Digital is an increasingly heavy industry

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Cloud computing and related practices are one of the most energy-intensive activities in the entire digital ecosystem.
On 10 March 2021, a fire completely destroyed one of the four Strasbourg data centres of OVH, the French leader in cloud computing. This unfortunate fire (see photo, p. 153) and its far-reaching consequences should encourage us to rethink the relationship between digital technology, the environment and our own sustainability. The damage and impact of this fire show that the cloud is not as ethereal as it seems. Quite the contrary. When the data centre burns down, it is indeed matter that burns. Our data is hosted and processed in factories, even if its physical reality, virtualised by marketing and media rhetoric, has become less and less perceptible to the end user.

From the illusion of dematerialisation to the reality of rematerialisation

There is no justification for associating digitisation with "dematerialisation", but rather with another type of "materialisation" [1-3]. We're not talking about cloud computing here, but rather a different kind of computing, located on the tarmac in data factories the size of dozens of football pitches, housing millions of hard disks, motherboards, processors, cables, computers and so on. So rather than talking about the dematerialisation of content, we should be talking about the "materialisation of containers".

In this short contribution, we will look at the environmental impact, on a global level, of what is called "digital" but which is, in reality, that of tens of millions of machines, information systems [4] and digital equipment.

Modern internet has allowed according to Melville [5] in 2010, Bohas *et al.* [6] in 2014, Harpet *et al.* [3] in 2022 and many other researchers - to increase the volume of what could be transported (the weight of data packets), the speed of exchanges (the requests between the input terminal and the response from the computer) and the complexity of the of the requests (the calculations performed and made available by the servers), and all this at a rate which, despite considerable technological progress, has resulted in a proliferation of newly-built equipment and an increase in energy consumption.

The volume of data exchanged has exploded: from the 2000s (Web 1.0), then the 2010s (Web 2.0) and today (Web 4.0), with the advent of artificial intelligence, the Internet of Things, hyper-algorithms and 5G to propel all this data simultaneously. These data are stored less and less "at home" or "down the hall", and are increasingly outsourced to the four corners of the world, from one country to another, as long as it's cold, there's water and electricity, and there's a bit of security and expertise. The world's data is stored and processed in California or Alaska, but also in Dublin, Oslo, Frankfurt and a little in France (Paris, Bordeaux, Nantes, Strasbourg, Nice...). But very little in Africa and South America, where data is protected neither from the folly of man nor from volcanoes

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Article available on website https://www.refletsdelaphysique.fr or https://doi.org/10.1051/refdp/2024s151

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and earthquakes. Where digital technology is not yet an achievement!

Internet 4.0 - and its corollary, all the connected objects in circulation around the world - is based on users and their workstations, data centres and data transport networks. These networks - satellites, undersea cables, wireless networks (wifi), fixed-line telephones, etc. - have become military-strategic issues, as their function is to connect all these objects and agents simultaneously. It is also a question of being able to do this - or offer it - wherever in the world the user wants to send a request from and is able to expect a response - provided that they have a sufficiently stable connection!

The usefulness of a few figures and orders of magnitude

To look at a few key figures, we can draw on fairly recent reports, articles and studies on all the electronic equipment that mobilises and manipulates data. We will be basing our analysis on two organisations that bring together players in the responsible digital sector: the think tank *The Shift Project* (with its *Lean ICT* project) and *Green IT*. Both sources are available online: one, since 2010, *via* the link https://cutt.ly/shiftproject (led by Jean-Marc Jancovici); the other, since 2004, *via* the platform www.greenit.fr (led by Frédéric Bordage, author in 2019 of the book *Sobriété numérique, les clés pour agir* [7]). These two teams have identified three major sources of environmental impact - users, networks and data centres - as well as four major indicators for measuring this impact and its growing scale since the early 2000s: depletion of abiotic resources, global warming, energy balance and pressure on fresh water. Electricity consumption is also cited in the indicators. All the data shows a significant increase in the environmental footprint of digital technology since 2010, with alarming trends and forecasts for 2025 (*Green IT*) and 2030 (*Shift Project*).

Let's start by looking at some basic data associated with the 34 billion devices handled by around 4.5 billion users (i.e. around ten per individual): this represents a total mass of around 220 million tonnes of materials of all kinds, spread across the globe in an obviously very disparate way - sub-Saharan Africa being the great forgotten in this distribution.

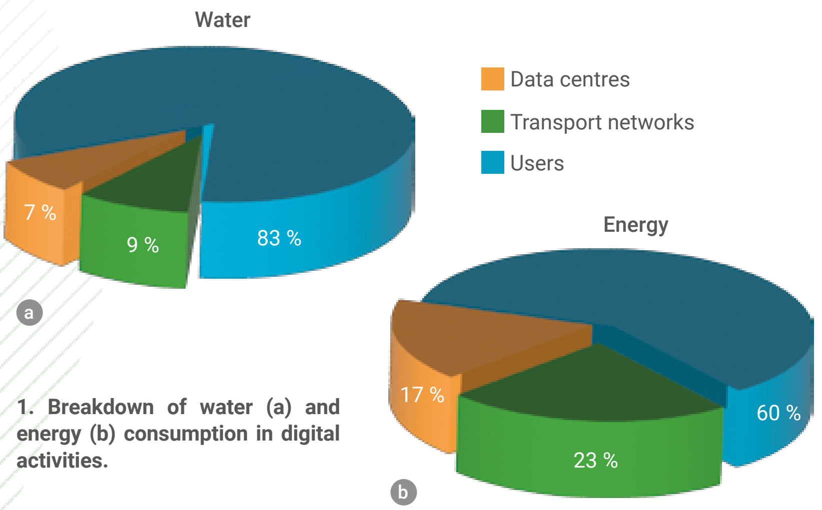
According to *Green IT*, the global environmental footprint of digital technology in 2018[a] is around 6,800 TWh of primary energy, 1,400 million tonnes of greenhouse gases, 7.8 million cubic metres of fresh water, 22 million tonnes of antimony and 1,300 TWh of electricity consumed, i.e. around three times France's total footprint or 5% of humanity's global footprint. Worldwide, the digital footprint accounts for 4.2% of primary energy consumption, 3.8% of greenhouse gas emissions, 0.2% of water consumption and 5.5% of electricity consumption: that's already significant, and it's growing fast (by around 6% a year!).

To explain the nature of these figures, we need to look at the life cycle of this equipment. The most 'expensive' aspect in terms of impact is still the manufacture of the equipment, which accounts for 30% of the overall energy balance and 74% of freshwater consumption. This is followed by electricity consumption, network electricity consumption and data centre electricity consumption, and then the manufacture of network equipment (cables, satellites, etc.) and servers hosted in global data centres. What's more, the hierarchy of impacts is also evolving: for example, the overall impact of the manufacture and use of computers has been eclipsed, giving way in 2019 to that of *smartphones*, connected objects and televisions. A contrario, the hierarchy of impacting factors has hardly changed: first come users - with the manufacture of their 34 billion items of equipment - who consume 60% of the energy and 83% of the water; then the network, which consumes 23% and 9% respectively; and finally data centres, which consume around 17% and 7%.

The two diagrams in Figure 1 summarise the hierarchy of energy and water consumption for the three main components of the global digital economy (users and their workstations, the data transport network and data centres).

To reduce these impacts, we simply need to tackle their main sources:
(i) limit the production and use of connected objects in the broadest sense, with, for example, more pooling and sharing;
(ii) increase their lifespan, by better combating obsolescence and encouraging re-use (rather than recycling);
(iii) lastly, better educate users and inform them about these impacts and the inflationary bias of certain uses and subscriptions that encourage the production and consumption of data, often unnecessarily (geolocation, streaming, automatic updates, exports to the cloud, etc.).

We also need to do a better job of "eco-designing" digital products and services, by favouring practices - and components - that consume the least energy, i.e. requiring less computing power and less data production and transmission. This task is made all the more difficult by the fact that the



1. Breakdown of water (a) and energy (b) consumption in digital activities.

The fire at the OVH data centre in Strasbourg on 10 March 2021. Part of the premises was completely destroyed. The data, which was backed up daily, was restored (with the exception of the data from 9 March) on a new server the same day.

current business models of the major operators are incompatible with these recommendations. We could even cite the example of digital health players, who are encouraging more and more data to be shared *via* the Internet of Things for the purposes of well-being, or even for therapeutic purposes [8]. The illusion of free use that they are promoting is also very disruptive when it comes to educating and informing users. How do you get across the message that "when it's free, it's because your data is paying the price!" ?

The need for new practices

Technologies are evolving and new markets are now accessible to digital technology on a massive scale. This is particularly the case with the advent of the blockchain, which aims to replace the human trusted third party (a notary, banker, lawyer, etc.) with a digital trusted third party (an open register distributed throughout the world). These blockchains require a lot of energy to validate transactions, at least with the most widespread validation method of "proof of work". This technology is therefore increasingly energy-intensive - even if miners[b] are looking for cheap electricity, which is often hydroelectric, as is the case in Central Asian countries - and its annual consumption is equivalent to that of a country like Norway. Cryptocurrencies (such as Bitcoin, Ethereum, Ripple, Dogecoin, Cardana, etc.) are also based on the blockchain (which was originally invented and deployed to support and guarantee the inviolability of Bitcoin), so payment by cryptocurrency is also largely energy-intensive[c].

As for telecommunications, the growing use of mobile technologies, in particular with the implementation of the 5G standard, is proving to be a major energy consumer not only because of the deployment of infrastructure equipment and its operation, but also because of the rebound effect of making new data-intensive uses possible everywhere and at any time (virtual reality, mobile online games, etc.)...). In its report of March 2021, the *Shift Project* recommends that the use of 5G should be reasoned and not massive, i.e. limited to uses that are truly useful to the community (health, security, education, etc.).

Finally, the Internet of Things (IoT), which consists of making communicating objects whose primary function is not to communicate, can also have worrying consequences if it develops according to a consumerist logic and not because of the societal relevance of the uses it enables. In the absence of a framework, the multitude of additional connections, accompanied by an exponential increase in the mass of data to be processed and stored, will lead to the creation not only ever more powerful data centres at the heart of the cloud, but also ever more data centres on the edge ('edge' or 'fog' computing)!

By way of illustration, we reproduce in Table 1 (p. 153) which show, in descending order, the electricity consumption (in TWh) for the annual activity of Bitcoin, data centres, Facebook and Google, compared with that of a number of countries.

Even if it seems paradoxical, the idea would be to go even further towards "low-tech" digital technology and even more demanding eco-design of digital products and services [10]. We need to move from digital responsibility to a form of digital sobriety, which would be a little more coercive. The idea is to consume less data, rather than consume it better!

The fire at the SBG2 data centre in Strasbourg (see photo p. 153) should also encourage us to better represent the cloud, not as a magical infrastructure "at the frontiers of reality", but rather as a vast delocalised and shared physical infrastructure. The idea of deploying more data picocentres (and not just megacentres) to increase resilience could gain ground, but should be confronted with the environmental consequences of this choice. Economies of scale

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Chine	united States	France	Data centres	Bitcoin	Norway	Belgium	Switzerland	Google	Facebook
6543	3989	449	205	143	124	82	56	12	3

Table 1. **Annual electricity consumption (in TWh) for selected countries, companies and activities.** (Source: Visual Capitalist, 2019).

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argue in favour of heavy, massive infrastructures to limit the consumption of energy, materials and surface areas. Similarly, the idea of quantum computing could muddy the waters by proposing solutions and servers that are, *a priori* much less energy-intensive - but we're still a long way from that! Still by way of illustration, the power cuts and digital blackouts suffered by the African continent, for example, also show that there are ways around this.

> **“We need to move from digital responsability to a form of digital sobriety, which would be a little more coercive”**

Conclusion and perspective

This spectacular - and dramatic for the operator's employees and customers - fire at one of France's cloud nuggets, which loudly proclaims "we provide accomodation" (≡ OVH, On Vous Héberge), should bring us back down to earth! We need to see the digital world in general, and the cloud in particular, as a vast tangle of concrete, cement, wood, iron, metal, cables, glass, copper, gold and plastic, so that we are fully aware of its reality and therefore its vulnerabilities. Let's hope that we can quickly come back down to earth and continue to use this wonderful invention, the Internet, soberly!

In any case, if we want the digital sector to be able to align itself with the emerging rationale of responsibility and sobriety, we will have to really grasp the three challenges, as the *Lean ICT* project and the *Shift* Project are urging us to do:

- think of a new approach to French and European governance of digital technology and its main activities (hardware, software and uses);
- revisit business models that are based on the illusion of free access and therefore encourage the hyperproduction of data that is largely useless, often unexploited and all too quickly obsolete;
- propose reliable, easy-to-read indicators for monitoring energy and carbon impact. ▮

(a) The 2018 footprint corresponds to the environmental impacts created by the production of digital equipment delivered in 2018, the use in 2018 of the installed base of digital equipment and services and the end-of-life of digital equipment leaving the installed base in 2018.

(b) Miners operate computer servers that validate transactions and add blocks to the existing chain in an unforgeable way; they receive financial compensation - in Bitcoin - if they succeed.

(c) The mechanisms of blockchain and its energy consequences are well described in a recent study by V. Coroama [9].

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