-11/IA_report-ICT_study_final_2020_(CIRCABC).pdf § Energy p. 91*

160 *Ibid, p.239*

161 *Game Consoles Market — Sharing, Size, and Growth, https://www.mordorintelligence.com/fr/industry-reports/gaming-console-market*

162 *FANGEAT Erwann, ADEME, Laurent ESKENAZI, Eric FOURBOUL, Hubblo, Julie ORGELETDELMAS, DDemain, Etienne LEES PERASSO, Firmin DOMON, LCIE Bureau Veritas, Environmental Impact Assessment of a Set of Refurbished Products — Final Report, 2022, https://librairie.ademe.fr/ged/6720/ademe_impact_environnemental_reconditionnement_rapport.pdf § p. 174*

163 *Study commissioned by the European Parliamentary group of the Greens/EFA Project headed by GreenIT.fr, with NegaOctet members (DDemain, GreenIT.fr, LCIE CODDE Bureau Veritas, APL data center), APPENDICES OF THE REPORT Digital technologies in Europe: an environmental life cycle approach, 2021, https://www.greenit.fr/wp-content/uploads/2021/12/EU-Study-Appendices-to-the-LCA-EN.pdf § p. 25*

- ***Technical characteristics***

We dissociate "living room" type consoles from portable consoles.

Consoles	Nintendo Switch[164]	Sony Play-station 5	MS Xbox Series X/S	Sony Play-station 4[165]	MS Xbox One / One S	Nintendo 3DS
Type	Portable	Living room	Living room	Living room	Living room	Portable
Total ventes / période étude en millions d'unités	131,16	52,3	28,04	53,62	19,66	8,90
Proportion	44,66 %	17,81 %	9,55 %	18,26 %	6,69 %	3,03 %

Table 42: *Distribution of game consoles by type as well as sales quantities*

That is to say the following proportion by type:

Handheld consoles	47,69 %
Home consoles	52,31 %

Table 43: *Grouping the distribution of game consoles by portable or living room type*

These two types of consoles are each based on a weighted mix of the following configurations:

Consoles	Nintendo Switch	Nintendo Switch Lite	Sony Playstation 5	Sony Playstation 4	MS Xbox One S
Type	Handheld Console	Handheld Console	Living Room Console	Living Room Console	Living Room Console
Equipment Mass (kg)	0,297	0,277	4,78	2,8	2,9
Screen Size (inch) / Technology	6,2 / LCD tactile	5,5 / LCD tactile	NA	NA	NA
PCB area (cm^2)	Not specified	Not specified	Not specified	838,75	904,72
Processor	Nvidia Tegra 20 nm	Nvidia Tegra 16 nm	AMD Zen 2	AMD Jaguar	AMD Jaguar
RAM Capacity (GB)	4	4	16	8	8
Video card	Integrated in the processor	Integrated in the processor	AMD RDNA 2	AMD Radeon	AMD Radeon
SSD Storage Capacity (GB)	32	32	825	0	0
HDD Storage Capacity (GB)	0	0	0	500	500

Table 44: *Characteristics of the game console configurations used in the model*

164 and derivatives such as Switch Lite or OLED

165 and derivatives such as the PS4 Pro

- *Bounds*

Excluded from the study are consoles dedicated to retrogaming, whose sales data are difficult to collect at the time of writing, nor new types of hybrid consoles (such as the Valve Steam Deck) using adapted Desktop or mobile OS (such as Linux or Android).

5.3.2.12 IoT - Connected objects

- *Definition*

Equipment that is connected to the Internet of Things (IoT) and generally interacts via embedded systems, some form of networked communication, as well as the combination of edge computing (calculations done locally or nearby) and cloud computing (calculations done remotely in data centers. Data from IoT-connected devices is often, but not exclusively, used to create new services for end users.

Computers, tablets or smartphones are not considered part of the IoT because they are mainly user terminals. RFID can be considered an embryonic first degree of IoT, but this is subject to discussion; in this study, we excluded RFID from our scope.

- *Number of units worldwide in 2023*

The company IoT Analytics estimated in 2019[166] that there would be nearly 19.8 billion active IoT devices worldwide in 2023. However, these forecasts are old. Transforma Insights estimates that there will be approximately 15.7 billion active IoT devices worldwide in 2023[167]. This new estimate is also consistent with Ericsson's estimate[168] of 15.712 billion IoT devices worldwide in 2023. We have therefore considered the average of these last 2 data, i.e. **15.706 billion connected objects in the world in 2023**.

In the absence of more recent data, we have broken down the distribution between the different categories of equipment by keeping the proportion of categories established by the IEA in 2019[169].

- *Power consumption*

Based on the IEA's consumption assumptions by[170] equipment type, mode, and average time over 24 of mode activation, we estimate global IoT consumption at 196,789,902.11 MWh for the year 2022.

- *Frequency of use*

The frequency of use considered is that proposed in the IAS study[171], by equipment category.

- *Average Lifespan*

The average lifespan considered is that proposed in the IAS study[172], by equipment category.

- *Penetration rate*

No data available. Data not used in the calculations.

166 Global IoT and non-IoT connections 2010-2025 | Statista, http://www.statista.com/statistics/1101442/iot-number-of-connected-devices-worldwide/

167 Current IoT Forecast Highlights - Transforma Insights, https://transformainsights.com/research/forecast/highlights

168 Wide-area and short-range IoT devices worldwide 2029 | Statista, http://www.statista.com/statistics/1016276/wide-area-and-short-range-iot-device-installed-base-worldwide/

169 Total Energy Model for Connected Devices, https://www.iea-4e.org/wp-content/uploads/publications/2019/06/A2b_-_EDNA_TEM_Report_V1.0.pdf

170 Ibid.

171 Ibid.

172 Ibid.

• ***Technical characteristics***

We used the same technical characteristics as those used in the study on the environmental impacts of digital technology in Europe[173], based on the 12 functional blocks of the study by Thibaut Pirson and David Bol published in 2021.[174]

5.3.3 Tier II – Networks

5.3.3.1 Definition

A **telecommunications network** is a network of links and nodes (switches, routers, etc.) that allow users to communicate with each other across the network or connect to the internet from their terminals.

There are two main categories of networks:

- **Fixed networks:** these allow access to the internet from a fixed location via a wired connection (private home, workplace, building open to the public, etc.). They mainly include:
  - xDSL technology, which uses copper cables;
  - Fiber (FTTx), more recently, which uses optical fibers. They allow more data to be transported over greater distances.
- **Mobile networks:** These allow wireless equipment to be used throughout the country, transmitting voice and data by radio waves. These systems are known as 2G, 3G, 4G, and 5G.

Other technologies exist, such as **satellite constellations**, but they are excluded from the study because they still account for a small proportion of traffic and very little data is available on the associated environmental impacts.

The **number of subscribers and the amounts of data worldwide in 2023** are summarized in the following table:

	Number of subscribers	Amount of data transferred (GB)
Fixed network	1 495 600 000[175]	4,486E+12 [176]
Mobile network	7 029 800 000[177]	1,054E+12 [178]

Table 45: *Number of subscribers and amount of data transferred in 2023 on fixed and mobile networks*

5.3.3.2 Methodology

5.3.3.2.1 Source study

The assessment of these impacts is based on the work carried out in the ADEME study on the assessment of the environmental footprint of the provision of internet access in France[179]. This study was carried out as part of a collective action with several French telecommunications operators (Orange, Bouygues Telecom, Iliad, SFR, Adista and Telecoop).

173 See the methodological annex: Study commissioned by the European Parliamentary group of the Greens/EFA Project headed by GreenIT.fr, with NegaOctet members (DDemain, GreenIT.fr, LCIE CODDE Bureau Veritas, APL data center), APPENDICES OF THE REPORT Digital technologies in Europe: an environmental life cycle approach, 2021, https://www.greenit.fr/wp-content/uploads/2021/12/EU-Study-Appendices-to-the-LCA-EN.pdf

174 Pirson, T. and Bol, D., [PDF] Assessing the embodied carbon footprint of IoT edge devices with a bottom-up life-cycle approach | Semantic Scholar, 2021, https://www.semanticscholar.org/paper/Assessing-the-embodied-carbon-footprint-of-IoT-edge-Pirson-Bol/49ac45f5d59ac2047548fd168eff62393dfdd2ed

175 ITU regional global_Key ICT indicator aggregates, Nov 2023, https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ITU_regional_global_Key_ICT_indicator_aggregates_Nov_2023.xlsx

176 Source: ibid. This amount of data was extrapolated from previous years' data indicating a constant average of 3 GB per subscription.

177 Source : ibid

178 Source: ibid. This amount of data has been extrapolated from data from previous years, indicating an increase since 2019, which could reach 0.15 GB per subscription in 2023

179 Evaluation of the environmental footprint of the provision of internet access in France - La librairie ADEME, https://librairie.ademe.fr/produire-autrement/6789-evaluation-de-l-empreinte-environnementale-de-la-fourniture-d-acces-a-internet-en-france.html

The study is based on metropolitan France, with data for the year 2022. It covers all network infrastructures managed by French operators, excluding international Internet transit networks (outside the scope), as shown in the Figure 11.

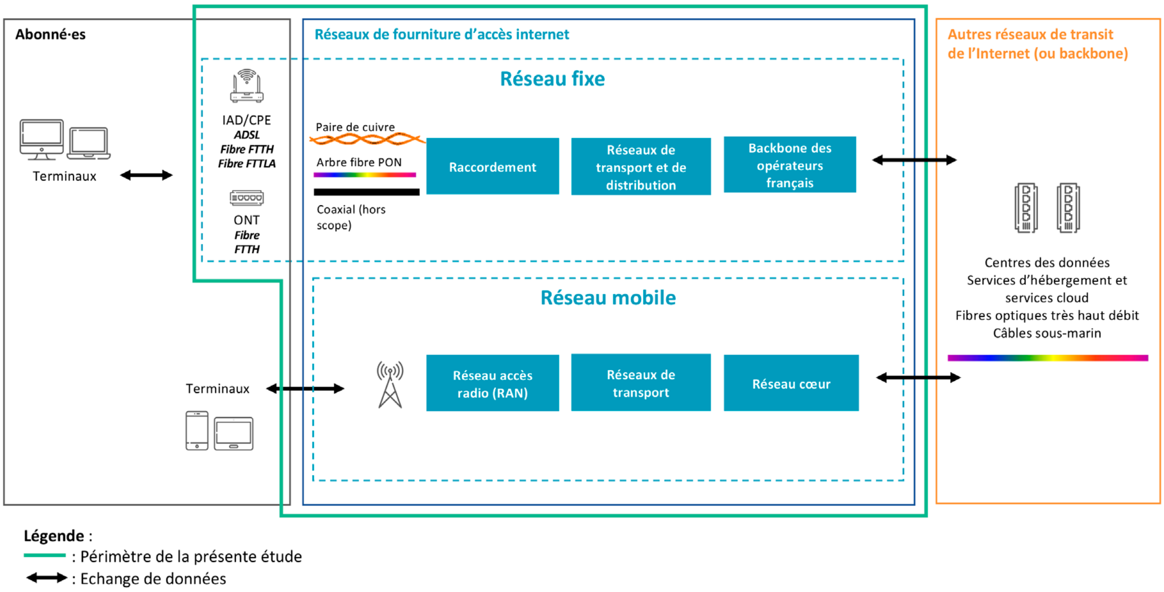


Figure 11 : Modelling of digital services in 3 Tiers Diagram of the scope of the study on the environmental impacts of networks in France

It includes:

- **For the fixed network:** from the subscriber's internet box to the core network,
- **For the mobile network:** from the antenna to the core network (the smartphone is not taken into account).

Network equipment and part of the civil engineering (trenching, antenna supports, etc.) are also taken into account.

This study follows the LCA methodology, considering all stages of the life cycle (manufacturing, distribution, installation, use and end-of-life) of equipment and infrastructure. Like all LCAs, the study is based on a functional unit (UF). This is the unit of measurement used to evaluate the service provided. In this study, the UF is as follows: "Provide Internet access to all users located throughout metropolitan France for 1 year."

5.3.3.2.2 Extrapolation

To extrapolate to the world in the context of this study, the ADEME study equipment inventory is used, but the electricity mix is modified to use the global average electricity mix rather than the French one. The results are recalculated in this case and normalized to the consumption of 1 GB by a fixed or mobile subscriber.

Finally, the values of the number of subscribers and the amount of data consumed on a global scale are used to obtain a result on a global scale.

5.3.3.2.3 Bounds

The limitations of this modelling are specific to the reference study[180], namely:

- **"Data representativeness:** This study was carried out using data from the 4 largest French telecom operators, which account for 94.7% of French subscribers";
- **"Local loops**: the modelling of local loops from Orange data carries more uncertainty than the other categories of the network";
- **"Excluded technologies:** The exclusion of fixed wireless access (FWA) connections and satellite internet access may result in an underestimation of the overall impacts."

The typologies of networks are very different from one country to another. Indeed, networks have various forms depending on many factors such as population density and distribution, geography, political choices, etc. which will impact the deployment of one network rather than another (fixed, mobile, satellite, etc.) as well as network technology (ADSL or fibre, etc.). Here, due to the lack of available data, we rely on the case of France to extrapolate around the world, which brings a lot of uncertainty.

5.3.4 Tier III – Data Centers

5.3.4.1 Definition

A **data center** is a physical space (a room, building, or facility) that houses the IT infrastructure used to create, run, and deliver applications and services, as well as to store and manage related data[181].

5.3.4.2 Methodology

Tier III modeling is based on an inventory of IT and non-IT equipment on a global scale.

Servers

Servers are divided into 5 categories:

- High-End servers, modeled by servers containing 2 high-end CPUs, 3072 GB, 8 TB SSD, 1 GPU
- Mid-Range servers, modeled by servers containing 2 high-end CPUs, 128 GB, 8 TB SSD
- HDD storage servers (48 disks)
- SSD storage servers (48 drives - TLC, 1024 GB per drive)
- AI servers are modeled from a rack server base suitable for these types of processing, to which a compute module equivalent to an SMX5 H100 graphics processor has been added

The Borderstep Institute published server stock estimates in 2024, with the aim of providing data for impact studies[182]. The report indicates an average estimate for 2024 of around 77.7 million units, based on an assumption of an average lifespan of 5.5 years. The study does not provide the precise figure for 2023. In line with the graph showing the stock estimates between 2019 and 2024 and the 2023 estimate ranges, we have chosen to use the number 77.7 million units.

The breakdown by type of server, excluding "specific application servers", was taken from the study of the environmental impact of digital technology in Europe[183].

180 Evaluation of the environmental footprint of the provision of internet access in France - La librairie ADEME, https://librairie.ademe.fr/produire-autrement/6789-evaluation-de-l-empreinte-environnementale-de-la-fourniture-d-acces-a-internet-en-france.html

181 What is a Data Center? | IBM, https://www.ibm.com/fr-fr/topics/data-centers

182 Server stock data – A basis for determining the energy and resource requirements of data centres, https://www.borderstep.org/wp-content/uploads/2024/06/Server-stock-data-EGG2024.pdf

183 Study commissioned by the European Parliamentary group of the Greens/EFA Project headed by GreenIT.fr, with NegaOctet members (DDemain, GreenIT.fr, LCIE CODDE Bureau Veritas, APL data center), APPENDICES OF THE REPORT Digital technologies in Europe: an environmental life cycle approach, 2021, https://www.greenit.fr/wp-content/uploads/2021/12/EU-Study-Appendices-to-the-LCA-EN.pdf

The Borderstep study does not estimate AI servers, we have reconstituted a stock based on analyst data (TrendForce[184] and Digitimes) on the basis of an average of the available data (2022 and 2023). This stock includes both "conventional" architecture servers prepared to accommodate several GPU boards or a special module (such as the configuration used to define the impact factors), and specialized FPGA/ASIC servers, for "HPC" purposes[185].

Servers	High-End	Mid-Range	HDD Storage	SSD Storage	AI
Distribution	0,15 %	3,67 %	49,79 %	44,16 %	2,24 %
Quantity	116 550	2 913 750	39 574 941	35 094 759	1 779 816
Lifetimes	5,5 ans	5,5 ans	5,5 ans	5,5 ans	5,5 ans

Table 46: *Server characteristics considered in data center modeling*

Network equipment

The network equipment was modeled by 48-port switches. According to the Masanet study[186], we can estimate that a server unit occupies 5 ports.

The number of network devices is therefore estimated at 8,229,473 units.

Non-IT equipment

Non-IT equipment in data centers is modeled by UPS, batteries, and air conditioning. Their quantity has been approximated according to the proportions of the study of the environmental impact of digital technology in Europe[187] per m² of data centre.

The estimated average lifespans were taken from the ADEME's Methodological Framework for Environmental Assessment of IT Hosting Services in Data Centers and Cloud Services[188].

Non-IT equipment	Onduleurs UPS 300 kVA	Batteries 35 kg	Air conditioning 0.8 MW
Quantity	899 030	58 548 400	225 686
Lifespan	10 ans	10 ans	15 ans

Table 47: *Non-IT Equipment Characteristics Considered in Data Center Modeling*

The power consumption of non-IT equipment was estimated from a global average PUE of 1.58[189]. Thus, to obtain the estimate of the total electricity consumption of Tier III, the total electricity consumption of servers and network equipment (electricity consumption of IT equipment) was multiplied by 1.58-1.

184 Global AI Server Demand Surge Expected to Drive 2024 Market Value to US$187 Billion; Represents 65% of Server Market, Says TrendForce, https://www.trendforce.com/presscenter/news/20240717-12227.html

185 "The growing energy footprint of artificial intelligence" by Vries, Alex - Joule, Volume 7, Issue 10, 2191 - 2194

186 Masanet, E., Shehabi, A., Lei, N., Smith, S., and J.G. Koomey (2020). "Recalibrating global data center energy use estimates." Science, Vol 367, Iss 6481.

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5.4 Limitations of the study

Assessing the environmental impacts of digital technology around the world in a reliable and comprehensive manner is complex. The main causes are the multiplicity of geographical areas with very varied uses, the lack of recent quantitative and environmental data available, etc.

This section aims to list the main limitations associated with the results of this study. This is intended to become aware of the existing limitations, in order to use the results in this context. In addition, it makes it possible to identify different areas on which to focus on for future work.

5.4.1 Limits associated with the study scope

- **Equipment and infrastructure excluded from the scope of the study**

Some equipment, flows and infrastructure were excluded from the scope of the study. The complete list is described in section 5.2.4.3. Exclusions are mainly due to a lack of data to characterize them. This leads to an underestimation of the real environmental impacts of digital technology. This underestimation is not quantified but it is estimated to be non-negligible. For example, the satellite network has a significant environmental impact through the design and launch of rockets. The same applies to submarine cables and the international core network, which are also excluded.

- **Consideration of maintenance, updates and refurbishment, and end-of-life**

During the use phase, some equipment requires maintenance (change of parts, cleaning, etc.), or upgrade (e.g. desktop computers). The impacts related to this maintenance have not been integrated.

In addition, this study considers a linear economy model that is still predominant in the digital sector. Repair refurbishment activities are progressing in the digital sector and are a strategic focus of impact reduction. However, the lack of data on a global scale did not allow us to include these impacts and to dissociate the possible second life from the first life of a piece of equipment.

Finally, the currently available data related to the end of life only allow us to deal with the hypothesis of 100% recycling of equipment, while more than 80% of electrical and electronic waste remains untraced in the world at the end of its life. For example, no study to date has quantified the environmental impacts associated with the landfilling of digital equipment at the end of its life, or the combustion of equipment.

5.4.2 Limitations associated with lifecycle inventory and data collection

The quality of an LCA study is highly dependent on the quality of the input data and therefore on the associated limitations identified individually for each equipment category in section 5.3.2

It should be added:

- **Uncertainty about energy consumption and lifespan**

A single energy consumption and a fixed lifespan attributed to an entire family of equipment do not reflect the variability that exists within that same family. This unique value is designed to represent a statistical average across the entire equipment category.

- **Uncertainty related to the extrapolation of impacts for networks (Tier II):**

Impacts from a study carried out in France. Extrapolation of these results to the global scale. However, network infrastructures vary enormously from one country to another with population density and distribution, geography, political choices, etc. which will impact the deployment of one network rather than another (fixed, mobile, satellite, etc.) as well as network technology (ADSL or fibre, etc.). The extrapolation carried out may lead to an underestimation or overestimation of the impacts depending on the country.

- **No distinction between personal and professional uses:**

We do not make a distinction between personal and professional use of the equipment, due to the lack of sufficiently precise sources on this point.

5.4.3 Summary of limits by third parties and recommendations

Domain concerned	Description of the boundary	Boundary Type	Level of criticality	Recommendation to address this limit
Tiers I, II et III	Exclusion of equipment: peripherals, 3D printers, docking stations, payment terminals, ATMs, security cameras, etc.	Inventory data	Priority	Further work to obtain missing lifecycle and inventory data
Tier II - Ré-seaux	Modelling the impacts of networks by extrapolation of a French study	Methodology	Priority	Further work to model the impact of networks on a global scale in a more representative way
Tiers I, II et III	Use of a unique power consumption and lifespan for each category of equip-ment	Inventory data	Medium	Additional work to obtain high and low terminals for the characteristics of each category of equipment (electrical consumption, service life, etc.)
Tiers I, II et III	Maintenance, update and reconditioning not taken into account	Methodology	Weak	Further work to include these aspects in the scope of the study.
Tiers I, II et III	No distinction between professional and personal uses	Methodology	Weak	Additional work to dis-tinguish the impacts. Interesting for prioritiz-ing good practices

Table 48: *Summary of limits by Third Party and recommendations*

Index of tables and figures

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https://t.ly/greeniteco.IENM2025