Study

The environmental footprint of the digital world

GreenIT.fr
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greenIT.fr

THE TEAM

GreenIT.fr brings together the Green IT actors since 2004. We structure the community in France and in Europe and we publish quality information at the crossroads between digital and sustainable development. As the reference Francophone media on the subject, GreenIT.fr regularly publishes exclusive studies by teams of experts and contributors.

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CONTENTS

01 INTRODUCTION

This study focuses on the quantification of the global digital environmental footprint and its evolution between 2010 and 2025.

At the beginning of each section, you will find a summary like this one:

This study covers all the electronic equipment that process binary data, worldwide.

It is based on a **Life Cycle Analysis methodology** and relies on **3 models for quantifying environmental impact (users, networks, data centres) aggregated by a meta model.**

Four environmental indicators were selected:
→ Abiotic resource depletion (ADP)
→ Global Warming (GWP)
→ Energy balance (PE)
→ Tension on fresh water (Water)

These four indicators only partially reflect the environmental footprint of the digital world.

Electricity consumption is not an environmental indicator, but given the constant demand to supply this indicator, we have chosen to provide it while systematically adding this comment**.**

1.1 SCOPE

The system studied – the digital world - consists of all electronic equipment processing binary data. This includes for example (non-exhaustive list) computers, smartphones, printers, video game consoles, television sets connected to a box, etc. See the exhaustive list in Appendices.

1.2. METHODOLOGY

To quantify the environmental impact of the digital world, we have followed **a simplified life cycle analysis (LCA)** approach, as close as possible to the ISO 14044/40 recommendations. The environmental impact quantification model is based on approximately **2,000 primary data.** The model was developed between December 2018 and July 2019. The data was collected between February and July 2019. The final calculations were made between June and July 2019. This report was written in the summer of 2019.

1.3 MODEL(S)

The global model used is based on **GreenIT.fr's 15 years of experience** in **quantifying the environmental impact of digital services and equipment.** We chose a **classic "three-tier" architecture:** users, networks, data centres. Each tier is subject to a specific model. A "meta model" aggregates the 3 specific models. See Appendices for more details.

1.4 ENVIRONMENTAL INDICATORS

We selected **four environmental indicators** that are well adapted to the impact of the digital world and easily understandable by the general public:

ABIOTIC RESOURCE DEPLETION (ADP):

The contribution to the depletion of abiotic resources (nonrenewable natural resources) assesses the impact in terms of depletion of mineral stocks and fossil fuels.

This indicator is expressed in kg antimony equivalent (kg SB eq.);

Global warming (GWP):

The anthropogenic emissions of different greenhouse gases in the atmosphere contribute to the global warming of water, air and soil. This global warming results in a disruption of local climates.

This indicator is expressed in kg CO2 equivalent (kg CO2 eq.);

Water
Drinking water is the second most important basic physiological resource for humans and millions of other life forms, just after breathing air. **In short: water is life!** Blue water is water that can be easily used by humans (as opposed to green water that can only be used by plants). The more blue water is consumed for the digital world, the less it is available for other uses at a given point in time. Like agriculture, the digital industry is responsible for periods of water stress during which humanity must arbitrate between several uses of available fresh water because there is not enough available.

This indicator is expressed in volume of blue water (l or m2 of water).

Primary energy (PE):
Primary energy is the energy needed to produce final energy. In the digital domain, depending on the stage of the equipment lifecycle, different primary energies are used to produce different final energies. For example, to extract minerals, petrol is converted into a mechanical force to operate an excavator. To power digital devices, electricity is made from different primary energy sources: solar radiation, nuclear reaction, coal combustion, etc.

This indicator should be expressed in Megajoules (MJ) per functional unit or time. For ease of use, we express it in kilowatt-hour (kWh) per unit of time (1kWh=3.6MJ).

Electricity consumption is not an environmental indicator, but given the constant demand to supply this indicator, we have chosen to provide it while systematically adding this comment.

Electricity consumption (final energy):
The production of electricity consumed by digital equipment is the source of some of the environmental impact listed above.

This indicator is expressed in kilowatt-hour (kWh) per unit of time.

1.5 PRESENTATION OF THE RESULTS

Given the nature of the study, the numbers are usually rounded to the nearest tens or hundreds.

02 FOOTPRINT

2.1 THE DIGITAL WORLD IN 2019

In 2019, the digital world is made up of **34 billion pieces of equipment with 4.1 billion users, i.e. 8 pieces of equipment per user.** This average equipment level hides very large disparities depending on the geographical area observed. In 2019, the mass of this digital world amounts to **223 million tonnes, the equivalent of 179 million cars of 1.3 tonnes (5 times the number of cars in France).**

The digital world is not immaterial, quite the contrary. It consists of computers, monitors, smartphones, millions of kilometres of copper and optical fibre cables, thousands of data centres, billions of phone chargers, and so on.

The digital world is usually broken down into **3 tiers: users, data centres, and networks** that connect users to each other and to data centres.

2.1.1 USERS

In 2019, the digital world is about **34 billion digital devices** (excluding accessories such as chargers, keyboards, mice, USB sticks, etc.) that had to be manufactured, connected by millions of kilometres of cables and that require electricity supply.

The most popular devices are **smartphones (3.5 billion), other phones (3.8 billion), display devices such as television sets, computer screens and video projectors (3.1 billion)**. And, of course, **connected objects:** Bluetooth speakers, watches, thermostat, lighting, etc. Almost non-existent 10 years ago, there are already approximately **19 billion connected objects in 2019 (from 8 to 30 billion according to different studies).**

2.1.2 NETWORKS

In the middle, the network connects user terminals to each other and to data centres. It mainly consists of the equipment that constitutes **the "local loop"** also called **"last mile". That is 1.1 billion DSL / fibre routers, 10 million GSM relays (2G to 5G) and about 200 million other active WAN (extended network outside the buildings) and LAN (local network inside the buildings) equipment.**

2.1.3 DATA CENTRES

In comparison, the few thousand **data centres** are marginal with at most **67 million hosted servers** and hardly any other computer equipment accompanying them.

2.1.4 NUMBER OF USERS AND MASS OF THE DIGITAL WORLD

All this equipment is used by about **4.1 billion people,** a little more than **8 devices per user,** with very large geographical disparities.

This digital world (excluding human beings) weighs **223 million tonnes,** that is as much as **179 million medium sedans (1.3 tonnes), 5 times the number of cars in France.**

2.2 ITS FOOTPRINT

In 2019, the digital world virtually represents a **7th continent**:
→ **2 to 3 times the size of France (depending on the observed environmental indicator);**
→ **and up to more than 5 times France** if we consider other indicators (mass, etc.).

Its contribution to the environmental footprint of humanity is far from negligible:
→ Primary energy consumption (PE): **4.2%**
→ Greenhouse gas emissions (GHG): **3.8%**
→ Water consumption (water): **0.2%**
→ Electricity consumption (Elec.): **5.5%***

Compared to everyday uses, this amounts to:
→ **GHG: 1.5 billion French employees going to work for 1 year**
→ **Water: 242 billion packs of mineral water (9 litres);**
→ **Electricity: 82 million electric heaters (1000 Watts each) permanently switched on*.**

* Electricity consumption is not a relevant environmental indicator.

2.2.1 FOOTPRINT

In 2019, the global digital environmental footprint is in the order of
→ **6,800 TWh of primary energy (PE);**
→ **1,400 million tonnes of greenhouse gases (GHG);**
→ **7.8 million m3 of fresh water (Water);**
→ **22 million tonnes of antimony (ADP).**

Technical and flow indicators
→ **223 million tonnes (mass), i.e. 179 million cars of 1.3 tonnes!**
→ **1,300 TWh of electricity consumed**

Such orders of magnitude are not easy to grasp, so we must put them into perspective. For example, by comparing them to the global footprint of humanity, of France, and of our daily habits.

2.2.2 CONTRIBUTION TO THE FOOTPRINT OF HUMANITY

The digital world contributes significantly to the environmental footprint of humanity. Its contribution to the environmental footprint of humanity is far from negligible [7], [8], [9], [10]:

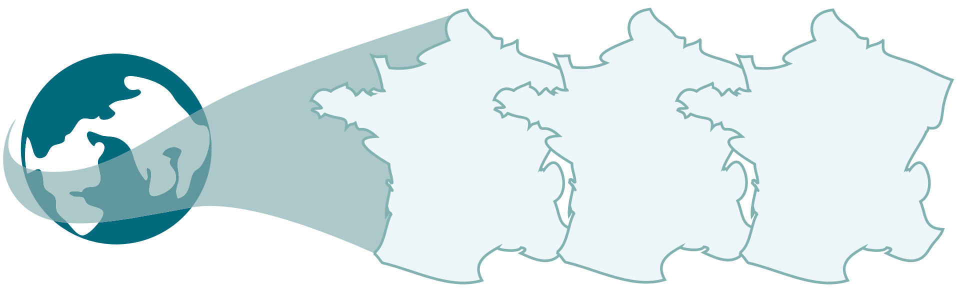
PRIMARY ENERGY CONSUMPTION (PE):
4.2 %

GREENHOUSEGAS EMISSIONS (GHG):
3.8 %

WATER CONSUMPTION (WATER):
0.2 %

ELECTRICITY CONSUMPTION (ELEC.):
5.5%*

These orders of magnitude - **from 0.2 to 5.6% of humanity's global footprint** - may seem minor. But if "Digital" was a country, it would have about **2 to 3 times the footprint of France.**



2.2.3 COMPARISON WITH THE FOOTPRINT OF FRANCE

In 2019, the environmental footprint of the digital world represents **a 7th continent 2 to 3 times the size of France** (depending on the observed environmental indicator) and up to **more than 5 times France** if we consider other indicators (masse etc.).

Footprint of the digital world compared to the global footprint of France:
→ **Greenhouse gas emissions: 2x**
→ **Water consumption: 2.1x**
→ **Electricity consumption: 2.6x**
→ **Mass: 5x the mass of all cars in France**

2.2.4 COMPARISON WITH EVERYDAY USE

Compared to everyday uses and / or everyday life, the numbers are staggering!

Impact of the digital world in 2019 expressed in equivalent uses in everyday life:

Greenhouse gas emissions:
→ **116 million round-the-world trips by car (42,000 kms each)**
→ **1.5 billion French employees traveling 25 km each day by car to work, for 1 year.**

Water:
→ **242 billion packs of mineral water (9 litres)**
→ **3.6 billion showers**

Electricity consumption:
→ **82 million electric heaters (1000 Watts each) permanently switched on**

2.3 BREAKDOWN OF IMPACT BY TIER AND BY LIFECYCLE STAGE

Because of their number **(34 billion)**, user equipment is the main source of impact of the digital world.

Their manufacturing systematically concentrates the most impact with **30% of the global energy balance, 39% of the GHG emissions, 74% of the water consumption and 76% of the contribution to the depletion of abiotic resources.**

If we add the impact associated with the production of the electricity they consume, **user equipment (excluding DSL / fibre routers) accounts for between 59% and 84% of the impact!**

In 2019, the hierarchy of sources of impact is as follows, in descending order of importance:

1. Manufacturing of user equipment;
2. Power consumption of user equipment;
3. Power consumption of the network;
4. Power consumption of data centres;
5. Manufacturing of network equipment;
6. Manufacturing of equipment hosted by data centres (servers, etc.).

While computers and associated display devices concentrated from **33% to 40%** of the total impact of the digital world in 2010, a new trend appeared in 2015, and is getting significantly stronger in 2019, with mainly 3 new sources of impact:

1. Television sets: 9 to 23% of the impact;
2. Smartphones: 6 to 19% of impact;
3. Connected objects: 10 to 14% of impact.

2.3.1 MAINLY THE MANUFACTURING OF USER EQUIPMENT

User equipment is the main source of environmental impact, accounting for between **59% and 84% of total impact** depending on the observed environmental indicator. Next come the network and data centres.

%	Energy	GHG	Water	Elec.	ADP
User equipment	60%	63%	83%	44%	75%
Network	23%	22%	9%	32%	16%
Data centres	17%	15%	7%	24%	8%

Breakdown of impact of the digital world in 2019

Regardless of the indicator observed, **the user equipment manufacturing stage is still the main unitary source of impact,** followed by their electricity consumption. Next come, in descending order of importance, the electrical consumption of the network, then that of data centres.

Regarding water consumption and the contribution to the depletion of abiotic resources (excluding fossil energy), it is overwhelmingly **(respectively 83% and 75%)** associated with the manufacturing of user equipment.

2.3.2 ELECTRICITY PRODUCTION COMES SECOND, EXCEPT FOR GHGs AND DEPLETION OF FOSSIL FUEL STOCKS

For example, for 2019 on **Primary Energy (PE)** and **Global Warming (GWP)** indicators:

PE balance	Manufacturing	Use	Total
User equipment	30%	30%	60%
Networks	3%	20%	23%
Data centres	2%	15%	17%
	35%	65%	

Primary energy balance 2019

Primary energy consumption is mainly due to **the production of electricity and then user equipment.**

GHG balance	Manufacturing	Use	Total
User equipment	40%	26%	66%
Networks	3%	17%	19%
Data centres	1%	14%	15%
	44%	56%	

Greenhouse gas emissions balance 2019

Emissions are mainly due to **the manufacturing of user equipment and then to the production of electricity required to power it.**

2.3.3 HIERARCHY OF IMPACT SOURCES

The hierarchy of impact sources is as follows, in descending order of importance:

1. **Manufacturing of user equipment;**
2. **Power consumption of user equipment;**
3. Power consumption of the network;
4. Power consumption of data centres;
5. Manufacturing of network equipment;
6. Manufacturing of equipment and data centres (servers, etc.).

The environmental footprint is primarily due to the quantity of equipment manufactured. It is first and foremost the number of equipment **(34 billion including 19 billion connected objects and on-board computing)** that explains the contribution of user equipment in the total balance sheet. The logic is the same for network equipment **(1.3 billion including more than 1 billion DSL / fibre routers) and data centres (67 million servers).**

2.3.4 IMPACT OF MANUFACTURING AND USE

Manufacturing of user equipment.

During manufacturing, most LCAs show that it is mainly **the extraction of raw materials (ores in particular) and their transformation into electronic components** that create environmental impact: **depletion of abiotic resources, pollution, GHG emissions, etc.**

Power consumption.

The production of electricity consumed by users induces different impact depending on the nature of the primary energy used (solar radiation, wind, coal, uranium, etc.) and the transformation process (combustion, nuclear reaction, etc.). On a global scale, it is mainly **responsible for the depletion of fossil fuels (oil, coal, gas, uranium, etc.) and the emission of greenhouse gases that contribute to global warming.**

Data centres.

If we consider only the PE and GHG indicators, electricity consumption is logically the main impact point. On the other hand, if the other indicators (ADP, Water, etc.) are considered, it is **the manufacturing of electronic equipment hosted by data centres (servers and switches in particular) that concentrates the impact.**

2.3.5 ENERGY BALANCE BY STAGE OF THE LIFE CYCLE

If we consider the **"primary energy"** indicator, which totals the energy spent during manufacturing and during use, three equipment profiles stand out clearly when we try to understand at which stage of the lifecycle the impact happens:

1. **Infrastructure equipment;**
2. **Leisure equipment;**
3. **"Traditional" equipment.**

Infrastructure equipment.

Excluding network cables, they account for about **4% of equipment and 0.5% of the mass of the digital world.** Infrastructure devices are those that operate 24 hours a day, 365 days a year, such as **routers, switches, GSM relays, servers, and so on.** Logically, the footprint of these devices comes mainly from the use phase. It is mainly related to **the production of the electricity** they consume.

Leisure equipment.

Excluding connected objects, they represent about **22% of user equipment and 20% of their mass.** With the notable exception of television sets, these are the devices that allow for entertainment: **video projectors (home theatre), TV boxes (decoder), video game consoles, etc.** Their energy balance is clearly associated with **the use phase.**

"Traditional" equipment.

Excluding connected objects, they represent about **73% of user equipment and 64% of their mass.** We categorise here anything that is not infrastructure or entertainment equipment: **smartphones and phones, tablets, laptops and desktops, computer screens, and so on.** With one notable exception: television sets are entertainment equipment, but their energy profile is identical to that of traditional equipment. For this category of equipment, **it is manufacturing that concentrates the impact.**

2.4 BREAKDOWN OF IMPACT BY ENVIRONMENTAL INDICATOR

If we analyse one indicator at a time, the situation is rather contrasted, with nevertheless:

→ **a predominance of impact related to user equipment;**

→ **two emerging patterns.**

For example, in 2019:

2.4.1 CONTRIBUTION TO THE DEPLETION OF ABIOTIC RESOURCES (EXCLUDING FOSSIL ENERGY)

ADP balance	Manufacturing	Use	Total
User equipment	76%	0%	76%
Networks	16%	0%	16%
Data centres	8%	0%	8%
	100%	0%	

Abiotic resources balance 2019

The depletion of stocks of abiotic resources (especially minerals) excluding fossil fuels is, logically, concentrated in the manufacturing of equipment, especially **user equipment because of their number.**

2.4.2 TENSION ON AVAILABLE FRESHWATER STOCKS

Water balance	Manufacturing	Use	Total
User equipment	75%	9%	84%
Networks	2%	6%	8%
Data centres	2%	6%	8%
	79%	21%	

Water balance 2019

The trend is the same for tensions on freshwater stocks. However, it is slightly modulated by the electricity production that also require large quantities of water to power the digital world, of the order of **1,614 million m3 (against 3 times more for the equipment manufacturing).**

2.4.3 CONTRIBUTION TO GLOBAL WARMING (GWP)

GHG balance	Manufacturing	Use	Total
User equipment	40%	26%	66%
Networks	3%	16%	19%
Data centres	1%	14%	15%
	44%	56%	

Greenhouse gas emissions balance 2019

Unsurprisingly, **greenhouse gas emissions** are directly correlated with the burning of **fossil primary energy.** It is used at all stages of the lifecycle of digital equipment: extraction of minerals, transformation into electronic components, distribution and marketing, use and end of life. **The manufacturing of user equipment** remains the main source of GHG emissions, followed by their electricity supply and by that of network equipment and data centres.

In total, it is **the use phase that emits the most greenhouse gases.** This is, paradoxically, good news. For a constant volume of GHG emissions, the more the use phase increases, the more it means that **the service life of the equipment increases:** the impact associated with the manufacturing phase is "amortised" over a longer period.

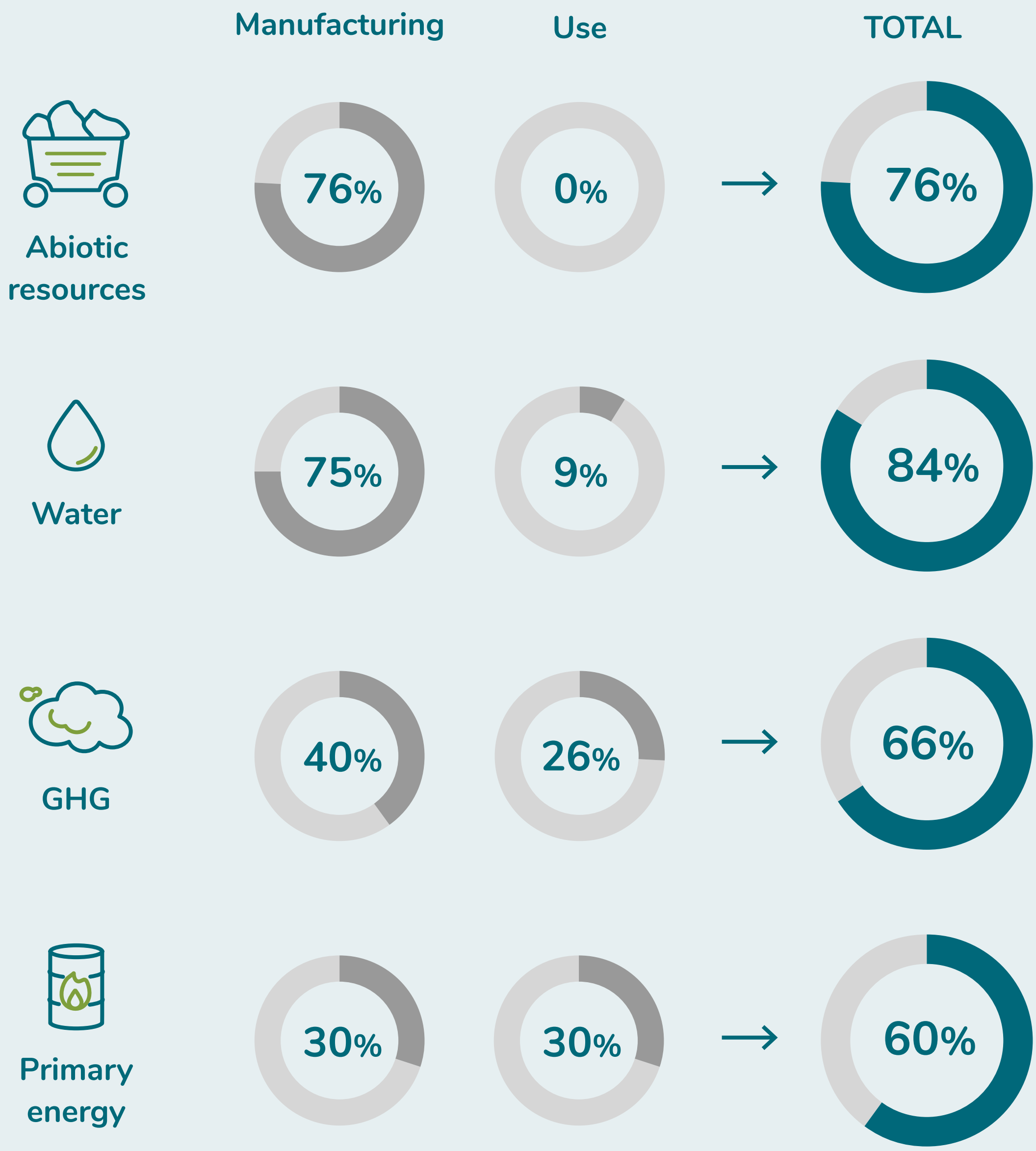
2.4.4 PRIMARY ENERGY CONSUMPTION (PE)

PE balance	Manufacturing	Use	Total
User equipment	30%	30%	60%
Networks	3%	20%	23%
Data centres	2%	15%	17%
	35%	65%	

Primary energy balance 2019

The energy balance focuses on **the use phase with 2/3 of the energy spent at this stage of the lifecycle.** The network and data centres are over-represented due to 24-hour operation 365 days a year.

SHARE OF THE USER EQUIPMENT IN THE FOOTPRINT OF THE DIGITAL WORLD IN 2019



03 EVOLUTION FROM 2010 TO 2025

In quantity, the size of the digital world will be multiplied by 5 between 2010 and 2025. This expansion results in a doubling, or even a tripling (depending on the observed indicator), of the environmental impact of the digital world in 15 years. An unprecedented increase in both its scale and speed.

Between 2010 and 2025, the digital share of humanity's footprint will rise from **2.5% to just under 6%.** The largest increase is **in greenhouse gas emissions, which will rise from 2.2% in 2010 to 5.5% in 2025.**

In 2025, user equipment will concentrate from 56% to 69% of the impact. For example, 62% of digital GHG emissions will be user-related, 35% of which comes from equipment manufacturing.

Apart from the growth in the number of users, the increase of the footprint of the digital world is mainly due to:

- → **connected objects,** whose number will be multiplied by 48 between 2010 and 2025;
- → **doubling the size of screens** (including television sets) between 2010 and 2025;
- → **declining energy efficiency gains;**
- → **equipment of emerging countries** whose electricity production is often more impacting than that of Western countries.

From a social / societal point of view, the fivefold increase of the mass of the digital world in 15 years will only increase the tensions related to raw materials and in particular reinforce the role of ores in the financing of armed conflicts in Africa and Asia, hence the name of "conflict minerals".

3.1 THE DIGITAL WORLD FROM 2010 TO 2025

The number of devices sold (computer, gaming console, etc.) stabilises from 2015 (+ 10% only between 2015 and 2025), with the notable exception of the number **of connected objects which is multiplied by 48 in 15 years (48 billion in 2025).**

Evolution	2010	2015	2020	2025
Users (million)	2 023	3 185	4 700	5 500
Devices (million)	13 531	18 405	19 041	20 278
Equipment level	7	6	4	4
IoT (million)	1 000	9 605	20 315	48 272
Devices incl. IoT (million)	14 531	28 010	39 356	68 550
Mass (million tonnes)	128	164	236	317

The digital world from 2010 to 2025

3.1.1 NUMBER OF DEVICES: +50%

Although the number of “standard” devices (excluding connected objects) has increased significantly between 2000 and 2015, it stabilises between 2015 and 2025 because the market is saturated. This results in a “moderate” increase of + 50% in equipment between 2010 and 2025.

Over the last decade studied (2015-2025), this trend conceals a decline in the number of standard terminals (computers, tablets, featured phones, video game consoles, etc.) in activity and an increase in the number of smartphones.

The most notable trend is the dramatic growth of the number of connected objects and on-board computing (now present in household robots, cars, etc.). This increases from **1 billion connected** objects in 2010 to **48 billion** in 2025. That is a factor of 10 between 2010 and 2015 then a factor of 2 (doubling) every 5 years until 2025.

3.1.2 HALF THE EQUIPMENT PER USER

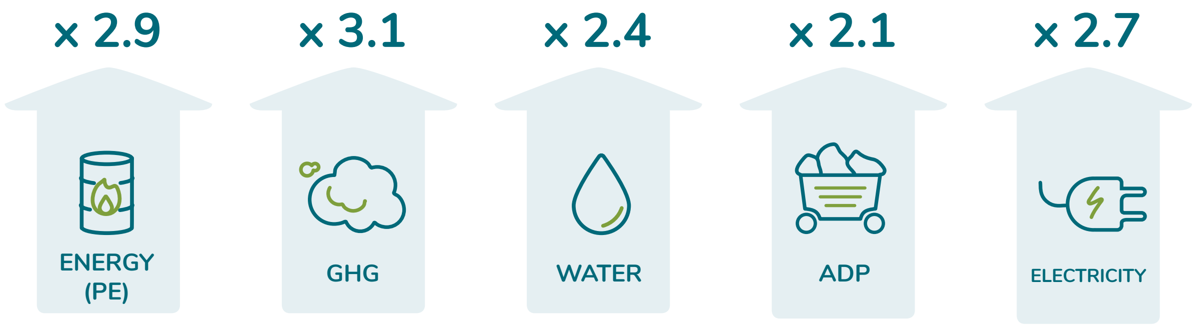
Excluding connected objects, the number of users increases faster than the number of devices put on the market, the equipment level thus falls from about 7 devices per user in 2010 to 3.5 in 2025. This trend is mainly due to the market in the developed countries being saturated; it is above all the emerging countries that get equipped, although with a lower purchasing power. This global trend obviously hides a very wide disparity in equipment levels between a developed country like France and an emerging country like Sudan.

3.1.3 MASS: X2.5

Although the mass per user decreases slightly, from 63 kg to 58 kg between 2010 and 2025, **the total mass** (user equipment, networks, data centres) **is multiplied by more than 2.5 in 15 years.** It increases from **128 million tonnes** in 2010 to 317 million tonnes in 2025. This explains the stress on raw materials, especially “conflict minerals” and other rare earths. “Conflict minerals” finance armed groups in Africa (DRC for Coltan for example) and in Asia. As far as China is concerned, it fights a real economic war to the rest of the world through rare earths.

3.2 FOOTPRINT EVOLUTION

In absolute value, depending on the indicator observed, the digital footprint doubles or triples in 15 years. This is an extremely quick progression.



As a result, there is a sharp increase in all indicators between 2010 and 2025:

However, there are two distinct periods:
→ Growth is particularly strong between 2010 and 2020;
→ It then slows down between 2020 and 2025.

The "sawtooth" evolution is explained by many factors that influence each other. For example:
→ Emerging countries with lower equipment levels take over from developed countries;
→ Progress in terms of energy efficiency is slowing down;
→ Sales of standard devices (computers, etc.) stabilise as new equipment (IoT) appears;

In relative value, compared to the footprint of humanity which also increases, the progression is slower. However, it remains much faster than most other sectors of the economy.

The very strong growth in global demand for electricity pushes the increase in electricity consumption of the digital world from a factor of 2.7 (absolute value) to 1.9 (relative value): the digital world is, by far, not the only contributor to the increase in electricity consumption in the world.

3.3 THE SPECIAL CASE OF CONNECTED OBJECTS AND TELEVISION SETS

The share of television sets and connected objects in the impact of the digital world will be multiplied by 5 between 2010 and 2025, growing from between **5% and 15% of the impact of the digital world in 2010, to between 27% and 43% in 2025,** depending on the observed indicator.

3.3.1 CONNECTED OBJECTS

The growth in the number of connected objects is exponential: from **1 billion** in 2010 to **48 billion** in 2025, roughly **50 times more** in only 15 years.

Their contribution to the impact of the digital world thus goes from less than **1%** (all environmental indicators combined) in 2010 to between **18% and 23%** in 2025. It is huge!

IN 2010

1 billion

1%

OF IMPACT

→

IN 2025

48 billion

18 to 23%

OF IMPACT

Fortunately, most of these devices are small and / or not (yet) all equipped with a large display. This limits the environmental impact related to their manufacturing.

In addition to the depletion of abiotic resources and the material entropy [1] that they generate, these objects also disperse and atomise "digital pollution".

It is therefore crucial to contain the growth of this market, not necessarily in economic terms, but most importantly with regards to the number of equipment manufactured.

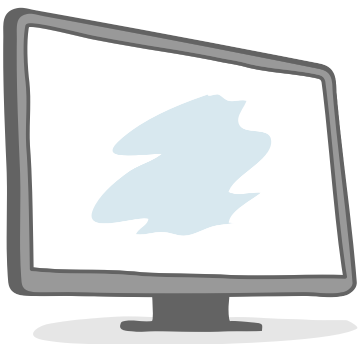
It is also crucial to ensure that their APIs are open to ensure that they will not become obsolete if the company that provides them with data goes bankrupt....

3.3.2 TELEVISION SETS

Digital TV sets - connected to a set-top box / TV box itself connected to a DSL / fibre router and smart TV sets - will grow **from 525 million in 2010 to 1.2 billion in 2025.** This growth is the strongest in the study, just after that of connected objects, and far ahead of the smartphone market, already saturated.

Coupled with a doubling of screen size - from an average diagonal of 31 inches in 2010 to 65 inches in 2025 - the doubling of the fleet in 15 years will dramatically increase the television sets' contribution to the overall digital footprint. It increases **from 5% - 15% in 2010 to 9% - 26% in 2025.**

In section 4.2, we propose some ways and alternatives to try to contain this source of impact.



IN 2010
0.525 billion
5 to 15%
OF IMPACT

→

IN 2025
1.2 billion
9 to 26%
OF IMPACT

3.4 OTHER NOTABLE TRENDS

ELECTRICITY	ENERGY	GHG
× 2.7	**× 2.9**	**× 3.1**
between 2010 and 2025	between 2010 and 2025	between 2010 and 2025

3.4.1 IMPROVING ENERGY EFFICIENCY IS NOT ENOUGH ANYMORE

Until now, the energy efficiency of digital equipment has been continuously improving. The number of digital operations per Joule doubled every two years [Koomey's law]. However, **the annual electricity consumption of the digital world will almost triple between 2010 and 2025** from about 700 TWh to 1900 TWh. This means that the energy efficiency gains in the use phase, which have been falling in recent years, no longer compensate for

the continued rise in screen size (rebound effect).

The overall energy balance, including in particular the grey energy needed to manufacture equipment, follows a comparable trend with around 3.400 TWh of primary energy in 2010 against 10.000 TWh in 2025.

The digital world will consume 3 times more energy because the number of devices increases, but also because some equipment consumes more and more energy. This is particularly the case of computer screens and televisions whose diagonal size will double between 2010 and 2025.

3.4.2 GLOBAL WARMING IS INCREASING THE MOST

Greenhouse gas emissions are the fastest growing indicator with 3.1 times more emissions between 2010 and 2025. From 738 million tonnes of CO_2 equivalent in 2010 to 2,278 million tonnes in 2025. This is partly due to the high-emission energy mix of the countries which equip themselves most over the period 2015-2025: Asia and emerging countries. But it is also because more and more equipment is produced. In 2025, more than a third of digital GHG emissions (35%) will be due to the manufacturing of user terminals.

3.4.3 THE NETWORK INCREASES THE MOST

Among the 3 tiers - users, networks, data centres - it is the network share that increases the most in relative value.

This is explained by the fact that the users' share falls **between -5% and -13%** in 15 years (depending on the indicator observed), which proportionally increases the impact of the network and data centres.

An additional explanation is the deployment of at least **10 million 4G and 5G GSM relays** (radio base station) between 2010 and 2025, in addition to the impact of existing network infrastructures, including DSL / fibre.

+10 million

RELAY ANTENNAS FROM 2010 TO 2025

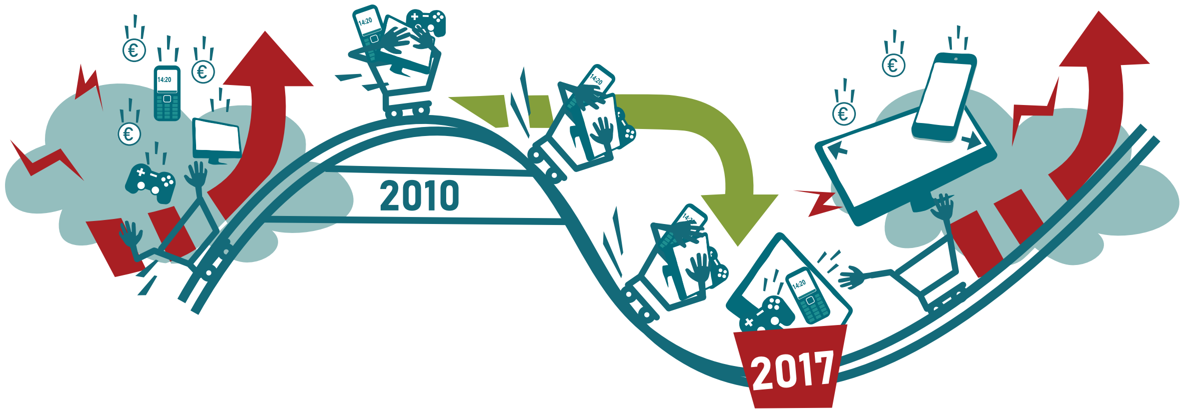
3.4.4 IMPACT PER USER DECREASES AND THEN INCREASES

The digital footprint of each user decreases overall between 2010 and 2015 to increase again from 2017.

This “roller coaster” coincides for its first part between 2010 and 2017 to a continuous increase of the energy efficiency, the increasing service life of equipment, and an economic context that is not favourable to the market.

From 2017, there is a cap on energy efficiency gains, a global economic recovery that boosts equipment sales and the take-off of emerging markets.

Moreover, it is also at this time that many cases of planned obsolescence are denounced in the world. There is also a crossover between the decline in equipment per user (limited impact of emerging countries) and the increase in the size of screens.



04 RECOMMENDATIONS

Some simple steps would significantly reduce the environmental footprint of the digital world by 2030:

1. **Reducing the number of connected objects** by promoting the pooling and substitution thereof and by opening their APIs.
2. **Reducing the number of flat screens** by replacing them with other display devices such as augmented / virtual reality glasses, LED video projectors, etc.
3. **Increasing the lifespan of equipment** by extending the legal warranty period, promoting reuse, and fighting against certain subscription plans.
4. **Reducing the requirements of digital services** through their eco-design.

Had they been implemented as of 2010, these 4 measures would have reduced the global digital footprint over the period observed (2010 to 2025) **by between 27% and 52%.** This would have helped maintain the 2025 digital footprint at its 2018 level despite the addition of 1.1 billion users.

4.1 LIMITING THE NUMBER OF CONNECTED OBJECTS

The exponential growth in the number of connected objects (from 1 billion in 2010 to 48 billion in 2025) is accompanied by an increase in their contribution to the impact of the digital world, from less than 1% in 2010 to between 18% and 23% in 2025. It is huge!

The only way to reduce their impact is to reduce their number. In addition to raising the awareness of the general public and the public authorities of the environmental impact of these objects, we must above all find technical solutions to pool them and new business models that make it possible to derive economic value from this pooling.

Pooling is the first lever for reducing impact and creating value for economic players who seize this opportunity. For example, it consists in aggregating DSL / fibre routers and associated TV sets boxes via a single centralised device per building, which would significantly reduce the impact of the network. As a reminder, it is the last mile (including the box DSL / fibre) that concentrates the bulk of the impact. However, there is no technical reason why each apartment in a building should have its own internet connection. In companies, the Internet connection has been shared for 20 years and this no longer poses any problem of speed or quality, quite the opposite. At the scale of a collective housing, one can imagine many other pooling: printer, video projector, video game console, etc.

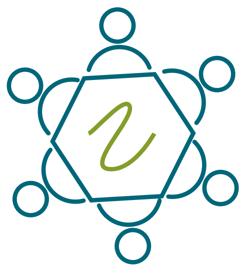
Another way, complementary to pooling the equipment between several users, is to substitute several equipment by one. For instance, to replace the 3 smart meters (water, gas, electricity) by one, or at least to share some parts: the router for example. Because if the sensors are specific to the measured flows, the means of transmitting the information can be shared.

Finally, it is possible **to extend the lifespan of connected objects by opening their APIs.** These programming interfaces are used to exchange data between the connected object and the servers of the manufacturer or its partners. Today, these communication interfaces are closed, much like a television that would be blocked on a single channel. By inducing (or forcing) manufacturers of connected objects to open their APIs, we guarantee that the object can be used even if the data / content provider disappears: just switch channels! The lifetime of these objects is thus logically lengthened, which makes it possible to spread the impact associated with their manufacturing over a longer period of use.

Hypothesis 1
2 times less connected objects between 2010 and 2025

H1 environmental gains by 2025 (in absolute and relative values of the "business as usual" footprint)

Energy	993 TWh	10 %
GHG	257 million t CO2 eq.	11 %
Water	946 million m^3	9 %
ADP	3 million t SB eq.	9 %
Electricity	169 TWh	9 %



4.2 REDUCING THE SIZE OF FLAT SCREENS

Although progress has been made by flat screen manufacturers, the impact of this equipment remains significant. The doubling of the average diagonal size from 31 inches to 65 inches over the period 2010-2025 contributes very significantly to the increased impact of the digital world. We must find alternative display solutions that meet both the desires of users and the challenges of sustainable development.

Virtual reality (VR) glasses can be a smart solution for solo use. However, the number one issue is to find an alternative to the giant screen that stands proudly in the middle of the living room.

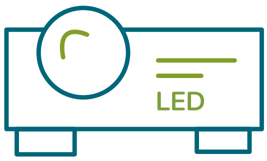
LED video projectors can be interesting. Thanks to a lower power consumption (compared to previous technologies), they can significantly increase the current diagonal (consumer wish) while significantly reducing the impact associated with manufacturing (compared to a flat screen). These manufacturing gains more than offset the increase in power consumption over the use phase. Obviously, in collective habitats such as buildings, the most judicious approach may be to create shared home cinema spaces in order to pool the equipment while offering a better service. See 4.1.

Hypothesis 2

Conversion of 50% of large screens to LED video projectors

H2 environmental gains by 2025 (in absolute and relative values of the “business as usual” footprint).

Energy	514 TWh	5 %
GHG	124 million t CO2 eq.	5 %
Water	1 319 million m³	12 %
ADP	1 million t SB eq.	4 %
Electricity	56 TWh	3 %



4.3 EXTENDING THE LIFESPAN OF EQUIPMENT

As equipment manufacturing is the main source of impact (**30 to 76% of the global digital footprint depending** on the observed indicator), it is necessary to manufacture less and use for a longer period of time.

Four key measures are still not implemented:
→ The extension of the **legal warranty** period;
→ A **deposit/refund scheme** for EEE, to increase the capture rate of WEEE;
→ Prohibiting almost-free equipment linked to telecom contracts;
→ Creating a **"re-use"** directive to complement the "WEEE" directive.

Extending the legal warranty period [2] is a measure that is both simple to implement, easy for consumers to understand, and very efficient for the environment. Today, the legal warranty period (2 years in France) is often completely disconnected from the actual lifespan of the equipment: 5 to 7 years for a laptop, 7 to 10 years for a computer screen, more than 6 years for a TV, etc. Unfortunately, Europe is currently harmonising a reduction in the legal warranty period...

In France, as in other Western countries, for various reasons too long to mention in this study, the collection level of waste electrical and electronic equipment is around 45%. It is even worse in the rest of the world. The only relatively simple measure to implement and which has proved its effectiveness in the past is to reintroduce the deposit/refund scheme. With a sufficiently high deposit amount (around 10% minimum of the price of the equipment) to dissuade the consumer from doing without it, capture rates can quickly reach more than 80% to 90% of the out of order equipment, all over the world.

Given the footprint of our digital uses, is it still acceptable in 2019, to push consumers to part with perfectly functional smartphones via promotional offers like "a smartphone at 1 euro against a new 24-months contract"? Certainly not. **The ban on "almost-free equipment"** promotional offers - or failing that, to mandate to display the real cost of the smartphone in the price of the new contract - would significantly extend the average lifespan of smartphones (currently only 2 years in Western countries).

Finally, it is essential to complement the existing European Waste of Electrical and Electronics Equipment (WEEE) directive, centred on the downstream management (waste), **with a new "re-use"** directive to effectively control the upstream approach: refurbishing for reuse of functional digital equipment. Indeed, the reuse of digital devices is a fundamental key to reduce their footprint.

In the absence of a strict legal framework, re-use is struggling to develop in the digital sector. On the one hand, the large private / public organisations, which are the main suppliers of "raw material" in the refurbishing industry, fear to find their computers in a landfill in Africa. On the other hand, consumers are afraid of being fooled by second-hand equipment that is not very reliable. A stricter legal framework would provide an effective answer to both these issues.

In addition, it is quite possible:

→ to increase the legal warranty period for reconditioned goods (currently 6 months)

→ and to require traceability of equipment to effectively fight the illegal export of our WEEE to Ghana and Asia (among others).

Other measures of this type are presented in the **"50 measures for sustainable consumption and production"** white paper published in February 2019 by the French "Stop Planned Obsolescence" Association (HOP - Halte à l'Obsolescence Programmée). See bibliography.

Hypothesis 3
30% increase in lifespan of user equipment over 15 years.

H3 environmental gains (in absolute and relative values of the 2025 "business as usual" footprint)

Energy	1683 TWh	17 %
GHG	405 million t CO_2 eq.	18 %
Water	2607 million m^3	24 %
ADP	6 million t SB eq.	21 %
Electricity	244 TWh	13 %

4.4 ECO-DESIGN OF DIGITAL SERVICES

The eco-design of digital services aims at reducing their environmental impact from the design phase. To achieve this, we seek to reduce the amount of computing resources - terminal power, bandwidth, number of servers, etc. - necessary to carry out the action that defines the digital service: find a train schedule, make an appointment with a doctor, communicate via an e-mail, etc.

By reducing the amount of resources needed, we:
→ mechanically reduce the impact by not producing unnecessary resources;
→ extend the lifespan of the user terminals.

Based on 10 years of experience, feedback from France and Europe show that it is possible to divide by a factor of 2 to 100 the amount of resources needed.

Hypothesis 4
→ **Reduction of servers required by a factor of 2**
→ **Reduction of the amount of transmitted data by 20%**
→ **40% increase in the lifespan of user equipment over 15 years.**

H4 environmental gains (in absolute and relative values of 2025 "business as usual" footprint)

Energy	**1967 TWh**	**20 %**
GHG	**422 million t CO_2 eq.**	**19 %**
Water	**2699 million m^3**	**25 %**
ADP	**7 million t SB eq.**	**22 %**
Electricity	**349 TWh**	**18 %**

4.5 IMPACT OF THE RECOMMENDATIONS AND CONCLUSION OF THE STUDY

In relative terms, these recommendations make it possible to reduce by between **-27% (GHG) and -52% (Water)**, depending on the indicator observed, the footprint per user between 2010 and 2025. These recommendations are essential both because they allow to compensate the sharp fall in energy efficiency gains and, secondly, because the two main recommendations - longer lifespan and eco-design - are also areas of competitiveness for France (and other countries) [3].

In absolute value, the cumulative gains made by these four recommendations can contain the 2025 footprint at its 2018 level, but with **1.1 billion more users.**

However, if these avoidable impacts are already very significant, we are still very far from reducing the environmental impact of the digital world by a factor 4 [5] necessary for sustainable development. As a reminder, in 2019, the average GHG footprint of an average user is of the order of 356 kg CO2 equivalent, or 20% of his “annual GHG package” of 1.7 tonnes of CO2 equivalent. It’s still too much.

Given the issues raised, it is no longer acceptable to voluntarily increase our digital footprint only to boost the economy. Because this is ultimately the main reason for the unbridled growth of the digital world and its environmental impact.

It is necessary to switch as quickly as possible to a new model of sobriety in digital uses, but also in the technology itself.

At the current rate and because of the fast depletion of abiotic resources, digital equipment will be considered a critical resource in less than a generation.

Beyond the simple and easy-to-implement recommendations presented above, we therefore advocate the following:

1. **the development of a ‘digital technology’;**
2. **effective coordination between ‘low’ and ‘high’ digital technology;**
3. **the radical eco-design of digital services.**

The idea of **digital low-tech** [4] is to use robust, simple, low impact and very widespread digital technologies such as 2G, SMS, etc. to meet daily needs. Most feedback gathered over the last 10 years shows that this approach is not considered as a regression but is instead well-received by users.

Radical eco-design aims to coordinate the use of low- and high-tech digital resources to best meet the needs of humanity while significantly reducing our digital footprint. To conclude with a simple example, it is not necessary to have a latest-generation smartphone connected in 4G or 5G to access weather forecasts. A simple SMS allows the forecast to be transmitted on a 2G mobile phone. On the other hand, calculating weather forecasts requires the use of advanced technologies.

Only by adopting this posture of sobriety and cleverly coordinating low and high digital technology will we be able to build a more enviable digital future and make it an effective tool for improving humanity's resilience to the already on-going collapse.

05 APPENDICES, METHODOLOGICAL NOTES

5.1. MODEL AND FUNCTIONAL UNIT

5.1.1 FUNCTIONAL UNIT

The objective of the study is to assess the environmental footprint of the digital world. The functional unit considered is "use the digital world for one year".

5.1.2 PHASES OF THE LIFECYCLE CONSIDERED

The manufacturing and use of equipment have been taken into account.

The impact associated with the distribution and end of life of the equipment was excluded from the general scope of the study. The distribution has overall little impact compared to the other phases. The end of life of equipment has not been taken into consideration as there is no reliable impact factor at the international level. As a matter of fact, 70% of global WEEE is trafficked. It is therefore impossible to know the logistic impact (transport of waste) as well as those associated with their "recycling".

5.1.3 MODEL

The model used is based on GreenIT.fr's 15 years of experience in quantifying the environmental impact of digital equipment and services. We chose a classic three-tier architecture: user, network, data centres.

For the terminals, we followed an inventory approach; in other words, we quantified the impact from the inventory (number of equipment in operation) each year between 2010 and 2025. This inventory does not exist: we extrapolated it from sales figures and average lifespan. In addition to these two dimensions, we have introduced many parameters to refine the model: improvement of the energy efficiency of the equipment, increase of the size of the screens, variations in the time of these parameters, etc.

For the network, we used a hybrid model, inventory-based for last mile devices (edge) and based on the amount of data transferred for the core network. The model takes into account the evolution of the distribution of technologies: DSL, fibre, 2G, 3G, 4G, etc.

Finally, for data centres, we estimated the impact based on the number of servers in operation. In addition to calculating the number of active servers, based on 3 different and converging approaches, we have sampled the overall average impact of a server based on the study of 3 computer centre LCAs that we realised between 2015 and 2018. Each server therefore integrates a small share of the building, cold groups, other computer equipment, etc.

More generally, the model considers many other global parameters such as the evolution of the geographical distribution of the digital world over the last 15 years, the evolution of the impact related to the production of electricity, etc.

5.2 SYSTEM BOUNDARIES AND CUT-OFF CRITERIA

5.2.1 SYSTEM BOUNDARIES

Exclusions

The following flows are excluded from the analysis:
→ Manufacturing and maintenance of plants and production machinery
→ Construction and maintenance of infrastructure (building) except for data centres
→ Lighting, heating, sanitation and cleaning of infrastructure,
→ End of life processing of equipment
→ Production of equipment distribution packaging.

These flows are usually excluded from perimeters for manufactured products of large series, which is the case of digital equipment.

The paper used with the printers was not taken into consideration, not that its impact was negligible but because we did not have enough solid data to include it. Also, because we wanted to limit ourselves to a blue water balance. Coming from plants, paper would have forced us to take into consideration green water, which makes the water balance more complex with two different perimeters.

Inclusions

We included the manufacturing of data centre buildings because they are built specifically to house computer and telecom equipment, unlike the homes and offices of users.

For the same reason, we took into account the optical fibres and the telephone cables (copper) which constitute the physical network connecting the users to each other and to the computer centres.

These two elements - data centres and physical networks - also contribute significantly to the global digital mass.

5.2.2 CUT-OFF CRITERIA

A simplified lifecycle analysis was carried out, i.e. all available information about the scope of the study was taken into consideration. However, no mass, energy or impact cut-off criteria could be clearly identified.

5.3 INVENTORY

Below is a list of equipment taken into consideration.

User
Smartphones
Mobile phones
Corded phones and DECT
Tablets
Laptops
Desktop computers
Screens
Projectors
TV boxes
TV sets
Game consoles
Printers
Connected objects (IoT)

Network
Private + company boxes
IP / PBX
Wi-Fi access points
Active network equipment (routers)
Core network

Data Centres
Servers
Other digital equipment

5.4 LIFESPAN AND EQUIPMENT LEVEL

Lifespan.
The lifespans come from studies that we have done previously, including WeGreenIT [6] for WWF and Club Green IT, and other studies such as those of ADEME [11].

Equipment level.
The equipment level is used primarily for estimating the footprint of data centres. It is based on 4 studies: the equipment level of the IT centres of 26 large French companies (WeGreenIT) and the study of 3 LCAs of data centres that we carried out between 2015 and 2018.

5.5 CONSISTENCY CHECKS

Throughout the project, we performed hundreds of consistency checks to ensure that the orders of quantity used were in line with the field. These controls were done at two levels: macro to ensure that our estimates for the whole world were in line with other studies; and micro. For example, for the evolution of the power consumption of laptops, we checked the data sheet of the same model over time (from IBM Thinkpad T60 to Lenovo Thinkpad T495). Another example, we compared the equipment levels of our model with those of studies targeted on this specific topic.

In addition to these permanent checks, we have submitted for verification the summary of our results to several researchers, experts, and authors of other studies of the same type.

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