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Transitioning towards sustainable digital business models

Hugues Ferreboeuf

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More information:
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Digitalization and growth independence: Utilizing technologies for environmental and economic resilience

Policy Paper for the D4S-Network
April 28th 2023

Hugues Ferreboeuf

Abstract

The unsustainable growth of the digital environmental footprint over the last decade is due to the rapid growth of digital "volumes", which have outpaced efficiency gains. This growth is a result of the business models of the dominant players of the digital economy, namely the largest digital platforms (GAFAM, BATX) and their derivatives (Netflix, TikTok etc.). To make digitalization sustainable, a transi-tion away from these digital superpowers is necessary, and alternative, sustainable business models must be adopted. The initiation and acceleration of this transition requires the implementation of appropriate public policies.

Hugues Ferreboeuf is an entrepreneur and associated with the think tank The Shift Project where he has been leading the Lean ICT project since 2017. He has spent most of his professional career in the information technology sector, including 20 years in senior management positions. Hugues Ferreboeuf's research includes modeling of digital systems' energy and carbon footprint and methodologies for sustainable digitalization.

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1 INTRODUCTION

It is common knowledge that a significant part of the economy and of our daily lives relies on digital technologies and services, especially in developed countries. However, the evidence suggests that we are still in the early stages of digitalization. As it is also thought that intensive digitalization is going to be a central strategy to fight climate change and reconcile economic growth and environmental preservation, there are good arguments to believe that the growth of the digital sector should continue at a quick pace over the next ten to twenty years.

A feature of advanced digitalization is the expansion of its "digital" economy, as shown in Figure 1. In 2017, this represented between 4.5% (narrow scope) and 15.5% (broad scope) of world GDP (UNCTAD, 2019). The digital economy has grown two-and-a-half times faster than global GDP over the previous 15 years (UNCTAD, 2019), with a handful of digital players driving much of the transformation, capturing the bulk of the value, and yielding growth at a very steady pace. This group is often referred to as 'Big Tech' and consists of Google, Amazon, Facebook, Apple, Microsoft, Baidu, Alibaba, Tencent, and Xiaomi, with Netflix, Twitter, and Bytedance (TikTok) next on the list.

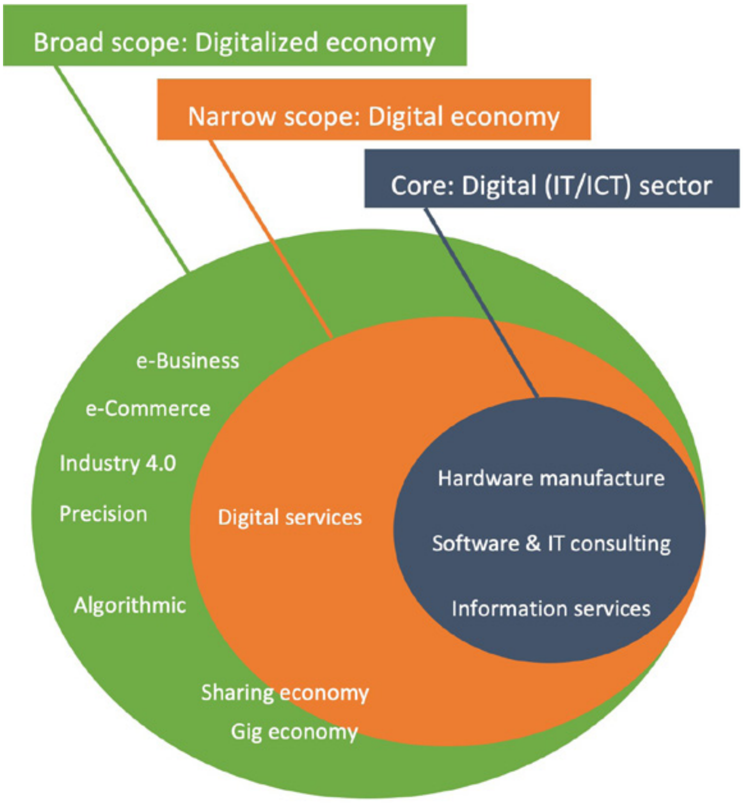

Figure 1: Scope of the digital economy (based on Bukht & Heeks, 2017)

Whereas the "Core Digital" players (see Figure 1) have experienced relatively modest revenue growth (1% to 5% per year) in the past ten years, Big Tech appear to be on a different league, doubling their revenue every three years (see Figure 2).

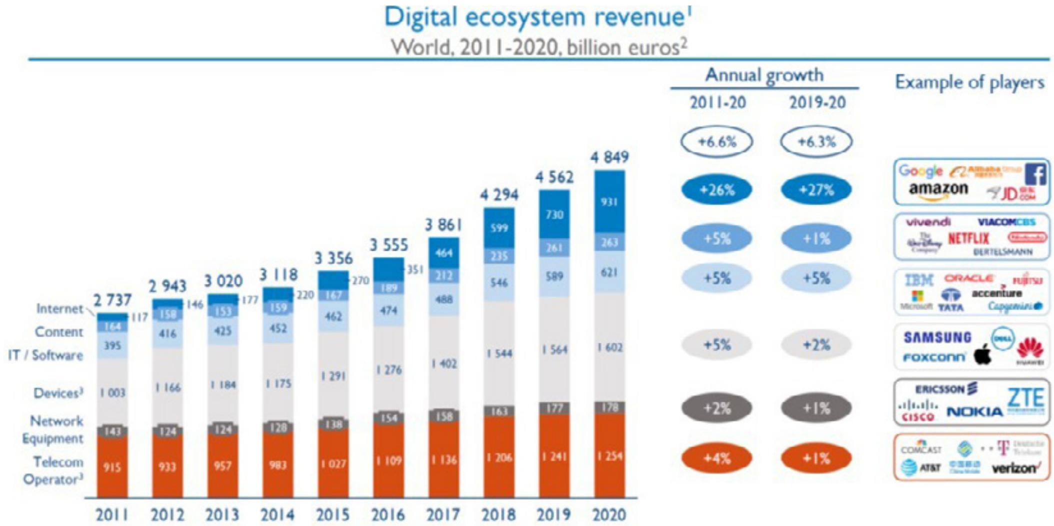

Figure 2: Digital economy revenue evolution 2011-2020 (Arthur D.Little, 2021)

However, this explosion in revenue (between 6% and 7% per year (Arthur D.Little, 2021)) has been matched with a similar growth in the energy footprint of the digital economy (6.2% per year (The Shift Project, 2021)). Thus, the digital sector is one of the few economic sectors whose energy intensity has not declined in the past decade. Indeed, the energy intensity of the world GDP fell by 2.3% year on year from 2010 and 2019 (IEA, 2022), mirroring declines in the energy intensity of the main European economic sectors between 2005 and 2017: 1.7% for Agriculture, 2,4% for Industry, and 1.2% for Services and for Transportation (EEA, 2019).

The energy intensity of the world GDP is the ratio obtained by the division of the global primary energy consumption by the world GDP. For a specific sector, it is the ratio obtained by the division of the global primary energy consumption by the gross output of the sector. Thus downward trends are required to reduce global greenhouse gas (GHG) emissions, as implied by the simplified Kaya identity outlined in Equation 1:

$$\text{GHG emissions} = \text{GDP} \times (\text{Energy Intensity of GDP}) \times (\text{Carbon Intensity of Energy})$$

Equation 1: GHG emissions

It is currently estimated that there should be a 35% reduction in global energy intensity between 2020 and 2030 to be on track with the Net Zero Emissions by 2050 Scenario, which aims to limit global warming to 2°C (IEA, 2021a). This means an average decrease of 4.2% per year over the next ten years (see Figure 3).

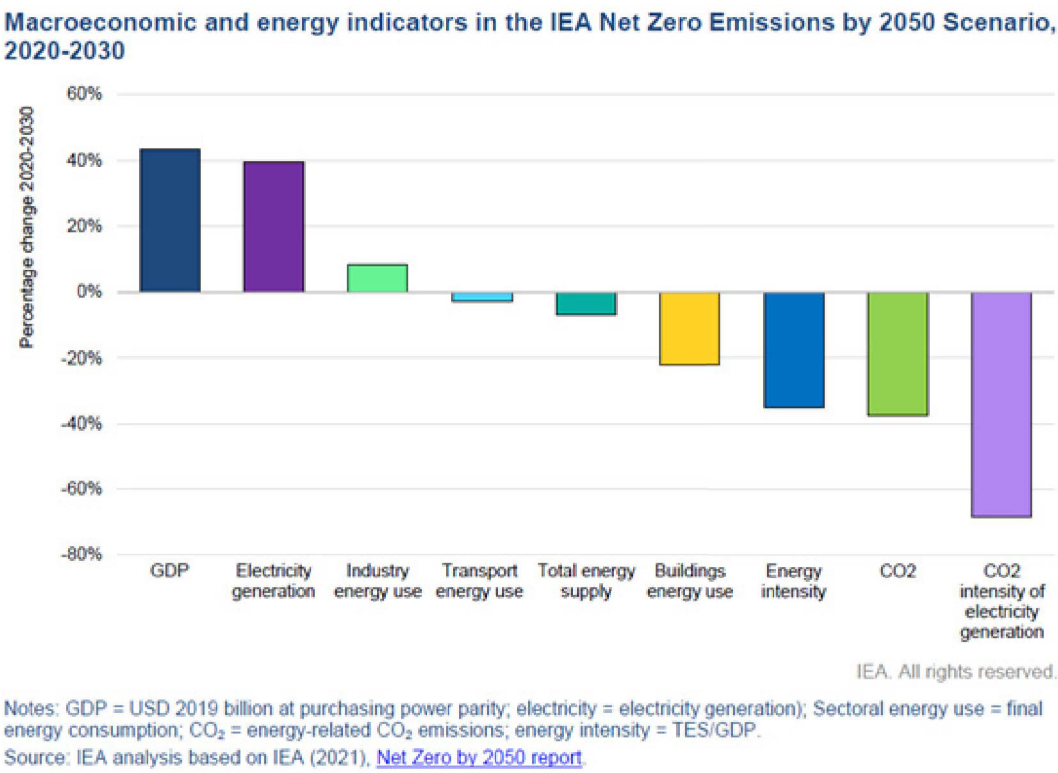

Figure 3: Evolution of key indicators 2020-2030 in the IEA Net Zero Emissions Scenario (IEA, 2021a)

It is striking, and, from an environmental or climate policy context, also worrying to observe that the financial growth in the digital sector has not been accompanied by a corresponding decrease in energy consumption, even though a growing part of the economy is being digitalized. There are several reasons why such a decoupling of the digital economy from energy and emissions remains a challenge, such as the duplication of physical infrastructures encouraged by public competition policies, and crosssectoral consumption habits that reduce the lifespan of consumer equipment, including digital devices.

However, another key factor driving up energy consumption may be the structure of the business models of the dominant market players (Big Tech). It is the purpose of this article to substantiate this statement. To this end, in Chapter 2, we examine the environmental and energy dynamics at play in the digital sector and explain why the so-called “carbon neutral” strategies proposed by Big Tech will not have a significant impact. This is because the root of the unsustainable digital trends, i.e., hyper-growth of the digital volumes (digital affluence), is an intrinsic part of their business models. In Chapter 3, we outline the alternative sustainable business models that should be targeted and the public policies that could facilitate this. Chapter 4 closes with our concluding remarks.

This paper has been developed as a working paper within the European dialogue project “Digitalization for Sustainability”. It mirrors a transdisciplinary endeavour to investigate the sustainability of digital business models from a scientific as well as a practitioner perspective. Accordingly, our analysis and calculations are based both on scientific literature and references from third parties, and on expert insights and experience from the Shift Project, a French think tank advocating the transition to a post-carbon economy that collaborates with, among others, telecommunications companies and the digital business sector.

2 WHY DOMINANT BUSINESS MODELS IN THE DIGITAL SECTOR MAKE IT UNSUSTAINABLE

To demonstrate that Big Tech's business models render the whole digital ecosystem unsustainable, we shall proceed in three steps:

// Precisely define the notion of sustainability

// Describe the physical dynamics that make the digital economy unsustainable despite so-called "carbon neutral" strategies publicized by Big Tech

// Explain how these dynamics result from the behaviors generated by Big Tech and why they will not change as long as these business models remain dominant

2.1 Definition of Sustainability

Sustainability is a multi-dimensional concept that covers economic, socio-cultural, and environmental issues. We shall concentrate on the environmental aspects and especially on climate change. This is not only for the sake of simplicity, but also because it is clear that if we do not solve the climate change issue, there will be further negative impacts. For instance, it will be harder to preserve the biosphere, access to fresh water will be limited, land and ecosystem degradation will accelerate, human health will decline, and social and economic inequalities will become more pronounced.

As far as climate change is concerned, there is a general consensus that the average temperature increase since the middle of the nineteenth century has been caused by anthropic GHG emissions. This rise should be limited to 1.5°C, and should by no means exceed 2°C, as ratified in the COP21 Paris agreement.

The most recent IPCC reports have made it clear that our dependency on CCUS (Carbon Capture, Utilization, and Storage) should be minimized. Indeed, the 2°C upper target requires that we halve anthropic $CO2$ emissions between 2020 and 2030 and reach carbon neutrality by 2050 (this scenario is often called Net Zero) (IPCC, 2021). By default, each industry sector must design and follow a pathway which halves its emissions over the same period. This amounts to an average reduction of 6.7% per year.

It is worth noting that a reduction of GHG emissions is a function of our capacity to substitute fossil-based energy with renewable and low-carbon energy at an accelerated pace. However, several IEA studies (2019; 2020; 2021a; 2022) have demonstrated that a reduction of the overall energy consumption is necessary in the very short term to realize the Net Zero (in IEA terms) scenario. Accordingly, having increased our energy supply by 7% from 2010 to 2020, we should now be geared towards a 7% reduction between 2020 and 2030 (see Figure 4).

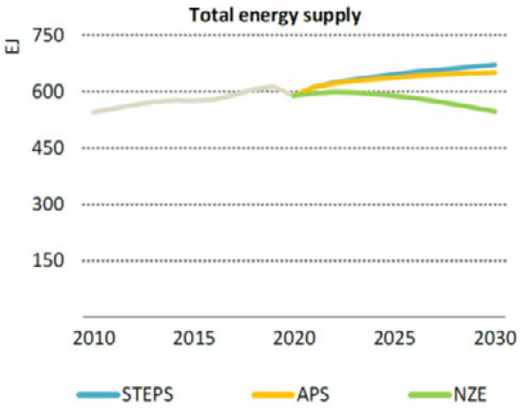

Figure 4: Global total energy supply by scenario (IEA, 2021a)

Box 1 : Types of Energy Scenarios

STEPS scenario: *Stated Policies Scenario: where the energy system might go without additional policy imple-mentation. Likely global warming above 3°C.*

APS scenario: *Announced Pledges Scenario: takes account of all the climate commitments made by govern-ments around the world, including Nationally Determined Contributions (defined in and since COP21) as well as longer term net zero targets, and assumes that they will be met in full and on time. Likely global warming around 2.5°C.*

NZE scenario: *Net Zero Emissions by 2050 Scenario: a normative IEA scenario that shows a narrow but achiev-able pathway to achieve net zero CO2 emissions by 2050, with advanced economies reaching net zero emis-sions in advance of others. Likely global warming around 1.5°C*

This reduction has an important consequence: to qualify as "sustainable", the evolution pathway of a given sector must not only show a division-by-half of GHG emissions but also a reduction of 7% of its use of primary energy between 2020 and 2030.

Furthermore, it is now well understood that GHG emissions attributable to a given company or sector must be calculated across the full value chain, including upstream and downstream activities (scope 3 according to GHG Protocol), as shown in Figure 5. Consequently, any meaningful assessment of the sustainability of the evolution pathway of a given company or sector must be conducted across the full value chain, and not solely on the basis of scopes 1 and 2.

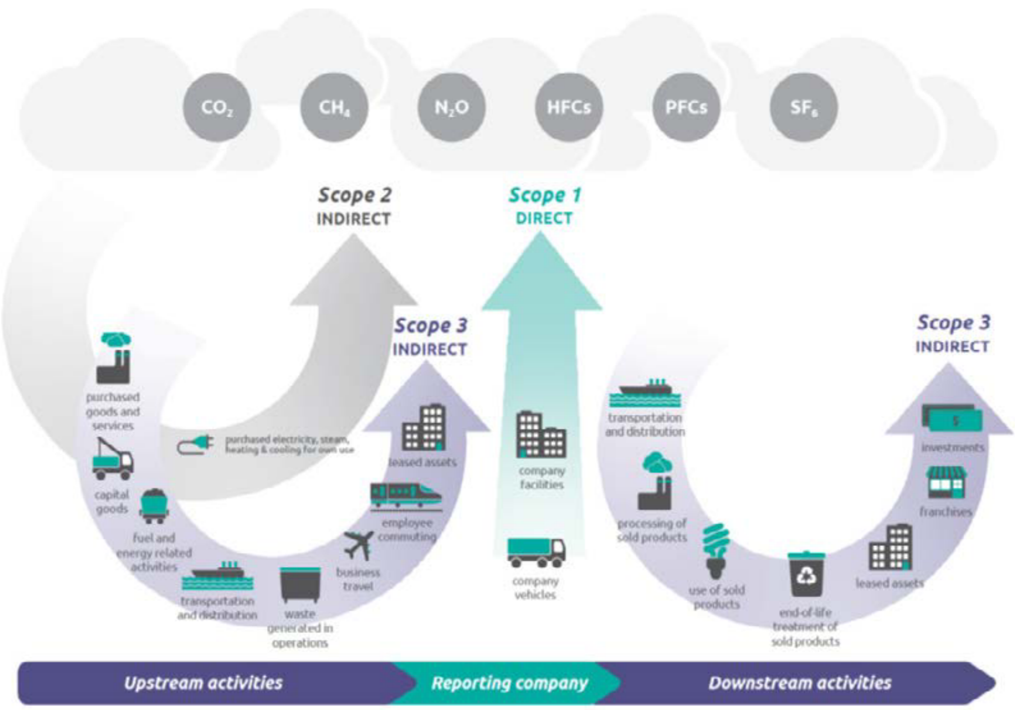

Figure 5: Overview of GHG Protocol scopes and emissions across the value chain (World Resource Institute & wbcsd, 2011).

2.2 Digital environmental and energy dynamics at work

The increase in equipment production and the growing reliance on digital technologies have led to a significant rise in their environmental footprint and energy consumption, which is unsustainable given current environmental constraints. According to the Shift Project (2021), digital technologies accounted for approximately 3.5% of global GHG emissions in 2019, and could double by 2025 in a worst-case scenario. In addition, digital technology's share of global primary energy consumption was about 5% in 2019, and could rise by 40% to 80% in the next six years.

Using a Kaya-like factor decomposition such that proposed by Bol et al. (2021) (see Figure 6), we can identify the factors that tend to inflate or deflate both the carbon and energy footprints (see Equation 2).

$$\text{Digital CO2 footprint} = \underbrace{\text{Population} \times \text{Digital Technology Affluence} \times \text{Energy Intensity of Technology} \times \text{Carbon Intensity}}_{\text{Digital Energy footprint}}$$

Equation 2: Digital CO2 footprint

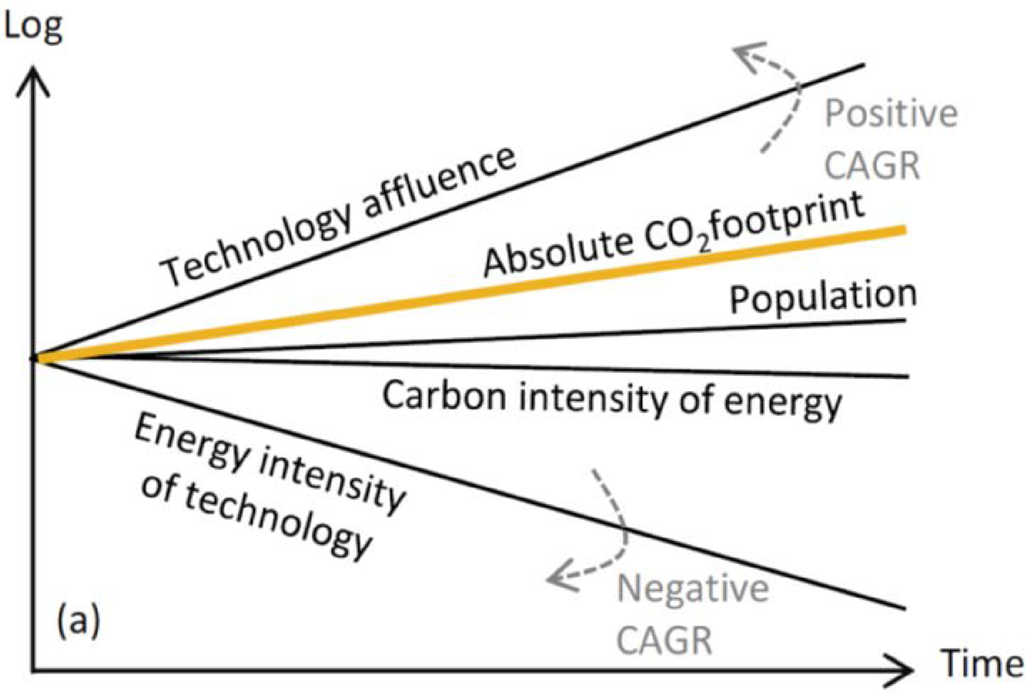

Figure 6 : Schematic representation of digital environmental and energy dynamics (Bol et al., 2021)

Box 2: Various terminologies and underlying concepts of digital environmental and energy dynamics

"Carbon Intensity" depends on the energy mix of the primary energy. In the case of the production of a device or infrastructure equipment, carbon intensity accounts for the multiple steps composing this "cradle-to-gate" phase. In the case of making a digital service unit available, electricity will be the final energy consumed and the carbon intensity will depend on the energy mix used to produce electricity.

"Carbon-intensity" is a deflation factor that can be more or less substantial: the carbon intensity of electricity declined at roughly 2% per year on average between 2016 and 2021 and should decline at 4% to 10% per year (IEA, 2021b) until 2030, depending on the level of worldwide mobilization to eliminate coal power plants and migrate to solar PV and wind generation. In case of the equipment production phase, the carbon intensity will decrease but at a much lower rate, as part of the production process (mining raw materials, shipping) will keep using oil.

"Energy Intensity of Technology" (Energy Efficiency is the inverse ratio) is the amount of (primary) energy:

- *consumed in the production phase of a digital device*
- *consumed to make a digital service unit available*

It is worth noting that energy intensity relates here to the amount of energy needed to produce a physical output and not to the amount of energy needed to produce an economic output referred to in chapter 1. These two ratios can evolve differently.

"Energy intensity of Technology" is clearly a high deflation factor as far as the use-phase of digital services is concerned: Technological progress and engineering innovations have allowed double digit improvements of computational and spectral efficiency on a yearly basis. This trend should continue until 2030, although it is likely to slow down as current technologies approach physical limits. Annual improvement rates are typically in the 0%-10% range for consumer devices, 20%-25% for mobile networks, and 10%-15% for data centres. In the case of the production of digital devices, "Energy intensity of Technology" tends to be a moderate inflation factor (0%-5%) in spite of industrial process improvements, as next generation devices become richer in functionalities (e.g., smartphones) or bigger (e.g., television sets), while the extraction phase of raw materials becomes more energy-intensive because of declining ore grades, deeper deposits, and local environmental protection measures (Mudd, 2019).

"Digital Technology Affluence" could be also seen as "digital intensity" per person and split into:

- *"Digital Acquisition Affluence": the number of digital devices newly acquired*
- *"Digital Device Affluence": the number of digital devices used*

"Digital Acquisition Affluence" is a key inflation factor, with the compounded effects of the growth of digitally connected people, the replacement of a significant part of the stock of in-use digital devices, and the introduction of new types of devices on the market. The average value depends on the type of device and varies from 0% to 50% (own calculations, based on studies by multiple ICT industry analysts).

"Digital Device Affluence" is also a key inflation factor, with the compounded effects of the

growth of digitally connected people, and the growth of IoT-type devices in developed countries. The average value depends on the type of device and varies from 0% to 50% (own calculations, based on studies by multiple ICT industry analysts).

"Digital Service Affluence" is the volume of digital service units consumed (itself dependent on the time spent on digital services and on the IT computing/storing/transmitting power directly and indirectly needed to make each of these services available).

"Digital Service Affluence" is again a key inflation factor, with video streaming, cloud gaming, social networks, and business intelligence being the main sources of growth. At least two variables can be used to illustrate the growth of service units: data traffic carried by networks (above 45% for mobile networks (Ericsson, 2021)) and workloads executed in data centres (about 25% (Andrae, 2019)).

"Population" is a limited inflation factor as the world population increases by about 1% a year. This trend should remain steady until 2030.

Although all the trends we have described are valid at a global level (which is partly the consequence of the proportion of digitally connected people increasing at roughly 6% per year (The World Bank, 2022)), it is worth noting that affluence factors are increasing fastest in the parts of the world where they are already the highest: North America, Korea, Japan, and Western Europe (see Table 1). This means that the digital divide between developed and developing countries is widening.

Table 1: Evolution of digital device affluence factors per region (Cisco, 2018a)

Digital Device Affluence	2018	2023	"CAGR (Compound Annual Growth Rate)"
Asia Pacific	2.1	3.1	8.1%
China	2.9	4.5	9.1%
India	1.1	1.4	5.0%
Korea	6.7	12.1	12.5%
Japan	6.4	11.1	11.6%
Central and Eastern Europe	2.5	4.0	9.1%
Latin America	2.2	3.1	7.0%
Middle East and Africa	1.1	1.5	5.4%
North America	8.2	13.4	11.0%
Western Europe	5.6	9.4	10.9%
World	2.4	3.6	8.5%

The overall result for the past five years is a significant annual increase (about 6%) of both the carbon and energy footprint (see Figure 7), mainly because the affluence factors are increasing faster than energy efficiency. It is likely that this trend will continue over the next few years, or even quicken in case of a slow-down in the reduction of energy intensity.

It is therefore clear that the current and projected evolution of the digital sector will remain unsustainable as long as the affluence factors keep increasing at the rate seen to date. A similar conclusion is drawn by Freitag et al. (2020).

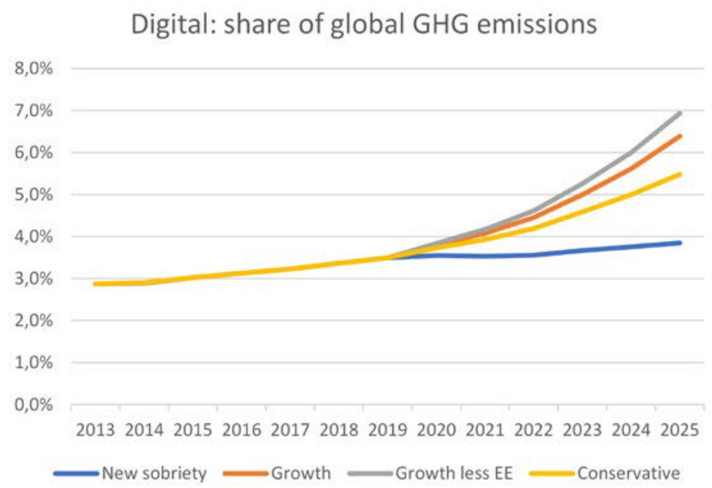

Figure 7 : Evolution of Digital share of GHG emissions (The Shift Project, 2021)

2.3 "Carbon-neutral" strategies: a misleading approach

As there is now a growing awareness that digital GHG emissions are unsustainable, most Big Tech companies have come up with "carbon neutral", "net zero carbon", or "carbon negative" pledges aiming to prove that they have individually taken action to ensure they contribute positively to the world reaching carbon neutrality by 2050. These promises may seem reassuring given the preponderance of these companies in the digital industry, but, as we will see, they are misleading.

Most if not all of these pledges rely on ensuring that all of a company's power consumption comes from renewable sources, such as solar, wind, and hydro. Companies can achieve this shift either by generating additional renewable energy onsite or buying "truly" renewable energy certificates.

Let's consider a theoretical best-case scenario (detailed assumptions and step-by-step calculations can be found in Annex 1) where Big Tech succeeds in powering all their data centres with renewable energy by 2030; this would cause the carbon intensity of the electricity they consume to be divided by a factor of 10.

In this best-case scenario, Big Tech data centres would have captured 48% of all data centre workloads in 2019 (Cisco, 2018b) and could capture 81% in 2030 (The Shift Project, 2021). They would also be responsible for a similar proportion of the data traffic carried over IP networks (Sandvine, 2022). For the sake of simplicity, we shall make the assumption that these ratios would also apply to the workload executed by the end-user devices.

Should the digital dynamics remain unchanged (except for the carbon intensity of the electricity directly consumed by Big Tech), then the power consumption of Big Tech data centres would surge from 70 TWh in 2019 to 349 TWh in 2030 (The Shift Project, 2021) but their direct (scope 1 and scope 2) GHG emissions would drop from 42 MtCO2eq down to 21 MtCO2eq. Based on these figures, it would be possible to conclude that Big Tech's "decarbonization" strategies put them on the right path towards sustainability.

However, this would only be true when considering solely their scope 1 and scope 2 emissions. Integrating scope 3 emissions means that (at least) two additional parts of the Big Tech value chain should be taken into account: the end-user devices used to communicate with the data centres, and the networks carrying the corresponding traffic. In this case, the overall energy consumption of the Big Tech value chain would rise from 480 TWh in 2019 to 1740 TWh in 2030 and the GHG emissions would increase by 105% from 288 MtCO2eq in 2019 to 438 MtCO2eq in 2030, despite the optimistic assumption that the world average carbon intensity of electricity consumption would decrease at 6% per year.

The conclusion is that simply "greening" Big Tech's energy consumption without altering affluence trends will not make Big Tech activities sustainable from an emissions-reduction perspective. Greening could even trigger an additional rebound effect by allowing digital consumption to grow under the pretext that the energy visibly consumed would be decarbonized: Being told that the services they use are carbon neutral, Big Tech customers may feel they can use them guilt-free.

Neither is such a scenario sustainable from an energy consumption perspective. Whereas the world is to align its energy consumption against a 7% reduction from 2020 to 2030 (see Figure 4), Big Tech would increase their direct energy consumption (data centres) by about 400%, with a corresponding energy consumption increase in their value chain of about 260% (detailed calculations described in Annex 1). Thus Big Tech's so-called "carbon neutral" strategies prove unsustainable when their impacts are calculated on a global scale, as both the GHG emissions and the energy consumption of their value chains would increase dramatically in this decade. This would happen despite major progress in terms of energy efficiency and energy carbon intensity.

Again using the Kaya-like equation (see Equation 2), it follows that the growth rate of digital affluence (see Equation 3) needs to be reduced in order for Big Tech companies' emissions to be compatible with a Net Zero scenario.

$$\text{Digital Affluence} = (\text{Population} \times \text{Digital Technology Affluence})$$

Equation 3: Digital Affluence

This finding is valid in a medium- and long-term perspective and should be addressed as a structural issue, regardless of short-term evolutions linked to the global economic context (Big Tech's growth indicators skyrocketed in 2021 and plunged in 2022, although remaining positive). Understanding how to slow the growth of digital affluence is therefore of paramount importance. However, this is a systemic challenge as Big Tech business models rely unequivocally on their ability to sustain an exponential growth of digital affluence.

2.4 Digital affluence hypergrowth underpins dominant business models

Big Tech companies are essentially Multi Sided Platforms (MSP) and derive most of their revenue from advertising. Such platforms act as intermediaries in accessing information, content, services, or goods published or provided by third parties. Beyond their technical interfaces, they organize and prioritize content for presentation and connection to end users.

An MSP can be defined as an organization that creates value primarily by enabling direct interactions between two (or more) distinct types of affiliated customers (Hagiu & Wright, 2015). It attracts users on one side of the market by offering services at an apparent zero cost and earns revenue on the other side of the market.

The goal of a platform is to maximize the number and engagement of its users. This will allow, directly, an increase in the transactions made by the users and, indirectly, the collection of more data in order to improve the content offered to users and extend the time they spend on the platform. MSPs monetize these data by providing targeted advertising services and/or selling information based on these data to third parties.

Consequently, the MSPs develop techniques (for instance addictive design such as autoplay, constant scrolling, embedded videos, ads, pop-ups, thumbnails, autoplay of the upcoming videos, removal of start and end credits in series episodes, automatic preview of videos before they start, automatic re-fresh of the news feed when the user is about to leave, etc.) to stimulate user engagement: "To intensify data extraction, platforms employ algorithms that promote content that is more likely to trigger user engagement. As a result, information is assessed regarding its utility for the platform, not for the user. The reason is simple: the longer a user remains on a platform, the more behavioural data and personal information is generated, in turn, increasing the revenue stream" (Frick et al. 2021: 10).

"Users" and "user engagement" can therefore be considered as the main drivers of current and future revenue streams underpinning the stock market value. As Birch et al. (2021: 162) points it out, "Big Tech firms turn "users" and "user engagement" into assets through the performative measurement, governance, and valuation of user metrics (e.g., user numbers, user engagement), rather than extending ownership and control rights over personal data per se."

In order to maximize their ability to attract users, develop user engagement, and enhance control of access to users, Big Tech deploy a number of techniques and practices ("techcraft" according to Birch et al. (2021), "artifacts" according to Cohen (2017)) to stimulate, monitor, and analyze the presence of users on their platforms. Such practices lead to mass accumulation of personal data and rely on an exponential use of digital technology, e.g., video messages, higher quality video standards, algorithms, and artificial intelligence.

This results in an exponential rise of digital affluence – further stimulated by the fact that Big Tech companies only bear part of the resulting financial or environmental costs. For instance, Big Tech companies do not pay for the actual costs of using networks and end-user devices, and they are not required to measure the scope 3 part of their GHG emissions.

It follows from the description of this business model that there should be a high degree of correlation between stock market value, revenue, and digital affluence, itself impacting energy consumption. In order to check the reality of this correlation, we ran a quantitative analysis, with the examples of Google and Meta. The analysis was conducted over a five-year period, using publicly available data on market capitalization, revenue, and energy consumption. Detailed information can be found in Annex 2.

Both Google and Meta saw their revenue and market capitalization increase at high growth rates between 2015 and 2020 (as far as revenue is concerned this trend is still valid on a mid-term perspective, though the timing and the size of its Metaverse investments led to a plunge in Meta's market capitalization in 2017). Their energy consumption followed a similar trend (see Figure 8 and Figure 9; in 2021, Google's energy consumption increased by 21% and Meta's by 31%, 2022 figures are not yet known).

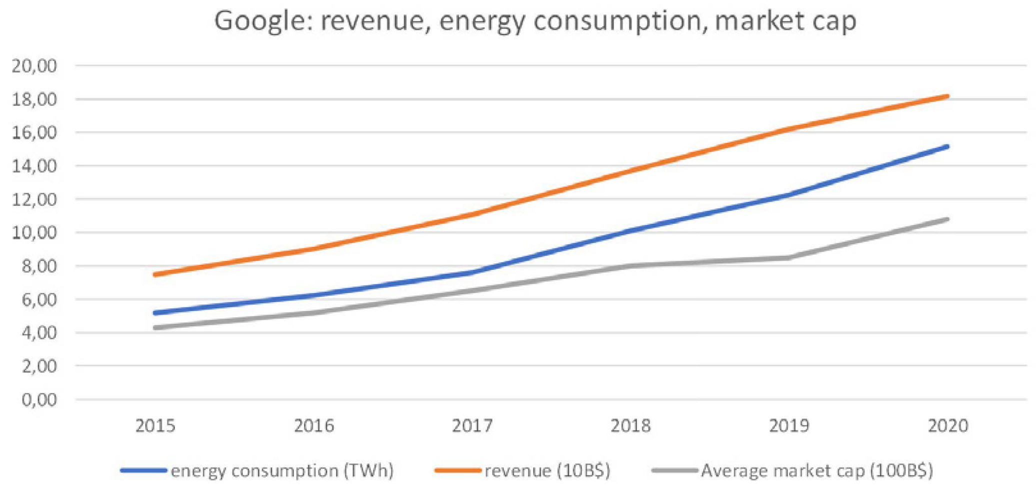

Figure 8: Correlated evolution of Google's revenue, energy consumption, and market capitalization (Statista, 2022b; Macrotrends, 2022c; 2022d); note that Google's figures are considered equal to Alphabet's, as Google's business represents more than 99% of its parent company's

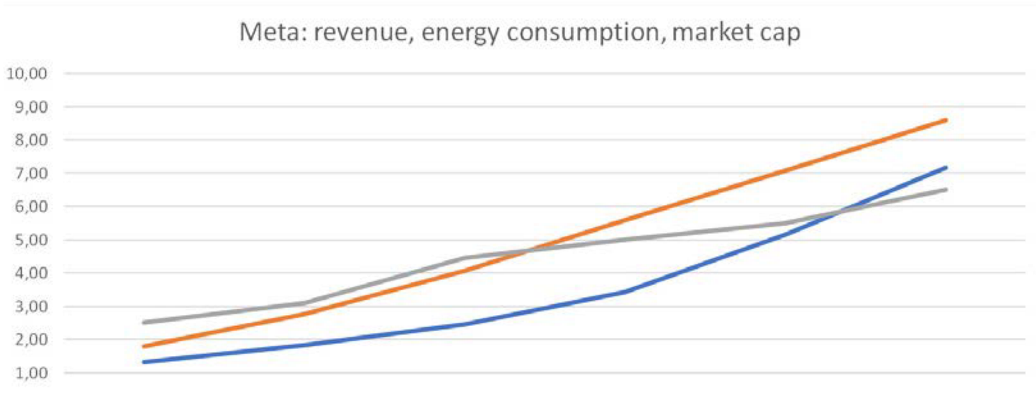

Figure 9: correlated evolution of Meta's revenue, energy consumption, and market capitalization (Statista, 2022a; Macrotrends, 2022a; 2022b)

However, their (direct) energy consumption increased even more rapidly, and with it their revenue energy intensity (see Table 2). In other words, while all industry sectors have been working on decoupling their economic growth from their energy consumption, Google and Meta (and probably most Big Tech companies) have based their financial success on business models that have become more energy intensive every year.

As their technical infrastructure (hyperscale data centres) becomes more efficient every year, one can induce that the volume of data and computation instances they need to manage is increasing even faster. The digital (service) affluence they generate can be represented by their upstream and downstream internet traffic. Based on the fact that their energy consumption increases at annual rates of 24% and 40% (Google and Meta, respectively), and taking into account year-on-year energy efficiency improvements, one can infer that the traffic generated by these two companies increases annually by about 42% and 60% respectively – whereas the global internet traffic increases annually by 29% (Ericsson, 2021). Detailed assumptions and step-by-step calculations can be found in Annex 2.

Table 2: Google and Meta, average annual growth rates 2015-2020 (see Annex 2 for details)

CAGR 2015-2020	Google	Meta
Revenue	20.0%	37.0%
Energy Consumption	24.0%	40.0%
Market capitalization	20.0%	21.0%
Revenue energy intensity	3.8%	2.7%
Internet traffic	42.0%	60.0%

The result is that they now capture/generate more than one third of the overall internet traffic (see Table 3) and are by themselves dramatically augmenting of the growth of the overall traffic. Based on these figures, Google and Meta together have been responsible for 43% of the growth over the 2015-2020 period.

Table 3: 2021 traffic share by application group (Sandvine, 2022)

Application Group		Total Volume
1	Google	20.99%
2	Meta	15.39%
3	Netflix	9.39%
4	Apple	4.18%
5	Amazon	3.68%
6	Microsoft	3.32%
TOTAL		59.96%

In other words, if the traffic generated by Google and Meta had grown at the same rate as the rest of the traffic, the overall traffic would have increased at a yearly rate of 23% instead of 29%. This would have caused the electricity consumption of mobile networks to increase by only 3% a year instead of the observed increase of 10% per year (The Shift Project, 2021).

We can conclude that Google and Meta not only operate unsustainable business models, but that their business logic, combined with their market power, creates service affluence trends which make the whole digital infrastructure sector unsustainable. It is likely that if we were to extend this analysis to the other Big Tech companies, we would arrive at a similar conclusion. Unfortunately, the data are not always made available in a similarly transparent way.

Although more difficult to evaluate quantitatively, the impact of Big Tech on acquisition affluence and device affluence is also undeniable. Not only do they have dominant market shares for new types of devices (for instance, 87% for smart speakers (Scott, 2022), they also create future sources of growth by stimulating the proliferation of these devices, which can extend and improve data related to users and user behaviors. As Cohen (2017) describes it, "those [design] imperatives have shaped the emergence of smart mobile devices, wearable computing, and the Internet of Things, dictating implementations that emphasize seamless tracking, fine grained measurement of patterns of behaviour and attention, extraction of continuous flows of data, and configuration of data flows into forms best suited to analysis and commercial exploitation."

Therefore, it is legitimate to infer that the business models of Big Tech companies result in disproportionate affluence trends that render the entire digital sector unsustainable. This is aggravated by inadequate market and environmental regulations, which fail to hold these companies accountable for the financial and environmental impacts of their practices.

This means that making digitalization sustainable calls for a transition to alternative business models that are designed for sustainability or, at the very least, are not incompatible with sustainability goals.

3 TRANSITION TOWARDS SUSTAINABLE DIGITAL BUSINESS MODELS AND PUBLIC POLICIES

Whereas the responsibility of current dominant business models regarding digital (un) sustainability is clear, one should be aware that changing them or, at least, reducing their dominance, will require behaviors and buying patterns to evolve equally on the demand side of the digital market. Coordinated policies will then be needed to enable systemic shifts: deterring unsustainable practices, promoting new modes of production and consumption, and addressing financial and psychological barriers to change.

3.1 Control and reduce the attractiveness of Big Tech business models

Reducing the attractiveness of Big Tech business models is important in two ways. It will first lower their market power, and thus their impact on the entire digital ecosystem, and it will send a market signal to other companies showing them that such business models are no longer the de facto standard.

Indeed, a growing number of enterprises are becoming digital (see Figure 1) and are moving to a platform-focused approach (see Figure 10) on the grounds that it will maximize their market impact and optimize their ability to capture economic value. As current Big Tech business models are intrinsically unsustainable, it is therefore key to avoid a replication of these models on an even larger scale.

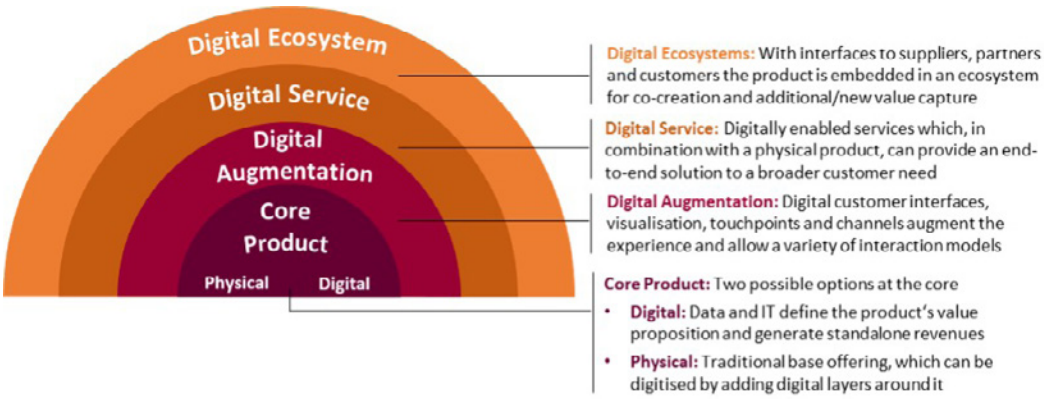

Figure 10: Phases of digitalization (based on PWC, 2016)

First, the unprecedented societal power of Big Tech – from their market dominance to their data supremacy – needs to be controlled and subordinated to democratic control. This will send a strong signal to venture capital firms and shareholders that such business models are no longer the standard. Several initiatives in the European Union are already underway to reduce Big Tech's power: The Digital Markets Act, the Digital Services Act, the Data Governance Act, and the Data Act. In the United States, the proposed Platform Competition and Opportunity Act has similar objectives. These regulations allow governments to review mergers and avoid so-called 'killer acquisitions' that eliminate competitors. Further rules promote interoperability between platforms and open up access to data generated from use of the platforms. However, competition and monopoly law must include additional tools that can effectively redress data monopolies and the crossmarket power of the platforms, since Big Tech platforms often serve as gatekeepers for third companies accessing the market and control distribution channels (Digitalization for Sustainability (D4S), 2022). Whether some consider it a measure of last resort or believe it is already overdue, antitrust authorities should be equipped with an explicit break-up instrument for such cases, as recently proposed by the German Federal Ministry for Economic Affairs and Climate Action (2022).

Second, Big Tech's exploitative and extractive business models must be ended. This requires measures in different policy fields, including fiscal policy, competition, digital sector regulation, and corporate sustainability reporting standards. These measures should ensure that Big Tech pay adequate and regular taxes (building on the OECD global minimum corporate tax agreement), and internalize financial costs which have so far remained external (e.g., network costs). Moreover, the acquisition of personal data 'by default' should be banned, and any use of personal data that undermines digital sovereignty should be curtailed (see next chapter).

Finally, to ensure digital business models contribute to environmental goals, a set of measures must be implemented. For example, most platform markets lack "production standards". This means that there are no energy standards for video streaming or social media platforms, and services provided by rental or sharing platforms are not required to support low-energy housing or carbon-free transportation options. Since even comparatively strong platform legislation, such as the EU's Digital Services Package, does not fill this void, future legislation that includes environmental and social standards for service provision in platform markets is needed (Digitalization for Sustainability (D4S), 2022). In the meantime, since scope 3 emissions are at least one order of magnitude larger (SBTi, 2021) than scope 1 and scope 2 emissions (accounting for three key sub-categories: Capital Goods, Use of sold products, purchased goods and services), mandatory reporting of so-called 'scope 3' emissions, which would cover greenhouse gas emissions stemming from the application of digital services throughout society, should be enforced. This will trigger Big Tech companies to pursue more ambitious climate pledges and accept responsibility for mitigating their impact on the environment.

Such regulations may lead to more complexity and price increases, triggering negative reactions beyond Big Tech. This is due to the "network effect" which, in the case of multi-sided platforms, creates a community of interests between consumers, vendors, and the platform. It will therefore be vital to facilitate the growth of these new, sustainable business models and spur competition, while contextualizing the regulations.

3.2 Support the creation of alternative platforms with sustainable business models

Sustainable business models pursue the common good rather than profit-maximization via advertising and unsolicited data extraction. Such models are more likely to be implemented by civil society or public companies than profit-driven platforms. Therefore, building public support for non-profit platforms, such as Wikipedia, is a helpful strategy, particularly in cases of natural monopolies. Another possible option is to develop and financially support platform cooperatives (Scholz, 2016). These are cooperatively owned businesses that use a digital infrastructure to facilitate the sale of goods and services. They can be multi-stakeholder, which fits well with multi-sided markets. Contrary to Big Tech business models, they rely on the voluntary and explicit provision of specific data by consumers to vendors rather than on the extraction of personal data based on hidden algorithms and attention-capturing ploys. Such platform cooperatives can result from the digitalization of existing conventional cooperatives – according to the International Organization of Industrial and Service Cooperatives, 220,000 cooperatives exist in Europe. Alternatively, new cooperative start-ups can be supported, such as Fairbnb (a platform for short-term holiday rentals in Italy) or Les Coursiers Nancéiens (providing ethical, solidary, ecological, and local delivery services by bike in Nancy, France). Initiatives such as the P2P Models project, trying to "[…] combine new technologies and commons-oriented models to build platforms where no single entity controls the infrastructure, where communities have a voice in how they operate, and where profits are more widely distributed across users" (Hassan, 2020), should be encouraged and given visibility.

Public policies should therefore be implemented to install platform cooperatives as role models for MSPs by facilitating access of cooperative start-ups to financing (public investments, specific tax regime etc.) and by supporting financially and accelerating technically the digitalization of existing cooperatives towards platform-based business models.

As the current internet architecture facilitates some of the techniques which are central in Big Tech business models, it is necessary to introduce new specifications as safeguard measures. Projects such as "Solid", created by Tim Berners-Lee – the inventor of the World Wide Web – which develops specifications and techniques giving individual users full control over the usage of their data through personal online data stores ("pods"), should be given a better public exposure to inspire public and private strategic visions. Others, such as Web 3, originally defined by Gavin Wood – co-founder of Ethereum and creator of Polkadot and Kusama – as "a decentralized online ecosystem based on blockchain" (Edelman, 2021), are subject to various interpretations and now controversy, as some critics argue that they could become too dependent on the blockchain industry (blockchain application programming interfaces, cryptocurrency exchanges, etc.).

More generally, there is a need to re-design digital systems, which implies a new approach to many activities (including the design itself). According to Diez & Hankey (2022), integrating digital and hybrid solutions into design practice offers opportunities to develop diverse design approaches that can drive the regeneration of our natural ecosystems, rather than just mitigating their destruction.

Current EU policy reviews also provide the opportunity to implement sustainable digital market design in upcoming initiatives, with many advantages for the ecological transformation of the economy. As illustrated by Staab et al. (2022), the availability, accessibility, and usability of product and ecological impact data via new digital intermediaries can substantially contribute to reducing CO2 emissions, material consumption, and waste by allowing the systematic digital tracking of material flows. This enables the better reuse, repair, and recycling of products. The move to Circular Economy (CE) business models can also be facilitated by digital CE-platforms, where participants exchange used products, product components, or secondary raw materials; build communities; match information providers and service contractors with users; or exchange peer-to-peer services offline.

3.3 Induce a shift on the demand side

The transition which is necessary on the supply side will occur more quickly and smoothly if it is encouraged by new behaviors on the demand side.

As far as enterprises are concerned, a growing proportion are now aware of the weight of their digital systems in their carbon footprint, which can be as high as 50% for some service companies. As a result, they put pressure on their main suppliers, including Cloud operators, to be more transparent about the footprint of the services or the products they purchase. They are also starting to integrate environmental performance indicators in their purchasing criteria, which in turn causes the vendors to invest in sustainability initiatives.

This evolution, which is already noticeable in some European countries (for instance France, Denmark, Germany, UK, etc.), should be enlarged to the whole of Europe so that enough market power can be activated. Appropriate communication of this trend should be organized by the European Commission. As for Big Tech and digital vendors, it is also essential that reporting on scope 3 emissions is made mandatory to create the right regulatory framework. Without this, GHG emissions due to purchased cloud services (scope 3) will not be accounted for.

The main challenge that is often encountered within an enterprise on this path is the widespread belief that reducing the growth of digital uses (digital affluence) may impede revenue growth and undermine competitiveness. On the contrary, better and earlier prioritization of digital projects often proves more efficient in the long-term. Nevertheless, a debate at the management board level is necessary to reconcile digital sustainability orientations with other corporate objectives.

As for consumers, the first target is to help them regain control over their digital use by raising awareness of their environmental impact. Public awareness campaigns should be run, and product and service environmental information and labelling should be introduced, so that people can understand the environmental impact of their digital consumption and act with knowledge. Relevant teaching should also be introduced at all levels of the education system. Examples of such measures can be found in the first chapter of the REEN law ("Loi pour la reduction de l'empreinte environnementale du numérique en France") passed in France in November 2021 (French Parliament, 2021).

4 CONCLUSION

Big Tech business models are not sustainable from a climate change and energy perspective. Even if these companies succeeded in powering all their operations with low-carbon electricity by 2030, if they keep increasing their energy consumption at the current rate, their total carbon footprint, consisting of the emissions generated over their entire value chain (as defined by the GHG protocol) would still double compared to 2019. Quantitatively, this would mean an increase in their direct energy consumption of about 400%, and, in their value chain, of over 250%. This would make the task of decarbonization even more challenging for the rest of the economy.

Whereas the exponential rise of digital affluence is the root cause of this unsustainable evolution, it is also what fuels Big Tech's profitability and market value. They therefore have a vested interest in promoting digital affluence and unsustainable practices. As Big Tech companies have a significant impact on market dynamics and digital consumption patterns due to their dominant market footprint, we therefore either need to reduce the dominance of Big Tech's business models, or replace them altogether with models which prioritize sustainability, such as cooperative platforms.

Given Big Tech's significant market power, active public policies are needed to discourage their current business models and promote alternatives. To facilitate this transition, awareness campaigns should be conducted among both enterprises and consumers to encourage them to reappraise the value of more sustainable digital practices.

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ANNEX 1

The purpose of this annex is to describe the details of the calculation demonstrating that the "carbon-neutral" strategies announced by most Big Tech companies will, if their business patterns remain unchanged, actually increase the environmental footprint of the digital sector between 2019 and 2030.

The model underpinning the calculation of digital environmental footprints is that used in the "conservative scenario" described in The Shift Project (2021). It has been extended to cover the 2025-2030 period by prolongating the average trends calculated in the 2019-2025 period.

The data resulting from this approach and used in this paper's calculation are the following:

Table 4: Key data taken from The Shift Project (2021)

	2019	CAGR 2019/2025	2030
Hyperscale data centres: electricity consumption (TWh)	70	15.8%	349
Networks: electricity consumption (TWh)	349	5.0%	598
End-user devices electricity consumption (TWh)	505	7.5%	1120
Hyperscale data centres: share of total data centre workload	0.48	4.0%	0.81

The following assumptions are made:

Assumption #1: Big Tech will power all their sites (data centres) with renewable energy by 2030. It is assumed that the carbon intensity of the electricity they consume in 2019 is the worldwide average value. Thus, as the world average carbon intensity of electricity generation is about 450 gCO2/kWh in 2019 (IEA, 2021b) and the average carbon intensity of electricity generated from renewable sources is about 45 gCO2/kWh (Ademe, 2022), the carbon intensity of the electricity Big Tech consumes in 2019 will be divided by a factor of 10 in 2030. The carbon intensity of the electricity consumed at the plug is higher than the carbon intensity of the electricity generated in power plants; here we use the 2019 value chosen in The Shift Project (2021) for the world average carbon intensity of electricity consumption, i.e., 600 gCO2/kWh. Furthermore, we assume a best-case scenario for the evolution of the world average carbon intensity of electricity consumption, i.e., a decrease of 50% between 2019 and 2030. This leads to the overall carbon intensity of 300 gCO_2/kWh in 2030 for the world average value, compared to a carbon intensity of 60 gCO_2/kWh in 2030 for the electricity consumed by Big Tech data centres.

Assumption #2: All hyperscale data centres are operated by Big Tech, and all Big Tech data centres are hyperscale. Hyperscale data centres are massive business-critical facilities designed to efficiently support robust, scalable applications and are significantly larger and more efficient than enterprise data centres; any data centre containing 5,000 servers, spanning a minimum of 1,000 square meters, and offering at least 40 MW of capacity is usually considered as hyperscale although the trend is towards a much larger size (100,000 square meters, 100 MW). There were about 650 hyperscale data centres worldwide in May 2022 that are operated by and for Big Tech companies, and most Big Tech computing instances are executed in hyperscale data centres. So, it is assumed in this scenario that hyperscale data centres are the Big Tech's data centres.

Assumption #3: We assume Big Tech's share of the workload executed by end-user devices is identical to Big Tech's share of network traffic. (The end-user devices considered for this calculation are those considered in The Shift Project (2021) but with a discount applied to some of them – 50% on residential Wi-Fi routers and IoT modules, 80% on television sets, 100% on printers and public display screens. This ensures the approach based on traffic pro-rata is justified).

Assumption #4: We adopt a restrictive definition of scope 3. We consider this to be composed solely of the network services Big Tech are using and of their usage-share of end-user devices.

The calculations (based on The Shift Project, 2021 and using data from Table 4) are as follows:

Big Tech data centre electricity consumption in 2019 is:

$$ELEC2019(Big\ Tech) = 70\ TWh$$

Extending to 2030, the electricity efficiency (kWh/Gb) improvement and workload growth trends (11% per year and 30% per year respectively) used in The Shift Project (2021), the power consumption of Big Tech data centres will surge to:

$$ELEC2030(Big\ Tech) =349\ TWh$$

Hence a CAGR slightly lower than 16%, which seems conservative given the observed growth rate of Google's and Meta's power consumption between 2015 and 2020.

The electricity consumed by networks because of the need to carry Big Tech traffic is:

$$ELEC2019(networks) = 0.48*349\ TWh = 168\ TWh$$

and

$$ELEC2030(networks) = 0.81*598\ TWh = 484\ TWh$$

The electricity consumed by end-user devices when using Big Tech services is:

```
ELEC2019(devices) = 0.48*505TWh = 242 TWh
```

and

```
ELEC2030(devices) = 0.81*1.120TWh = 907 TWh
```

According to Equation 4, the overall electricity consumption of the Big Tech value chain is therefore:

```
ELEC(value chain) = ELEC(BigTech) + ELEC(networks) + ELEC(devices)
```

Equation 4: Overall electricity consumption of Big Tech

```
ELEC2019(value chain) = 70+168+242 = 480 TWh
```

and

```
ELEC2030(value chain) = 349+484+907 = 1.740 TWh
```

GHG emissions are calculated according to Equation 5:

```
GHG (data centers, networks, devices) =
ELEC(data centres, networks, devices) * (carbon intensity of
electricity consumed)
```

According to assumption #1 (see above), Big Tech data center emissions will drop from

```
GHG2019(BigTech) = 0.6*70TWhH = 42 MtCO2
```

to

```
GHG2030(BigTech) = 0.06* 349 TWh = 21 MtCO2
```

According to assumption #1 (see above), the GHG emissions of the network and end-user devices parts of the Big Tech value chain will be:

```
GHG2019(networks) = 0.6*168 = 101 MtCO2
```

and

```
GHG2030(networks) = 0.3*484 = 145 MtCO2
```

```
GHG2019(devices) = 0.6*242 = 145 MtCO2
```

and

```
GHG2030(devices) = 0.3*907 = 272 MtCO2
```

The overall GHG emissions of the Big Tech value chain are calculated according to Equation 6:

```
GHG(value chain) = GHG(BigTech) + GHG(networks) + GHG(devices)
```

Equation 6: GHG emissions of Big Tech value chain

```
GHG2019(value chain) = 42+101+145 = 288 MtCO2
```

and

```
GHG2030(value chain) = 21+145+272 = 438 MtCO2
```

It follows from these calculations that the overall energy consumption of the Big Tech value chain would rise from 480 TWh in 2019 to 1740 TWh in 2030 (+ 262%) and the GHG emissions would increase from 288 MtCO2eq in 2019 to 438 MtCO2eq in 2030 (+105%), whereas the energy consumption of the Big Tech data centres would rise from 70 TWh in 2019 to 349 TWh (+400%) and the GHG emissions of Big Tech data centres (which represent 99% of the Big Tech's scope 1 and 2 GHG emissions) would drop from 42 MtCO2 to 21 MtCO2 (-50%).

This demonstrates that the "carbon-neutral" strategies announced by most Big Tech companies will actually double the GHG emissions of their value chain (scope 1 + scope2 + scope3) between 2019 and 2030, while dividing by half their scope 1 and scope 2 emissions.

ANNEX 2

The purpose of this annex is to describe the details of the calculation showing Google's and Meta's contribution to internet traffic and traffic growth based on data from Table 5 and Table 6.

Table 5: Evolution of Google's energy consumption, revenue, and market capitalization (Statista, 2022b; Macrotrends 2022c; 2022d); note that Google's figures are considered here equal to Alphabet's, as Google's business represents more than 99% of Alphabet's.

Google	2015	2016	2017	2018	2019	2020
Electricity Consumption (TWh)	5.20	6.21	7.61	10.1	12.24	15.14
Revenue (10B$)	7.50	09.03	11.09	13.68	16.19	18.17
Average market cap (100B$)	4.30	5.20	6.50	8.00	8.50	10.80

Table 6: Evolution of Meta's energy consumption, revenue, and market capitalization (Statista 2022a; Macrotrends 2022a; 2022b)

Meta	2015	2016	2017	2018	2019	2020
Electricity Consumption (TWh)	1.31	1.83	2.46	3.43	5.14	7.17
Revenue (10B$)	1.79	2.76	04.06	5.58	07.07	8.60
Average market cap (100B$)	2.50	3.10	4.45	5.00	5.50	6.50

The electricity consumption (of Google or Meta) in a given year can be calculated as:

```
Electricity consumption = (Energy intensity) * (Digital service affluence)
```

Equation 7: Growth rate of internet traffic

The year-on-year evolution of electricity consumption will depend on the year-on-year reduction of the energy intensity (i.e., the year-on-year improvement in energy efficiency) and on the growth of the affluence.

We make the additional assumption that the volume of internet traffic generated (by Google or Meta) and its year-on-year evolution are representative of the affluence of the digital services provided (by Google or Meta) and of its year-on-year evolution.

Therefore, we can derive the growth rate of internet traffic (generated by Google or Meta) from the data on electricity consumption if we know the evolution of the energy intensity/efficiency according to Equation 8:

$$\mathrm{GROWTH}_{\mathrm{TRAFFIC}} = [(1+\mathrm{GROWTH}_{\mathrm{ELECTRICITY\ CONSUMPTION}})/(1+\mathrm{GROWTH}_{\mathrm{ENERGY\ INTENSITY}})] - 1$$

Equation 8: Growth rate of internet traffic

Box 3: Explanation of the components of the formula to compute Big Tech internet traffic growth

$GROWTH_{TRAFFIC}$ is Google's or Meta's internet traffic growth rate,

$GROWTH_{ELECTRICITY\ CONSUMPTION}$ is Google's or Meta's electricity consumption growth rate,

$GROWTH_{ENERGY\ INTENSITY}$ is Google's or Meta's energy intensity growth rate.

Energy intensity data are business-sensitive and are never disclosed by the hyperscalers. However, simulations show that, for hyperscalers, likely values of yearly energy intensity (EI) improvements are in the 10% to 15% range (The Shift Project, 2021).

Depending on the assumptions of the reduction of the Energy Intensity factor and on the time period, the average internet traffic growth rates for Google and Meta can be calculated as follows (see Table 7):

Table 7: Calculated growth rates of Google's internet traffic (own calculation)

Google	2015-2020		2018-2020	
CAGR	EI - 10%	EI - 15%	EI - 10%	EI - 15%
Energy Consumption	24%	24%	22%	22%
Internet Traffic	38%	46%	36%	44%

Based on Table 7, the average value for Google's internet traffic growth rate is 42%.

Table 8: Calculated growth rates of Meta's internet traffic (own calculation)

Meta	2015-2020		2018-2020	
CAGR	EI - 10%	EI - 15%	EI - 10%	EI - 15%
Energy Consumption	40%	40%	45%	45%
Internet Traffic	56%	65%	61%	70%

Based on Table 8, the average value for Meta's internet traffic growth rate is 60%.

In order to calculate the contribution of Google and Meta to the growth of total internet traffic, we can use the estimates of Google's and Meta's internet traffic shares for 2021 as reference points (see Table 9):

Table 9: 2021 traffic share by application group (Sandvine, 2022)

Application Group		Total Volume
1	Google	20.99%
2	Meta	15.39%
3	Netflix	9.39%
4	Apple	4.18%
5	Amazon	3.68%
6	Microsoft	3.32%
TOTAL		59.96%

Taking the yearly average growth rate of the total internet traffic (29%; Ericsson, 2021) and the yearly average growth rates of Google's (42%) and Meta's (60%) internet traffic, we can calculate their contribution to the growth of the total internet traffic between 2016 and 2021 using Equation 9:

SPECIFIC CONTRIBUTION=(SPECIFIC TRAFFIC SHARE IN 2021)×
[(1+TOTAL GROWTH RATE)5÷(1+SPECIFIC GROWTH RATE)5]×
([((1+SPECIFIC GROWTH RATE)5-1)÷((1+TOTAL GROWTH RATE)5 - 1)]

Box 4: Explanation of the components of the formula for specific contribution to total internet traffic

SPECIFIC CONTRIBUTION is Google's or Meta's contribution to the growth of the total internet traffic,

SPECIFIC TRAFFIC SHARE is Google's or Meta's share of the total internet traffic in 2021,

TOTAL GROWTH RATE is the average growth rate of the total internet traffic between 2016 and 2021,

SPECIFIC GROWTH RATE is the average growth rate of Google's or Meta's internet traffic between 2016 and 2021.

These calculations lead to the following results:

// Google contributed 24% of the growth of the total internet traffic between 2016 and 2021.

// Meta contributed 19% of the growth of the total internet traffic between 2016 and 2021.

// Hence 43% of the growth of total internet traffic between 2016 and 2021 was due to Google and Meta.

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