THE SHIFT PROJECT

AI, data, and computing: shaping infrastructures for a decarbonised world

FINAL REPORT - OCTOBER, 2025

AS PART OF OUR
ACTION PLAN FOR 2027

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About The Shift Project

The Shift Project is a think tank working towards a carbon-free economy. As a recognised non-profit organisation operating under the 1901 French law, and guided by the demand for scientific rigor, its mission is to enlighten and influence the debate on energy and climate transition in Europe. It has been supported since 2010 by major French and European companies, as well as public bodies, business associations, and SMEs. It is supported by a network of tens of thousands of volunteers gathered within a non-profit association: The Shifters, established in 2014 to provide voluntary support to The Shift Project.

The Shift Project's ambition is to engage companies, public authorities, and intermediary bodies on the risks - but also and above all - on the opportunities generated by the "double carbon constraint", represented jointly by the pressures on energy supply and climate change. Its approach is thus shaped by a specific analytical perspective, based on the conviction that energy is a primary factor in development: therefore, the risks induced by climate change, closely linked to the use of energy, involve a particular systemic and transdisciplinary complexity. Climate-energy issues will determine the future of humanity, so we need to integrate this dimension into our social model as quickly as possible.

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I. Digital technology: both a tool and a challenge for decarbonising the economy

Information technologies, now central to the key activities of our societies, could have a crucial role in the transformation of our economy. Although digital devices - and the systems that underpin them - and the uses they enable and promise may seem designed to meet ever greater challenges, this should not spare them from consideration of their environmental relevance. Indeed, in a world of finite resources, it is important to remember that every process requires energy and materials - including transforming, creating, storing, or exchanging information. Digital technologies are no exception: they are not intangible tools, but physical systems and infrastructures, even if their material nature is not always immediately visible to us.

Digital technologies form a global-scale system: devices (smartphones, computers, tablets, etc.) connect to one another through network infrastructures (terrestrial and submarine cables, mobile network antennas, fibre optics, satellites, etc.) in order to exchange information that is stored and processed in data centres, the beating heart of this system. Each of these components requires energy not only to operate (use phase) but also, beforehand, to be built (production phase): mining, transport and refining of raw materials, industrial processes of transformation and manufacturing, followed by delivery to consumers, and finally end-of-life (recycling, landfill, waste incineration, etc.). The entire life cycle of these elements demands both biotic and abiotic resources.

Every digital service provided to users relies on physical infrastructures whose resilience and relevance must be assessed in light of the dual carbon constraint (reducing the emissions from our activities and freeing ourselves from dependence on fossil fuels). Digital technology acts as a catalyst: wherever it is deployed, it enables optimisation, acceleration, streamlining, and running processes simultaneously. Artificial intelligence is one of these tools, with generative AI adding new layers of use.

Rolling out these systems without a long-term strategy that incorporates the dual carbon constraint only accelerates existing trends, including those most at odds with our resilience objectives. Making digital technology a genuine tool for transforming how we live and work so that it stays within the planet's limits requires a systemic consideration of its impacts.

II. An unsustainable path that calls for change

The digital sector already accounted for almost 4% of global greenhouse gas emissions in 2020 (The Shift Project, 2021), roughly the same as all the world's heavy-duty vehicles (IEA, 2021a). In France, it accounted for 4.4% of the country's carbon footprint in 2022 (ADEME, 2025) (ADEME – French Agency for Ecological Transition).

What sets the digital sector apart is the rapid growth of its emissions, rising along a trend that is particularly at odds with decarbonisation: an average of +6% per year worldwide (The Shift Project, 2021) and +2 to 4% per year in France (ADEME & Arcep, 2023; HCC, 2020; Sénat, 2020) (Arcep - French Electronic Communications, Postal and Print media distribution Regulatory Authority, HCC - High Council on Climate, Sénat - French Senate). Technical and operational optimisations have not offset the sustained roll-out of infrastructures, equipment and data flows[1]. This continues to be the case, as shown over the past five years, which some studies had suggested would mark a peak in these impacts thanks to technological progress and energy efficiency[2]. The large-scale deployment of AI, and of its generative branch in particular, further aggravates these already unsustainable trends. This report aims to shed light on them.

In France as well as globally, the digital sector accounted for around 10% of total electricity consumption in 2022 (ADEME, 2025; The Shift Project, 2021, 2023), a significant share that should earn it the same level of attention as other sectors. In the context of rapid electrification across mobility, buildings, and industry, the digital sector is also central to the challenge of planning system transformation and prioritising access to resources, with electricity among them.

Making the digital sector compatible with the dual carbon constraint therefore does not just mean strengthening the optimisation measures already in place, but putting it on a fundamentally different trajectory from the one it is currently following. Like other sectors of the economy, it must meet its decarbonisation target, which industry actors themselves (GSMA, GeSI[3]) have adopted through the SBTi initiative and on the basis of a recommendation from the ITU (SBTi et al., 2020)(p. 9) set as a 45% reduction in global[4] emissions by 2030 compared with 2020 levels.

Our digital system is built through many interactions between the technical infrastructure and the uses it supports. A systemic analysis of energy and climate issues shows that limiting the impacts of digital technologies requires careful reflection on the roll-out of services, the adoption of certain uses over others, and the role of digital sobriety. Cutting back on the amount of devices, data, and computing is in fact one of the essential conditions for controlling energy consumption through improvements in energy efficiency (The Shift Project, 2023).

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[1] (ADEME & Arcep, 2023; Bol et al., 2020; European Commission, 2020; GreenIT.fr, 2019; IEA, 2022, 2024a; LBNL et al., 2024; The Shift Project, 2023, 2025b)

[2] (IEA, 2019; ITU-T, 2020; Masanet E. et al., 2020)

[3] GSMA: GSM Association, association that brings together international players in mobile connectivity (manufacturers, operators, etc.). | GeSI: Global enabling Sustainability Initiative, group of international players in digital technology and telecommunications, whose mission is to promote sustainable digital practices.

[4] A non-quantitative framework of commitments exists at national level, set by French industry as part of the digital sector's decarbonisation roadmaps.

III. Why is The Shift Project focusing on artificial intelligence and data centres?

Generative artificial intelligence made a dramatic entrance into public debate in November 2022 with the launch of the conversational agent ChatGPT. Adoption of this free tool was rapid: 1 million users in just 5 days, 100 million within 2 months, and today[5] around 180 million visitors generating about 1 billion queries every day[6]. In France, 39% of people say they use artificial intelligence in their daily lives, mainly in a personal context but also professionally, rising to 74% among 18-24 year-olds[7].

This breakthrough is the result of a combination of factors: several decades of research in natural language processing; integration into "natural" dialogue interfaces; technological strategies to increase processor power (particularly graphics processors); the shift of storage and computing to the cloud; and access to large text datasets made possible by massive data gathering and enriched with linguistic annotations.

The term **artificial intelligence** keeps evolving and is always shaped by technological and temporal context rather than by any fixed standard. In France at least, artificial intelligence usually refers to the most advanced automation applications at a given point in time, whether in terms of information processing, task complexity, accuracy, or reliability. In this sense, the term points to a shifting technological frontier.

Generative artificial intelligence has become the most visible form of AI today. What makes it distinctive is its ability to produce information with unprecedented features: realistic (hard to distinguish from human-created content), fast, versatile (text, image, audio), and accessible through easy-to-use interfaces (chatbots, voice commands)[8].

This model is now evolving towards what is known as an agentic approach, where systems are no longer limited to simple conversational chatbots but are becoming fully autonomous agents, capable of planning and carrying out complex tasks by interacting with external tools.

Today, the large-scale, indiscriminate use of generative artificial intelligence is driving the expansion of the digital system, particularly the data centre sector, whose energy and carbon footprint is already rising at a steady pace.

The way artificial intelligence is developing is part of an interplay between infrastructures and uses that affects the entire digital system (see Figure 1):

- The drive to develop the new applications promised by the "generative AI moment" justifies the roll-out of additional technical capacity (improving processor performance, growing server rack capacity, building new data centres, etc.): this is the usage effect.

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[5] As of June 2025
[6] (Digital Information World, s. d.; Sagot B., 2023)
[7] Survey (Ipsos, 2025) from February 2025 shared by (Arcep, 2025)
[8] (Commission de l'intelligence artificielle & Gouvernement français, 2024)

- The roll-out of new technical capacity, in turn, drives the development of new applications (for example, the ability to obtain a response or an image quickly and easily thanks to very large computing power): this is the supply effect.

Uses and infrastructures remain two sides of the same coin. What is perhaps distinctive about the "generative AI moment" is the speed and intensity with which this loop is being set in motion: the financial, human, and technical investments required for the technology are being committed on a massive scale, both to drive the large-scale deployment of data centres and to accelerate the adoption of the new uses they make possible - thus sustaining these dynamics.

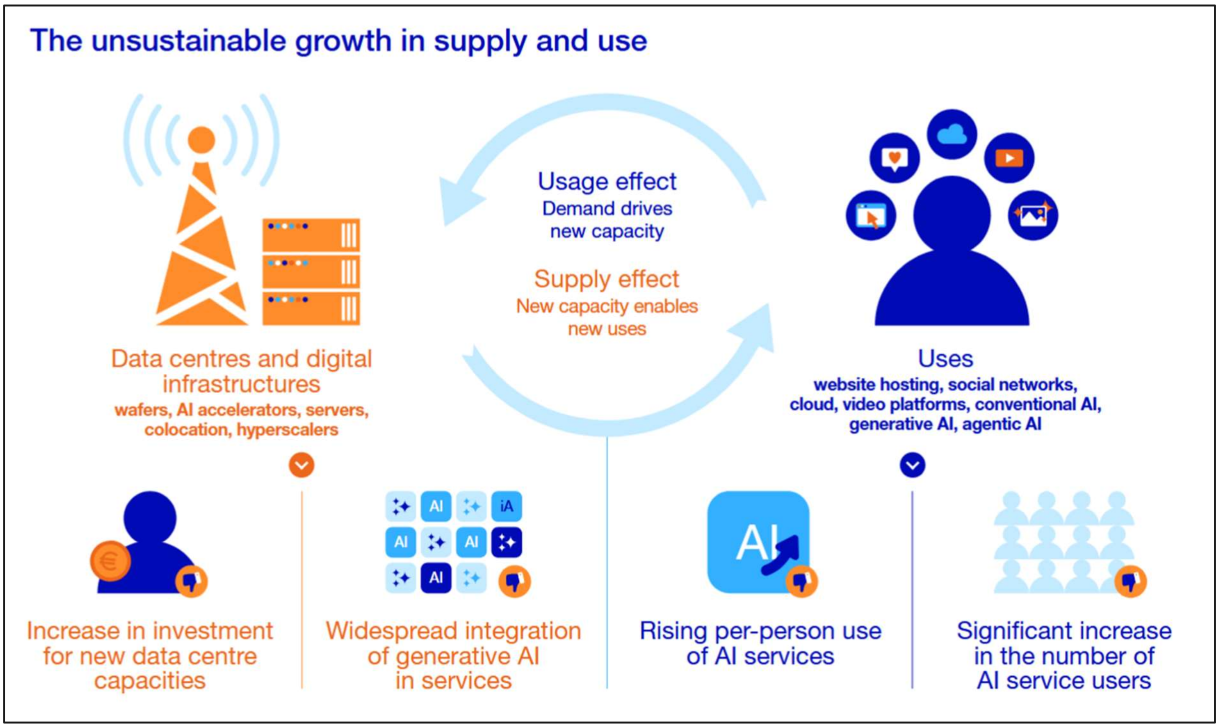

Figure 1 - Our uses and our infrastructures are two sides of the same process. Source: (The Shift Project, 2025b)

Intended to inform public debate, this report is structured into three chapters:

- Chapter 1: What energy and climate trajectories are global data centres following, and how does the "generative AI moment" accelerate this trend?
- Chapter 2: What impact does this trend have on electricity planning at the French and European levels?
- Chapter 3: In light of these findings, how can the development of artificial intelligence be steered along a trajectory that is compatible with physical constraints?

It therefore helps to set out the energy and climate challenges surrounding artificial intelligence at different scales: globally (Chapter 1), at the European and French levels (Chapter 2); and it does so both from a material perspective, by examining the data centre sector (Chapters 1 and 2), and by looking at AI supply and uses (Chapter 3).

The multiple meanings of "AI" and how they are addressed in this report

AI and digital technologies: continuity and expansion:

- The term "AI" builds on the concept of "digital", as illustrated by the renaming[9] of ministries, state secretariats, and national councils[10].
- The shift from "digital" to "AI", however, reflects a focus on the growing power of computing and processing capabilities.
- For the purposes of this report, we will use the expression "digital/AI" to refer to the sector as a whole, its technologies, its products, and its services.

AI and generative AI: confusion and the "generative AI moment":

- As described in the introduction, AI cannot be reduced to generative AI: AI refers to a constantly shifting technological frontier, of which generative AI - deployed on a massive and undifferentiated scale - is today the most visible use.
- AI is used as an argument both to support the continuation of energy-intensive trajectories (Google, 2024; Microsoft, 2024) and to promote the roll-out of data centres (Elysée, 2025), It benefits from a media aura - partly linked to major economic or geopolitical stakes - which, for the time being, largely spares it from having to justify itself.
- In this report, we will use the expression **"generative AI moment" or "generative AI phenomenon"** to designate this period in which large-scale infrastructure investments are being justified by this type of AI.

AI and data centres: the chicken and the egg:

- As noted earlier in connection with Figure 1 it takes between six months and five years to build a data centre[11]. These projects are therefore based on forward-looking assumptions, requiring investments that must later be made profitable.
- Even before the "generative AI moment", data centre growth was already strong, with no direct link to AI (for example, expected demand linked to accelerated digitalisation during COVID). Since then, expansion is often justified "by AI" - or by the perceived risk of under-investing rather than over-investing.
- In this report, we will use the terms **"computing capacity" or "processing capacity", and "IT power" or "computing power"**, to refer to the IT content of these infrastructures, and we will use **"data centre sector"** to describe the ecosystem of all players[12].

Chapters I and II focus on the data centre sector[13][14]:

- While also examining how the "generative AI moment" reinforces this trend: both physically, by analysing the resources required by generative AI, and symbolically, by identifying investments presented as being made "for" AI.
- And keeping in mind that data centres also support other uses: web services, cloud, crypto-assets, etc.

Chapter III focuses on:

- The **"digital/AI"** sector as a whole, in order to identify means of action within the industry - particularly in the design of goods and services and in their business models.
- **Contextualised AI use cases**, since only this level of detail allows a differentiated assessment of the benefits and environmental impacts associated with a given service or product.

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[9] In France and Europe, the terminology has shifted over time. The terms do not always cover exactly the same scope, but point to a clear trend: computing, the Plan Calcul (a French governmental programme to promote a national or European computer industry and associated research and education activities), information technologies, telecommunications, information and media, digital, tech, digital transition, digital economy…

[10] In September 2024, the Secretary of State for Digital Affairs became the Secretary of State for Artificial Intelligence and Digital Technology. In June 2025, the CNNum became the CIAN (National Council for AI and Digital Technology).

[11] It depends on its size, complexity, location, and regulatory constraints…

[12] Even if it is no longer only about "data" but also about "computing".

[13] The *AI & Energy* report (IEA, 2025a) also examines the data centre industry as a whole, not just uses linked to generative AI.

[14] With the exception of a short qualitative analysis of the potential effects of AI on the other two components of the digital system: networks and devices.

Chapter 1

Data centres: global climate and energy trajectories

IV. The data centre sector: a trajectory increasingly at odds with energy and climate goals

A. Current choices are leading to an unprecedented rise in greenhouse gas emissions

By 2030, current choices - driven by the industrial strategies of US Big Tech companies and already being replicated by many other digital players - in the design and deployment of data centres worldwide **would put the sector in an unsustainable position with respect to the climate constraint: its direct greenhouse gas emissions could reach between 630 $MtCO_2e$ and 920 $MtCO_2e$, up to twice France's total emissions[15].**

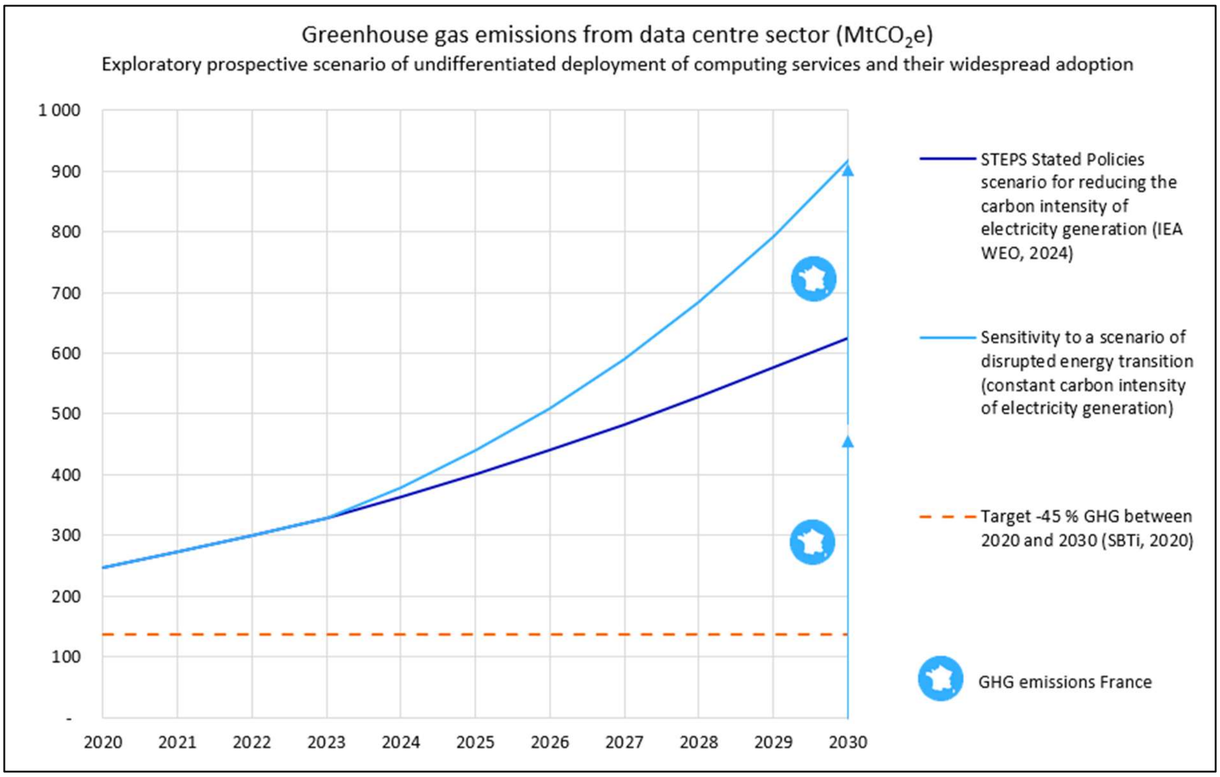

Figure 2 - Greenhouse gas emissions ($MtCO_2e$) from our exploratory forward-looking scenario of undifferentiated deployment of computing capacity and its widespread adoption, for different levels of electricity carbon intensity, and comparison with the target scenario. Source: (The Shift Project, 2025b)

This carbon footprint includes both the direct emissions linked to electricity consumption and those generated by the construction of data centres and the production of the equipment they host (servers, IT hardware, cooling infrastructure, buildings, etc.).

[15] Approximative average of national emissions and the carbon footprint: 373 MtCO2e in 2023 for national emissions, 623 MtCO2e in 2022 for the footprint (Haut Conseil pour le Climat, 2024) (Haut Conseil pour le Climat = High Council on Climate).

This estimate draws on the trends in the data centre sector described and analysed in this report[16] :

- Electricity consumption could rise from 530 TWh in 2023 to 1,490 TWh in 2030 (and 3,000 TWh in 2035) in the event of large-scale deployment of computing capacity and widespread adoption of services across all uses: website hosting, cloud services, video on demand, online gaming, social networks, storage, company data processing, artificial intelligence including generative AI, and cryptocurrencies.
- The carbon content of the electricity consumed could follow different scenarios:
  - That of current national climate policy ambitions, falling from 458 gCO_2e/kWh in 2023 to 312 gCO_2e/kWh in 2030 (IEA, 2024b) (Stated Policies Scenario – STEPS, p. 301, October 2024) ;
  - That of a deterioration of current national climate and policy ambitions, modelled here as remaining constant at 458 gCO_2e/kWh between 2023 and 2030, to illustrate what a stagnation in the emissions factor[17] would mean.

For comparison, 600 $MtCO_2e$ of greenhouse gas emissions (Stated Policies climate scenario) from the global data centre sector in 2030 would represent:

- 2.5 times the 250 $MtCO_2e$ recorded in 2020,
- 76% of emissions from the shipping sector[18] or 57% of CO_2-only emissions from the civil aviation sector[19],
- 1.2% to 1.4% of total global greenhouse gas emissions in 2030, across all sectors[20,21].

At this level of GHG emissions, factoring this sector into development scenarios and climate targets becomes unavoidable: it is a fully fledged industrial sector which, in the absence of compatible development scenarios, risks generating even higher direct emissions - contributing to a greater drift away from climate goals than expected.

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[16] Trends in electricity consumption are set out in section **Erreur ! Source du renvoi introuvable.**. Trends in carbon intensity of electricity are set out in **Erreur ! Source du renvoi introuvable.**. All calculations are presented in appendix C (The Shift Project, 2025a).

[17] This stagnation reflects both the fact that when low-carbon capacity is used by data centres, it delays the energy transition in other sectors, which explains the constant modelling. It also reflects the response to the unexpected and unprecedented additional demand from AI, met by gas plants deployed in the global electricity mix (see section **Erreur ! Source du renvoi introuvable.**). In this case, modelling at 458 gCO2e/kWh falls within the upper range for gas plants 350/370/490 gCO_2e/kWh (IPCC, 2018).

[18] 0,825 $GtCO_2$ in 2020 according to IEA estimates (IEA, 2021a)

[19] *Pouvoir Voler en 2050* summary, p2, 1.1 $GtCO_2e$ in 2018 (The Shift Project & Supaero Decarbo, 2021)

[20] These 1.2% to 1.4% concern only the data centre sector and not the digital sector as a whole: networks (fixed, mobile, satellite, global backbones) and devices (TVs, computers, smartphones, connected objects, etc.) are not included..

[21] By comparison with 54 GtCO2eq in 2030 under a 3°C (>50%) pathway (Table SPM.2, Intergovernmental Panel on Climate Change (IPCC), 2023), the share comes to 1.7%. Compared with 44 GtCO2eq in 2030 under a 2°C (>67%) pathway (Table SPM.2, IPCC, 2023), it comes to 1.4%. The compatibility of this scenario with a 2°C (>67%) global trajectory is highly questionable, since this "surprise increase" of 350 MtCO2e between 2020 and 2030 is not offset by any adjustment for another sector in the scenario.

In this Stated Policies scenario, it is worth noting that:

- The increase in computing capacity is so large that it wipes out around 30% of the gains from improvements in the electricity mix[22], with GHG emissions still growing at a compound annual rate of 9%.
- This pace contrasts with the order of magnitude of a roughly 5% annual linear reduction trajectory needed to reach the net-zero emissions target.

Continuing on this trajectory - and therefore with current decisions - would mean moving sharply away from the SBTi target, which sets a 45% reduction in emissions between 2020 and 2030 (Figure 2).

In 2035, under the same scenario[23], emissions would reach 920 $MtCO_2e$, widening the gap with the objective of a 90% reduction in emissions by 2050 compared with 2020 (Figure 3).

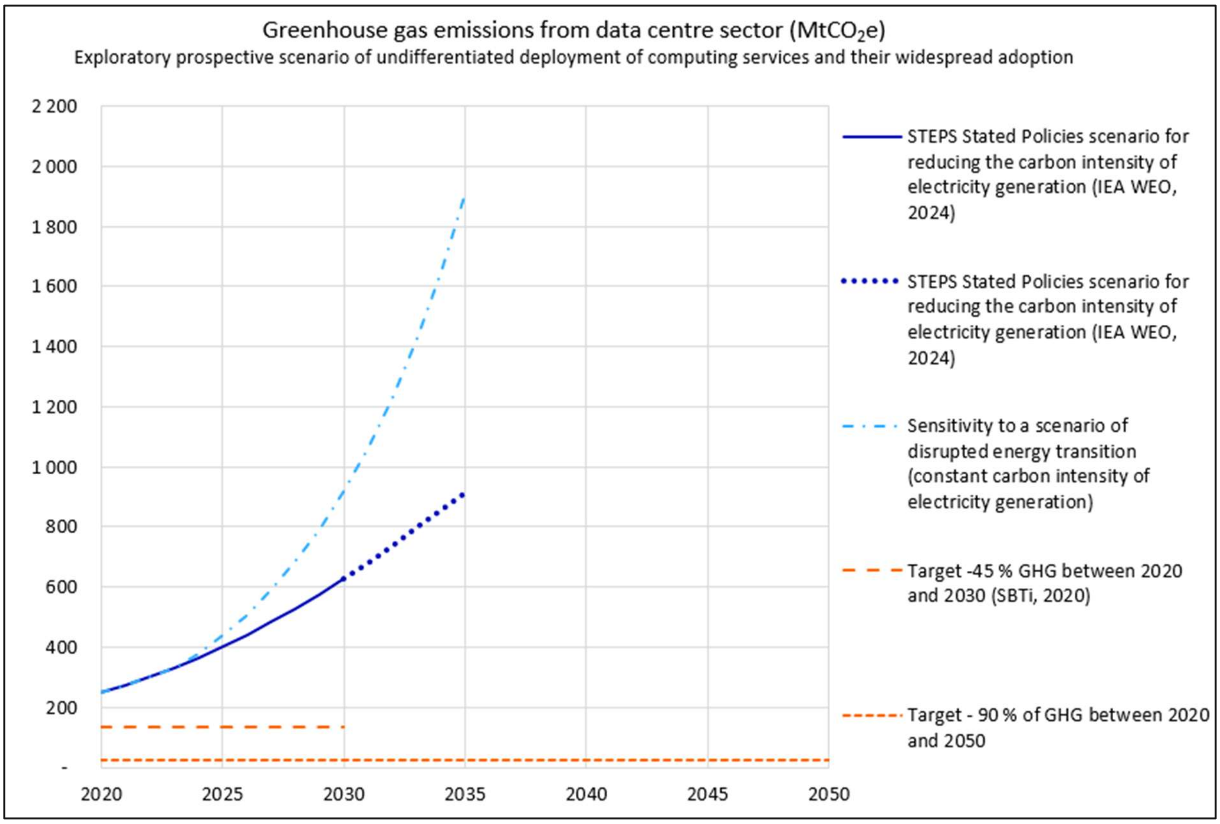


Figure 3 - Greenhouse gas emissions ($MtCO_2e$) from our exploratory forward-looking scenario of undifferentiated computing capacity deployment and its widespread adoption, for different levels of electricity carbon intensity, and comparison with the target scenarios. Source: (The Shift Project, 2025b)

[22] This reflects the reduction in the carbon intensity of electricity generation from 458 gCO2e/kWh in 2023 to 312 gCO2e/kWh. Without this reduction (the second scenario), emissions would be 900 MtCO2e instead of 600 MtCO2e.

[23] Based on current climate policies: 458 gCO2e/kWh in 2023, 312 gCO2e/kWh in 2030, 219 gCO2e/kWh in 2035 and 111 gCO2e/kWh in 2050 (IEA, 2024b) (Stated Policies Scenario - STEPS, p.301, October 2024).

Setting clear targets for this sector, supported by carbon policies, is essential. The longer the delay, the more inertia builds up: a data centre is built with a lifespan of 20 to 25 years, and postponing the introduction of such policies by just one year means accepting an additional 50 $MtCO_2e$ each year.

Modelling approach

Here we put forward a transparent projection[24] of how electricity consumption in data centres could evolve in the case of a widespread roll-out of AI computing capacity.

This scenario stands out as forward-looking when compared with the variety of scenarios currently available: for example, four from the IEA (Lift-off, Base, High Efficiency, Headwinds) (IEA, 2025a), four scenarios for Schneider Electric (Abundance, Sustainable AI, Energy Crunch, Limits to Growth) (Schneider Electric, 2024), a range for LBNL between 6,7 % and 12 % (LBNL et al., 2024), two scenarios for Deloitte (Baseline, High Adoption) (Deloitte, 2024). This scenario builds on those that focus specifically on widespread deployment.

Our approach is also intended to highlight the variables and factors that shape how the climate impact evolves, namely electricity consumption (use), the embodied carbon footprint (mainly from manufacturing), and the carbon intensity of electricity generation.

The sensitivity to embodied carbon footprint in this estimate has been assessed: 37 $MtCO_2e$ (out of 620) by 2030 when shifting from a 75/25 split between use and manufacturing to an 80/20 split.

Between 2025 and 2030, this split is modelled as constant despite a decrease in the carbon intensity of energy, which would therefore also imply a reduction in the carbon intensity of equipment (see "The carbon footprint of manufacturing across the value chain can no longer be overlooked").

B. A sustainable climate trajectory means capping electricity use in the data centre sector

Setting a target of reducing greenhouse gas emissions by 90% between 2020 and 2050 for the data centre sector provides a target scenario worth exploring in order to shape a long-term climate neutrality strategy for 2050 (Commission européenne, 2019)[25]. This scenario shows that there is a cap on electricity consumption, determined by the scale of embodied carbon (servers, computer equipment, cooling infrastructure, buildings, etc.) and by the success of the energy transition (Figure 4). For example :

- In the Stated Policies scenario for 2050[26], with an unusual 90/10 split between use and manufacturing[27], the upper limit is 200 TWh per year.

24 Trends in electricity consumption are set out in section **Erreur ! Source du renvoi introuvable.**. Trends in the carbon intensity of electricity are set out in section **Erreur ! Source du renvoi introuvable.**. The estimate of the carbon footprint of manufacturing is set out in section **Erreur ! Source du renvoi introuvable.**. All calculations are presented in appendices 1 to 6 (The Shift Project, 2025a).

25 Commission européenne = European Commission

26 Based on current climate policies: 458 gCO2e/kWh in 2023, 312 gCO2e/kWh in 2030, 219 gCO2e/kWh in 2035 and 111 gCO2e/kWh in 2050 (IEA, 2024b) (Stated Policies Scenario - STEPS, p.301, October 2024).

27 An unusual and striking distribution, since today with electricity decarbonisation this ratio of around 75/25 tends to balance out at about 55/45. In other words, with the same hardware the manufacturing-to-use ratio increases as energy decarbonises. In this case, it would mean not only that electricity is decarbonising, but that the embedded carbon footprint is falling even faster. See section "The carbon footprint of manufacturing across the value chain can no longer be overlooked"

- Even in a heavily decarbonised configuration - both in energy (electricity at 25 gCO_2/kWh in 2050) and in equipment production (a 95/5[28] use/manufacturing split) - there is still an upper limit, and it stands at 950 TWh per year.

200 TWh - and even more so 1,000 TWh - therefore represents an absolute maximum that must not be exceeded.

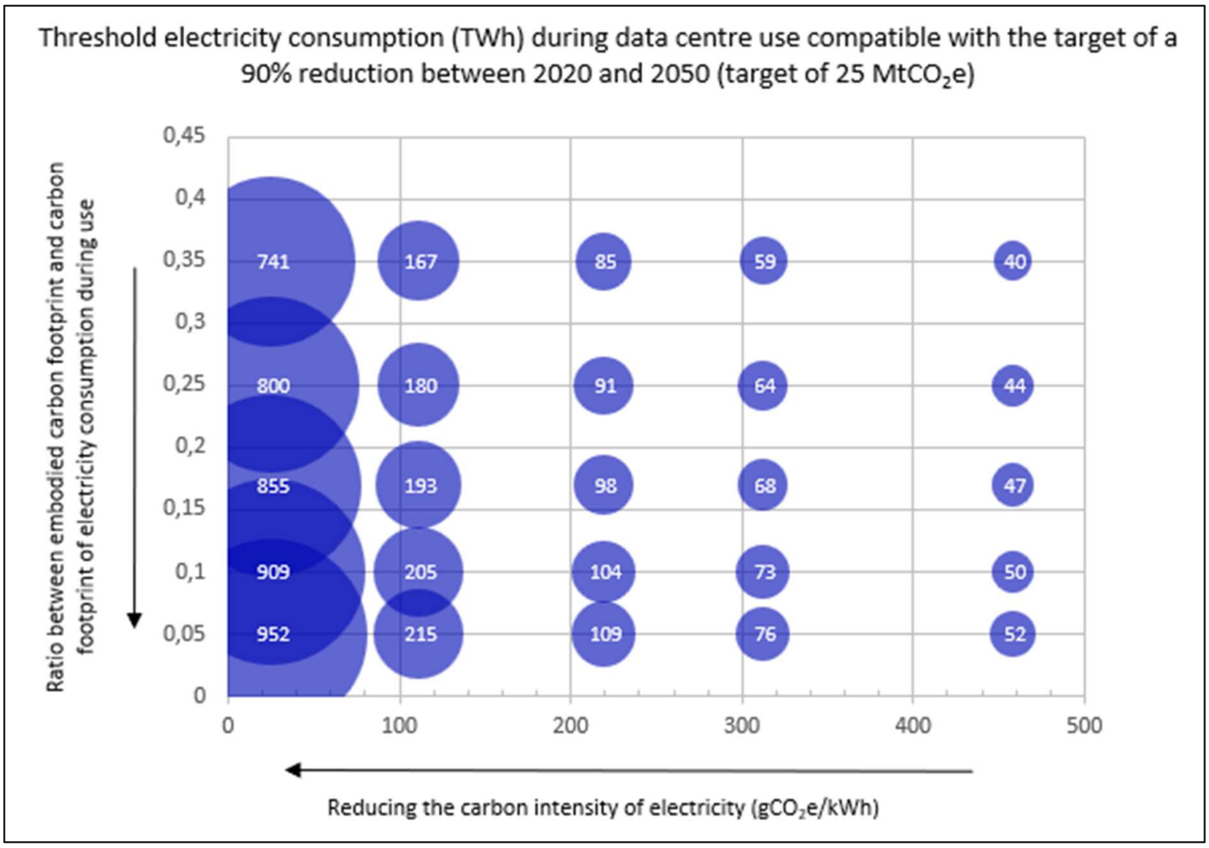
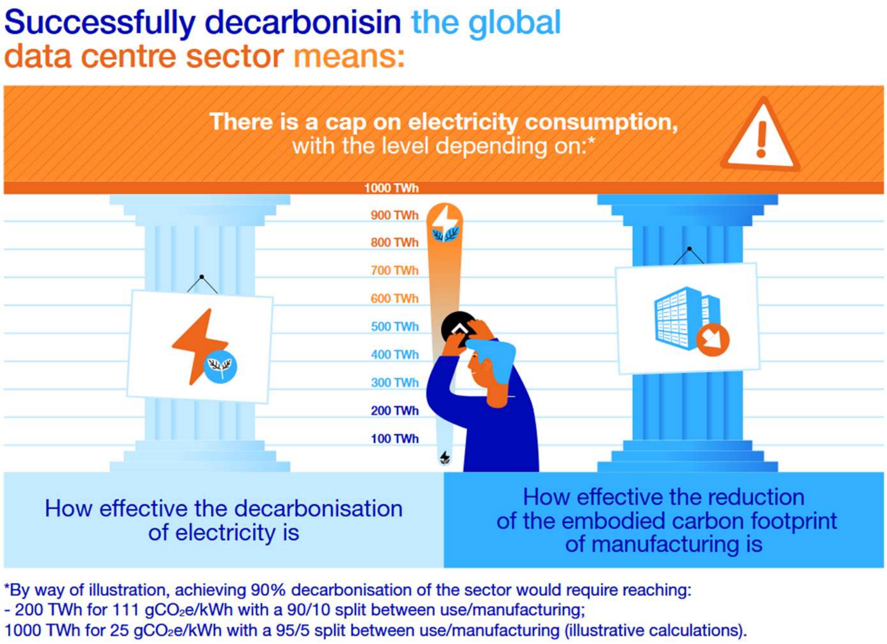


Figure 4 - Threshold electricity consumption (TWh) in the use phase of data centres compatible with a target objective of a 90% reduction between 2020 and 2050. Source: (The Shift Project, 2025b)

28 Which once again assumes that hardware is decarbonised at a much faster pace than energy.



V. Energy trends in the data centre sector: a structural growth trend

A. Lessons from past estimates

Since 2005, **the electricity used by data centres has been rising steadily - in both scale and pace** - as well as in terms of installed power capacity (GW) and electricity consumption (TWh).

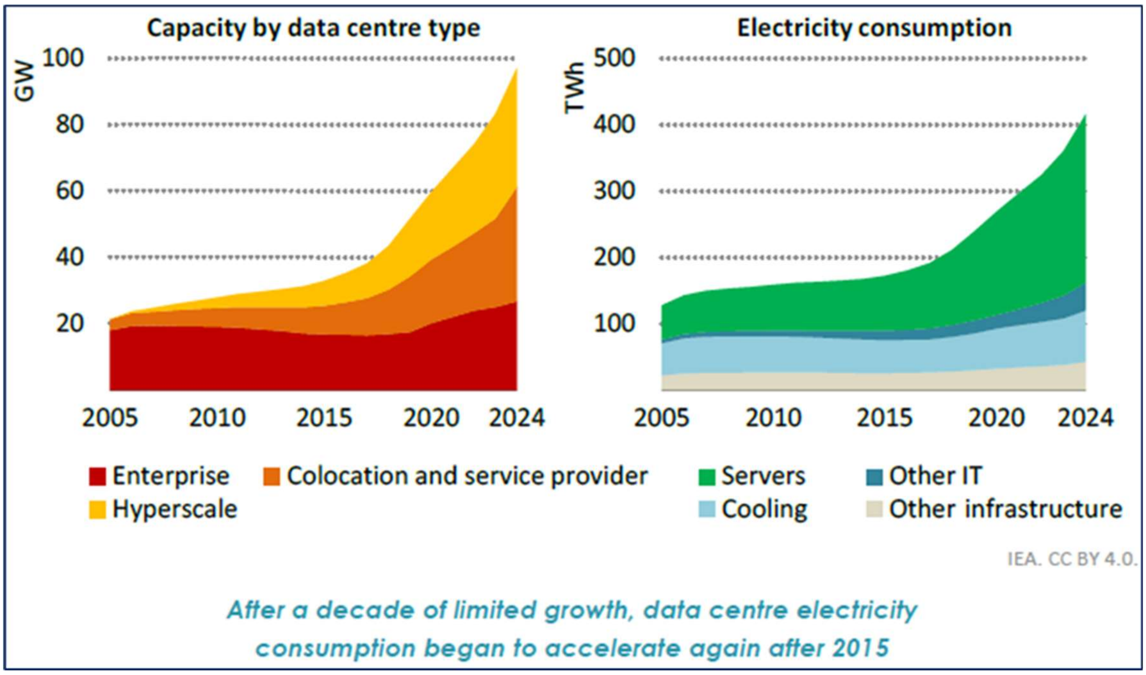


Figure 5 – Total installed electrical capacity (GW) and total electricity consumption (TWh) for data centre use29 Source: (IEA, 2025a)

According to the IEA (IEA, 2025a), between 2005 and 2024 annual electricity consumption from data centre operations rose from 120 TWh to 420 TWh - more than double the 200 TWh cap that had been hoped for in 2018-2022[30] (excluding cryptocurrencies). In 2024, total installed power capacity had reached almost 100 GW, with 30 GW added during the 2018–2022 period alone.

The pace has therefore been steadily increasing for the past two decades, but trend analysis shows three distinct phase (Figure 5 and Appendix 1 (The Shift Project, 2025a)) :

- A first period of moderate growth up until 2015,
- A sustained acceleration between 2015 and 2020 with the roll-out of cloud computing, reaching up to 9% CAGR over this period,
- Further intensification since then, with up to 13% CAGR over the past five years.

GW et TWh: Power and consumption:

A gigawatt (GW) measures the amount of installed power capacity at a given moment.
A terawatt-hour (TWh) measures the amount of energy consumed over a given period (here, one year) with a specific usage pattern[31].

Orders of magnitude and comparisons:

[29] Without cryptocurrencies
[30] See the following paragraphs for the analysis of this past controversy.
[31] Describable by a load factor for data centres.

100 GW? In 2024, 100 GW of power capacity was the equivalent of ten times the electricity used by all French industry (RTE, 2025c) (RTE, France's electricity transmission operator). By way of example, the three nuclear reactors at Flamanville have capacities of 1.3, 1.3 and 1.6 GW respectively (Wikipédia, s. d.).
420 TWh ? France's electricity consumption in 2024 was 450 TWh (RTE, 2025a).

Two variables to describe energy trends in the data centre sector:
TWh measure *recurring* electricity consumption, for example on an annual basis.
GW provide information on infrastructures: both in terms of the size of data centre sites, describing the installed computing power (in GW), and in terms of the electricity supply capacity that must be allocated or built to feed them (in GW).

This trend has been driven mainly by the US since 2015 (Figure 6), where data centres already account for 4.5% of national electricity consumption. The trajectory was well under way even before the public rise of generative artificial intelligence, with capacities doubling between 2014 and the end of 2021. The role of hyperscalers, colocation services, and infrastructure providers - the categories that include the largest US digital companies - is clearly visible in this development (Figure 5).

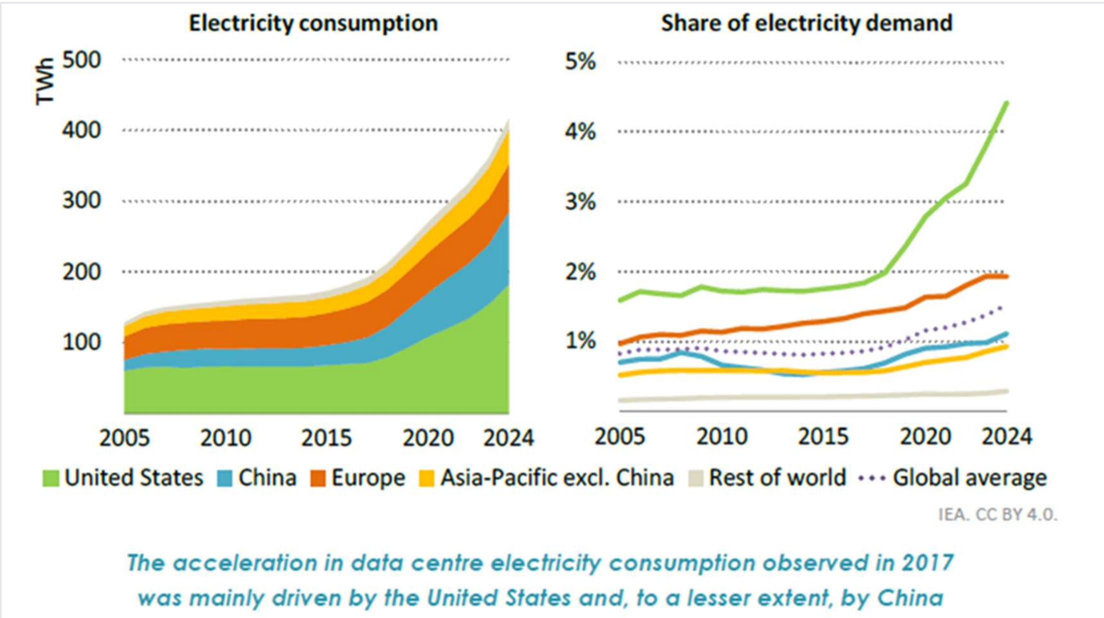


Figure 6 - Total electricity consumption (TWh) and share of regional demand (%) for data centre use[32]. Source: (IEA, 2025a)

Historical benchmarks for retrospectively analysing an exaggerated belief in energy efficiency as the sole lever to absorb the full growth in service supply

For many years, due to the lack of direct measurements and data, the only benchmarks for assessing electricity consumption in the data centre sector have come from estimates and modelling produced through academic research. Amongst these studies, several concluded that efficiency gains would be sufficient to offset a doubling of demand for data centres, allowing overall consumption to plateau (Masanet E. et al., 2020).

[32] Without cryptocurrencies

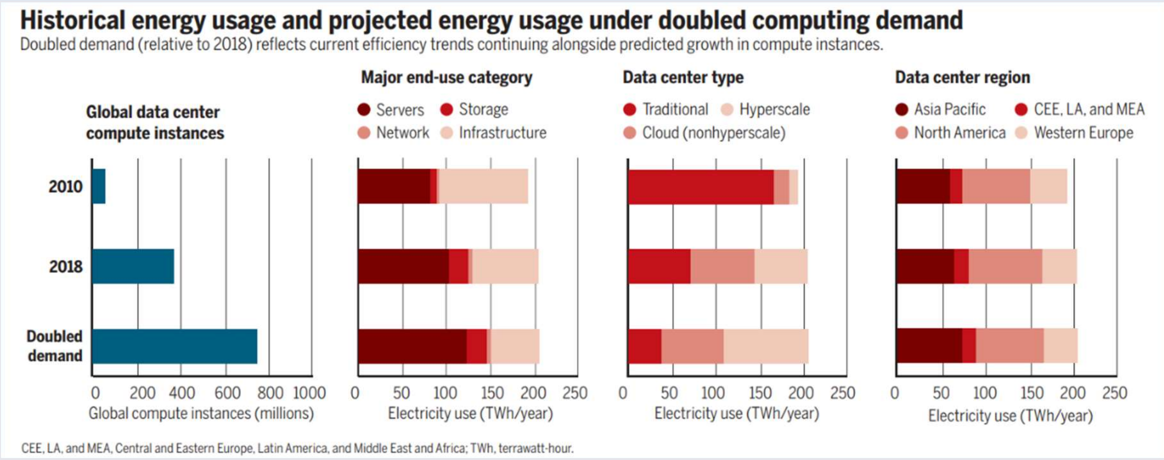


Figure 7 - Historical energy consumption and projected consumption in a scenario of doubled computing demand. Source : (Masanet E. et al., 2020)

These studies long fed into similar conclusions in IEA publications: "if current trends in the efficiency of data centre equipment and infrastructure can be maintained, global energy demand from data centres could remain almost flat through 2022, *despite a 60% increase in demand for services »* (IEA, 2021b).

In the wider public debate, the conclusions of this statement were repeatedly used at the edge of, or even outside their field of validity. This gave the impression that efficiency alone could absorb any increase in digital services, whatever its scale.

At the end of 2024, the Lawrence Berkeley National Laboratory (LBNL) made a shift in the debate with a landmark study reviewing past estimates, acknowledging a substantial rise in energy consumption rather than a plateauing (Figure 8). Improvements in energy efficiency did take place, but they were far outweighed by the rapid growth in digital uses.

The overview of past estimates could also have included the work of Borderstep, which in 2020 already foresaw the current trend: 350 TWh in 2017, 500 TWh in 2022 and up to 880 TWh in 2030 (Borderstep et al., 2020).

For comparison, the four scenarios developed in 2021 by The Shift Project to describe different trends in use and efficiency estimated data centre final energy consumption at 420 TWh in 2019, projecting it to range from 370 TWh to 549 TWh in 2022, and from 331 TWh to 734 TWh in 2025 (The Shift Project, 2021).

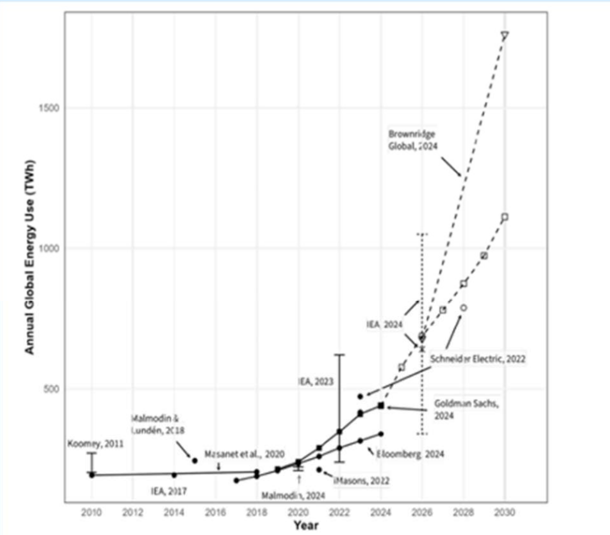


Figure 1.2. Academic and industry historical estimates of global data center energy use. *Plot also includes future projections from those sources. Historical estimates are shown with solid lines, and projections are shown with dashed lines.*

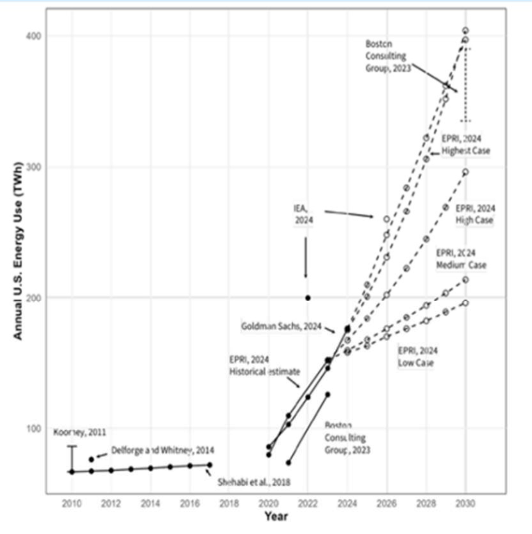


Figure 1.1. Academic and industry historical estimates of U.S. data center energy use. *Plot also includes future projections from those sources. Historical estimates are shown with solid lines and projections are shown with dashed lines.*

Figure 8 - Historical estimates of data centre electricity consumption worldwide between 2020 and 2030 (vertical scale starting at 100 TWh for the left-hand chart) and in the US
Source: (LBNL et al., 2024)

Recognition that consumption would not plateau gradually became widespread, eventually reaching full consensus[33].

The IEA is continuing to monitor and assess energy efficiency gains, and notes a slowdown in some of these indicators (Figure 9), even as the growth in services and demand continues to accelerate.

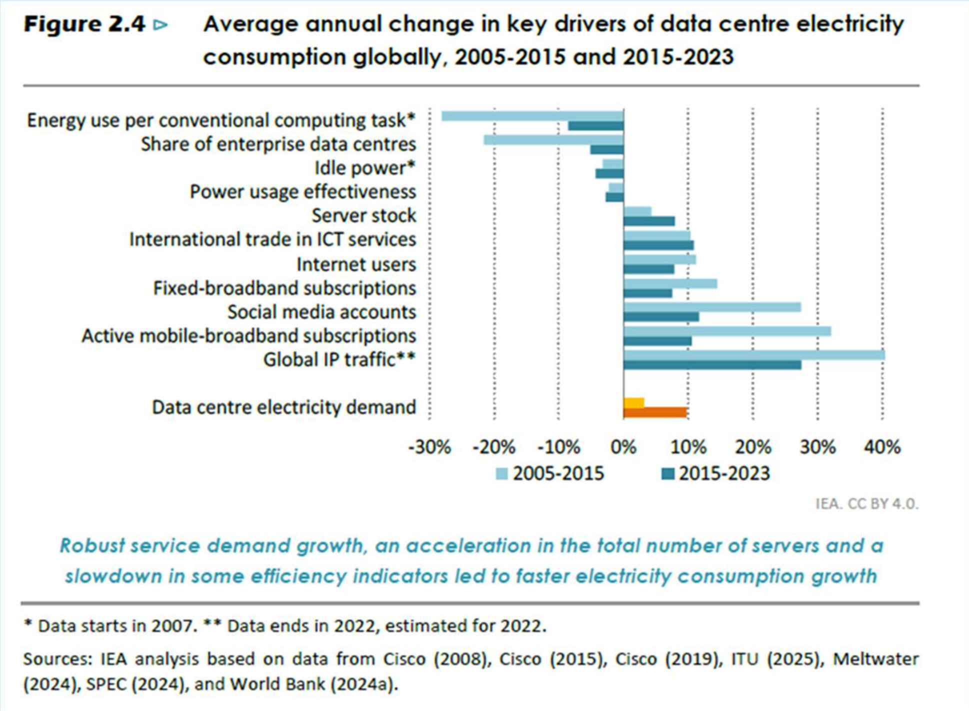


Figure 9 - Rapid growth in demand for services, the accelerating number of servers, and the slowdown in some efficiency indicators have led to a faster rise in electricity consumption. Source: (IEA, 2025a)

This historical review points to several recommendations that should be central to future decisions:

- **Fully acknowledge that the use of energy resources by the data centre sector has not yet levelled off, that it has continued to grow steadily, and that energy efficiency on its own cannot offset the expansion of services;**
- Monitor the electricity consumption of data centres and associated infrastructure, with sufficient frequency and coverage, which is essential to provide a reliable picture of the resources required by the sector. Approaches relying solely on modelling have often resulted

[33] •Until 2021, the IEA estimated data centre electricity consumption at about 200 TWh, remaining almost stable despite strong growth in use (IEA, 2021b). • In 2022, the IEA reported consumption in the range of 240–340 TWh for that year (IEA, 2022). • In 2023, EDNA (IEA collaboration on digital energy efficiency) raised the issue of demand growing too fast compared with efficiency gains (EDNA, Technology Collaboration Programme by IEA, 2023). • In 2024, the IEA gave a figure of 460 TWh for 2022 (IEA, 2024a). • In 2025, the IEA finally stated that after a decade of limited growth, data centre electricity consumption began accelerating again after 2015, citing a figure of 340 TWh for 2022 (IEA, 2025a). These changes also reflect changes in scope, depending on whether cryptocurrencies are included, whose share of total consumption is far from negligible.

in chronic underestimation, hindering effective management[34] while existing mechanisms such as the Energy Efficiency Directive (EED)[35] remain, for the time being, innefective;
- From a reflective standpoint, it would be useful for public authorities to assess the impacts of past decisions taken on the basis of poor information (notably the assumption that electricity demand had reached a plateau);
- Establish a governance framework (objectives, pathways, signals) - essential to moderate the sector's energy demand at a structural level.

B. Trends in data centres are pushing use phase electricity consumption onto an uncapped trajectory

Without major changes in current trends, by 2030 global data centre electricity consumption could reach between 1,250 TWh and 1,500 TWh - a 2.3- to 2.8-fold increase in just seven years. This would mean that by 2028 consumption would already exceed the 1,000 TWh upper limit identified in the previous section (See "A sustainable climate trajectory means capping electricity use in the data centre sector").

By 2035, this range could extend further, to between 2,250 TWh and 3,000 TWh.

These two figures represent two scenarios from Figure 10 the full set of data and assumptions for which is detailed later in this report, and in Appendix 3 (The Shift Project, 2025a) :

- The first scenario (in blue) is based on three patterns of data centre and computing resource use: the "non-AI" share, the "AI" share - mainly due to the "generative AI phenomenon" (see Accelerated servers and generative AI: key drivers of the data centre sector") - and cryptocurrencies, expected to maintain their current pace.
- The second scenario (in orange) is "conservative": it assumes a constant growth rate, even though that rate is in fact increasing.

Electricity consumption in the use phase in 2023 is estimated here at 530 TWh: this figure includes cryptocurrencies and was calculated using a region-based[36] approach.

[34] The few academic studies carried out on the subject provide reference points at the time they are produced, but they do not allow for continuous updating.

[35] The EED (Energy Efficiency Directive), by requiring reporting for data centres above 500 kW into a European database (Journal officiel de l'Union européenne, 2024) (Journal Officiel de l'Union Européenne = Official Journal of the European Union) could be a starting point. However, to date, only 14 TWh have been collected at an european level (European Commission et al., 2025).

[36] By way of comparison, without cryptocurrencies the estimated electricity consumption for 2023 would be 380 TWh, whereas the IEA reports 361 TWh (IEA, 2025a). See appendix 2 for the regionalised construction, the scope (with or without crypto), and the comparisons (The Shift Project, 2025a).

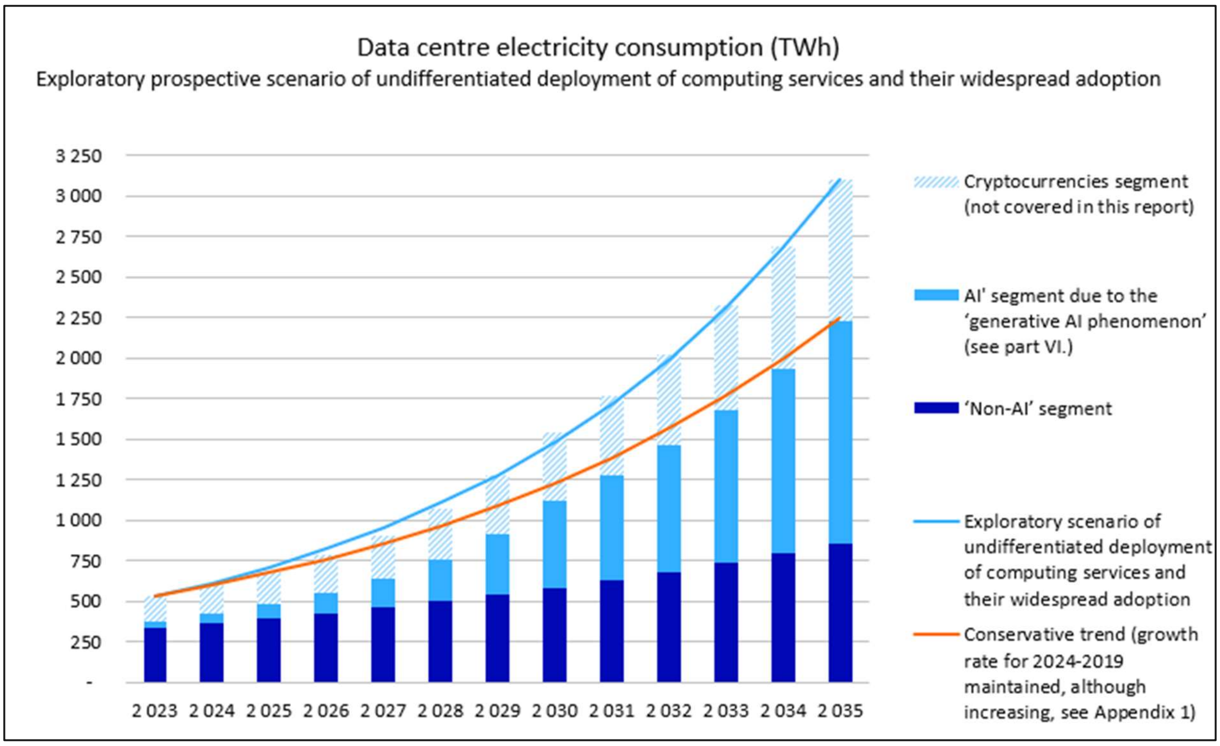


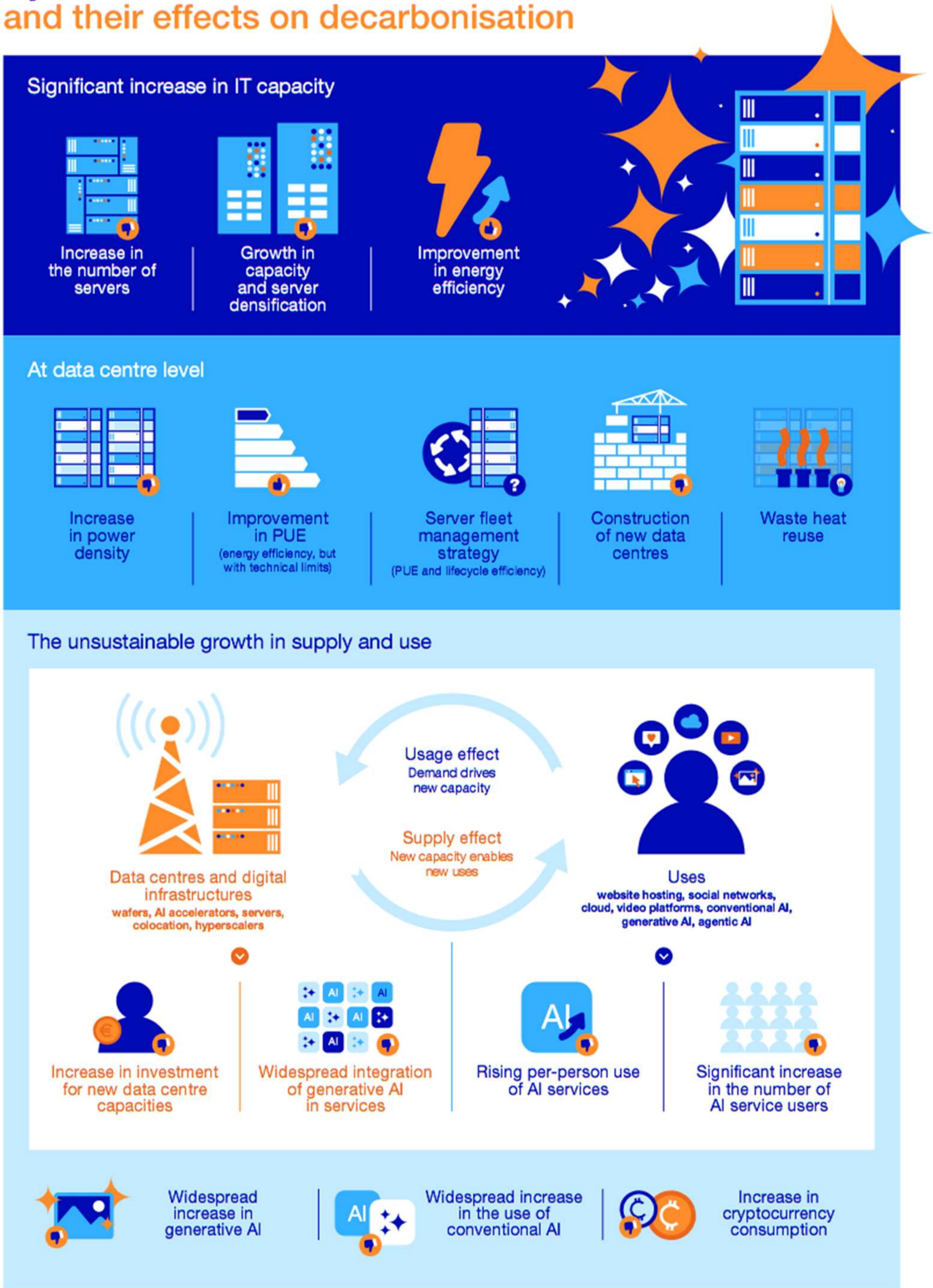
Figure 10 - Electricity consumption of data centres in the use phase (TWh) in our exploratory forward-looking scenario of undifferentiated computing capacity deployment and widespread adoption, compared with a conservative trend. Source: (The Shift Project, 2025a)

In the first scenario (in blue), the first trend represents strong demand for so-called "conventional" digital uses (Figure 5)**.** Launched at scale between 2000 and 2015, this trend covers website hosting, online gaming, social networks, cloud services, video-on-demand platforms, and company data storage and processing. On top of this layer of uses, the first deployments of so-called traditional AI ("trad AI") were gradually added, through applications such as machine translation, image processing, and recommendation engines.

The second trend, analysed in more detail in Part Erreur ! Source du renvoi introuvable.**, lies in the recent rise of generative artificial intelligence.** It is based on:

- Continuous improvement in hardware and algorithmic performance (for equivalent use);
- Gains in energy efficiency with each new generation of accelerated servers;
- An improvement in the effective utilisation of computing resources, alongside questions about equipment lifespan and hardware profitability;
- Larger and more powerful models, requiring greater computing capacity, particularly for training phases

Dynamics of the data centre sector and their effects on decarbonisation



Its pace is fuelled by massive investment in computing infrastructure, driven both by private players and by public industrial policies. This large-scale funding has led to the rapid roll-out of generative AI services for the general public, as part of a strategy to deploy and secure market share.

On the hardware side, the thermal power[37] of AI accelerators has increased more than tenfold in just a few years, with this trend expected to continue in the medium term.

With the installed base remaining constant, this densification leads to higher electricity consumption as well as the accelerated replacement of less efficient equipment (which may be resold and reused within the same base, in another base, or not at all). This increase in density affects the entire technical ecosystem, from servers to data centres, creating growing constraints in terms of power supply and cooling. It also generates significant needs for upgrading existing infrastructure, and in some cases for identifying new sites better suited to these technical requirements.

Finally, coupled with rapid and large-scale adoption of these services, this leads to increased load on data centres and to the construction of excess capacity, in order to prepare for future demand growth and ensure the continuous availability of services.

The last trend, often less studied, is related to cryptocurrencies. While the electricity consumption of Bitcoin is now relatively well documented (notably through the Cambridge Bitcoin Electricity Consumption Index (CBECI, s. d.)), that of other crypto-assets and blockchains remains more difficult to quantify and to forecast.

Finally, in terms of modelling, (see Appedix 2 and 3 (The Shift Project, 2025a)) :

- The first trend is modelled with a growth rate typical of the period when cloud computing was expanding (historical CAGR 2015–2020 of 8%, see Appendix 1 (The Shift Project, 2025a)).
- The second trend is modelled on our analysis of the installed base of accelerated servers (see Part C-1) and is close to the "Abundance" scenario (Schneider Electric, 2024), the "Lift-off" scenario (IEA, 2025) and the "High adoption" scenario (Deloitte, 2024).
- The cryptocurrency share, which is not covered in this report, is modelled with the same growth rate as both the "non-AI" and "AI" shares (CAGR 2023–2035 of 15.8%), a pace that remains below Bitcoin's growth in recent years (CAGR 2019–2023 of 22%).

The second, conservative scenario (in orange in Figure 10) based on maintaining the growth rate observed during 2018–2023 (CAGR of 12.8%). This choice is also conservative in that the annual growth rate is assumed to remain constant over the entire period, even though it has been increasing since 2015 (see Appendices 1 and 3 (The Shift Project, 2025a)).

The two curves shown do not reflect all possible trajectories, but only the continuation of current trends, without any shift towards a genuine decarbonisation trajectory for the sector or any disruption to the financial strategies of the actors involved. In reality, the range of possible outcomes is much broader, as illustrated by the various prospective models available:

[37] TDP, Thermal Design Power

- The International Energy Agency (IEA) presented four scenarios (Lift-off, Base, High Efficiency, Headwinds), projecting data centre electricity consumption (excluding cryptocurrencies) of between 670 and 1,265 TWh in 2030 (IEA, 2025a).
- Schneider Electric also explored four scenarios (Abundance, Sustainable AI, Energy Crunch, Limits to Growth), with projected electricity consumption for AI alone ranging from 510 to 880 TWh in 2030 (Schneider Electric, 2024).
- The Lawrence Berkeley National Laboratory (LBNL) estimated that between 6.7% and 12% of US electricity consumption could be attributable to data centres in 2028 (LBNL et al., 2024).
- Deloitte proposed two forward-looking scenarios (Baseline, High Adoption) with electricity consumption of 705 and 970 TWh in 2030 (Deloitte, 2024).
- Finally, DCByte also published development corridors that illustrate the diversity of possible trajectories (DCByte, 2025).

Among these scenarios, several assume rapid, even widespread deployment of the most compute- and energy-intensive technologies, particularly in the “Lift-off”, “Abundance” and “High Adoption” cases. These are the scenarios that current trends seem to lead to. Yet, to ensure the sustainability of the digital sector, the challenge is precisely to **move away from these so-called “Lift-off” or “Abundance” trajectories**, which would place excessive pressure on energy systems and the climate.

Given the deployment lead times in the sector, a significant share of the electricity consumption projected for 2027–2028 is already locked in through confirmed investments, infrastructure under construction, and uses currently in a market-capture phase (Figure 5, Figure 11). In this respect, it is **likely** that the major trends over the next three years will align with these business as usual scenarios - which only reinforces the urgency of developing credible and sustainable alternatives in the medium term.

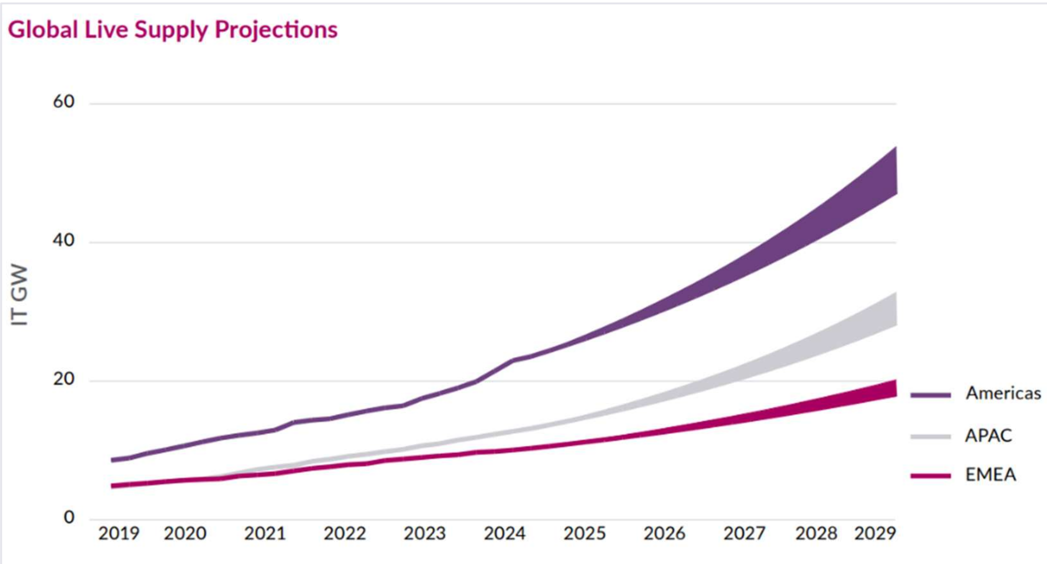


Figure 11 - P Projected IT capacity entering service in the coming years (GW).
Source: (DCByte, 2025)

C. The data centre sector is increasing reliance on fossil-based infrastructure

The scale and pace of electricity demand from data centres are exerting growing pressure on the energy sector.

In some US states, this pressure has led to a real energy wall, resulting in a "whatever it takes" search for new generation capacity, rather than an incentive to slow the pace of service deployment[38].

In response to these energy pressures, major digital players initially announced plans to source low-carbon electricity through the continuation of power purchase agreements (PPAs)[39]. For example, Amazon is exploring the deployment of 0.3 GW of small modular reactors (SMRs) (Data Center Dynamics, 2024b), Microsoft plans to enable the restart of the previously decommissioned Three Mile Island nuclear power plant (Le Monde, 2024), Sam Altman, CEO of OpenAI, is financing a nuclear fusion start-up (Le Monde, 2024) and Google is running a deep geothermal pilot aiming for 0.1 GW of capacity (Le Monde, 2025c). **However, SMRs and geothermal could not, at best, enter into service before 2030, and remain burdened by capacity, technological, and regulatory uncertainties** (IEA, 2025b).

In the meantime, the immediate response to rising energy demand is a large-scale revival of fossil infrastructure, particularly natural gas, mainly because of its flexibility and ease of deployment. For example, xAI's Colossus data centre is equipped with 400 MW of mobile natural gas generators (Data Center Dynamics, 2024a; L'usine digitale, 2025c), Meta plans to build three gas turbine power plants totalling 2.3 GW (The Register, 2024) and natural gas-powered data centre projects are multiplying, reaching capacities on the gigawatt scale (Data Center Dynamics, 2025b). In total, 85 gas power plants for data centres are currently under development worldwide (Financial Times, 2025). At least one project includes a partial solution, such as CO_2 capture (DCMag, 2025c). Overall, power grids in southeastern US plan to add 20 GW of natural gas capacity, which could represent up to 80 $MtCO_2e$ of annual emissions without CCS[40] (Data Center Dynamics, 2025a).

The expansion of gas pipelines, along with the rise in investment and orders for gas turbines[41], illustrates a structural shift in upstream energy towards a revival of fossil projects, to support the scale-up of the digital sector (Data Center Dynamics, 2025c; IEA, 2025b).

Lastly, the company FirstEnergy has cancelled the planned closure of two coal-fired power plants, which it now intends to operate until 2035-2040 (Financial Times, 2024).

38 Energy efficiency improvements have already been slowing for some years (Figure 9).

39 While they allow for theoretical accounting of carbon emissions, PPAs (Power Purchase Agreements) used by some digital players, which involve investing in renewable energy projects in territories other than where they operate, do not physically supply their sites. They therefore do not simultaneously decarbonise the electricity they consume and the electricity "produced by those renewable sources for other customers."

40 Carbon Capture and Storage

41 Siemens Energy, the German energy equipment manufacturer, reported a record order book of nearly €136 billion in August, driven by growing US demand for gas turbines used in data centres (Financial Times, 2025).

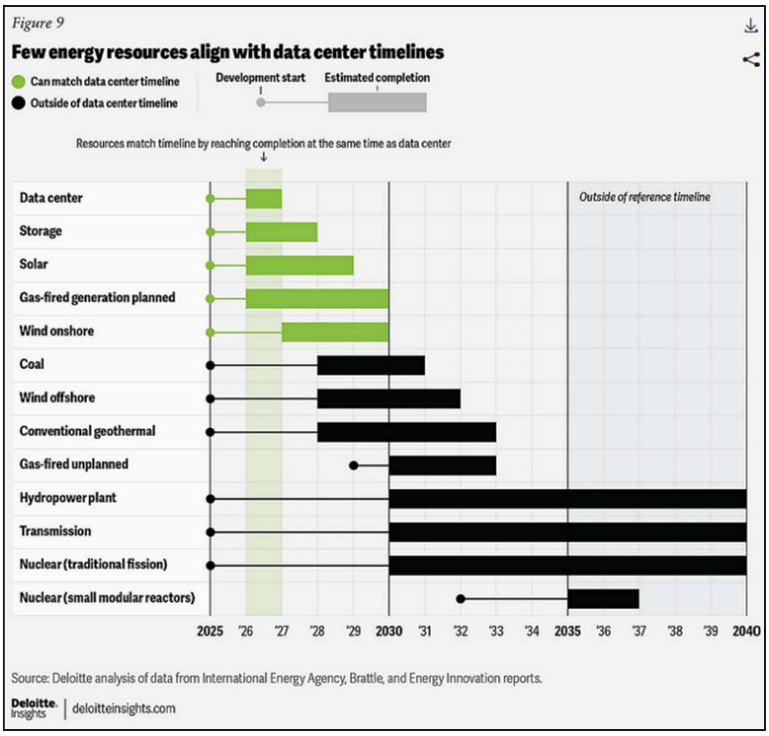


Figure 12 - Assessment of the compatibility of different types of energy resources with deployment timeframes in the data centre sector. Source: (Deloitte, 2025)

Figure 12 also highlights the gap between the immediate, rapidly growing demand from data centres (on a 1-2 year horizon) and the available energy capacities able to meet this pace: storage (batteries), solar, gas plants, and onshore wind. Ultimately, this new energy demand leads either to pre-empting low-carbon capacity that may already have been allocated for other purposes, or to deploying additional gas capacity.

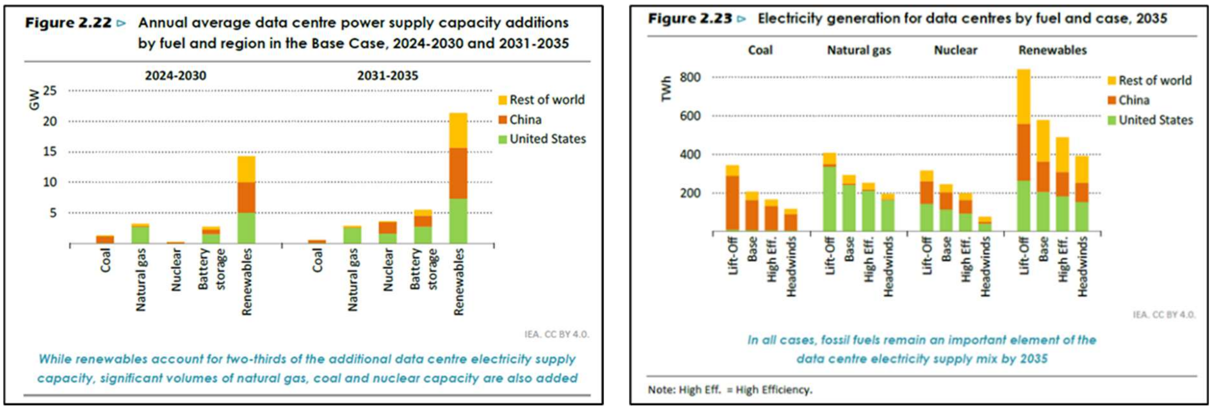


Figure 13 - Average annual addition of electricity generation capacity to supply data centres, by energy source, over the periods 2024–2030 and 2031–2035 (left), and electricity generation for data centres by energy source and by scenario in the four IEA scenarios in 2035 (right). Source : (IEA, 2025a)

According to the IEA, the current energy trend in the sector results each year in the addition of 3.3 GW of gas capacity and 1.5 GW of coal capacity (see Figure 13, left (IEA, 2025a). By 2030, 19 GW of gas power generation capacity for data centres could be brought into use in advanced economies, 95% of it in the United States, including 10-15 GW in Virginia by 2040 (IEA, 2025b).

Understanding the importance of the electricity mix:

What would Figure 14 look like if translated into greenhouse gas emissions instead of TWh? And if the chart were expressed in $MtCO_2e$, how would the bars be visually distorted?

To answer this question, it is important to bear in mind the orders of magnitude for electricity generation emission factors by energy source: around [800-1,000 gCO_2e/kWh] for a coal power plant, around [350-490 gCO_2e/kWh] for a gas plant, while low-carbon sources (nuclear, solar PV, wind, hydro, etc.) fall within the [10-60 gCO_2e/kWh] range - one to two orders of magnitude lower.

Using these electricity emission factors, in the “Lift-off” scenario the 800 TWh of renewables would generate 20 $MtCO_2e$ in the use phase, whereas the 725 TWh of fossil generation would emit 500 $MtCO_2e$.

Ultimately, looking at energy consumption out to 2035, a clear geo-energy split emerges (see Figure 13, right): the US relies on gas, while China relies on coal.

Far from serving as an incentive for efficiency, for the development of low-carbon products and services, or for moderating supply, energy scarcity is now perceived by the digital sector as a constraint to be bypassed (Data Center Frontier, 2025), **or even as an opportunity to expand its offering - placing the responsibility for the transition to decarbonisation onto energy systems, even though the sector itself could play a part in driving it.**

D. The carbon footprint of manufacturing across the value chain can no longer be overlooked

For a complete picture of the sector’s carbon footprint, beyond consumption in the use phase, it is important to account for the emissions generated during the construction of data centres (concrete, etc.) and the manufacturing of their components (servers, processors, power supply units, etc.).

Globally, **current estimates for data centres put the carbon footprint at roughly 75% from use and 25% from the embodied footprint**, based on data from (Schneider Electric, 2023)[42,43,44,45].

[42] In other words, the carbon footprint of manufacturing would represent about 35% of the use phase carbon footprint..

[43] See appendix 6 (The Shift Project, 2025a)) : This estimate comes from an analysis of scope 3 for a hypothetical 1 MW data centre (1 MW; 50% load factor; 6 kW per rack; PUE of 1.34; electricity emission factor of 0.511 $kgCO_2e/kWh$; 5 tCO_2e/kW of embedded IT footprint; 94% storage servers and 6% networking equipment, populated at 50%), presented in the “Quantifying Data Center Scope 3 GHG Emissions to Prioritize Reduction Efforts” (Schneider Electric, 2023). Schneider also provides an online simulator to vary these parameters: https://www.se.com/ww/en/work/solutions/system/s1/data-center-and-network-systems/trade-off-tools/data-center-lifecycle-co2e-calculator/. This 35% ratio is based on a 15-year lifespan under the climate change indicator. The building is included. The method consists of starting from the scope 3 carbon footprint of a data centre, subtracting employee commuting, business travel, fuels and energy-related activities, to obtain the embedded carbon footprint of the data centre. This is then compared with its scope 2, on a location-based basis, linked to its use phase.

[44] This breakdown can be compared with that of (Malmodin J. et al., 2023) (p. 9), which estimates 69% of the carbon footprint in the use phase and 31% for manufacturing.

[45] This breakdown can be compared with that of (Boavizta, 2021b) for Europe: 20% for manufacturing versus 80% for the use phase in Europe (based on the 2017 assumption of a European electricity mix carbon intensity of 420 gCO_2e/kWh). This breakdown can be compared with that of (Boavizta, 2021b) for France: 45% for manufacturing versus 55% for the use phase in Europe (based on the 2020 assumption of a European electricity mix carbon intensity of 60 gCO_2e/kWh).These breakdowns show that the indicator reflects the carbon intensity of electricity, and will therefore vary in scenarios that include energy decarbonisation.

It is worth noting that this breakdown of the carbon footprint between use phase and embodied emissions (manufacturing, etc.) reflects the carbon intensity of the energy consumed in use. This implies that in scenarios where energy is decarbonised but equipment manufacturing is not decarbonised to the same extent, the manufacturing share becomes predominant.

For a data centre[46], within its embodied carbon footprint, the IT share (servers, electronic components, etc.) is significant compared with infrastructure management (data centre construction, batteries, etc.): around 75-80% (Figure 14).

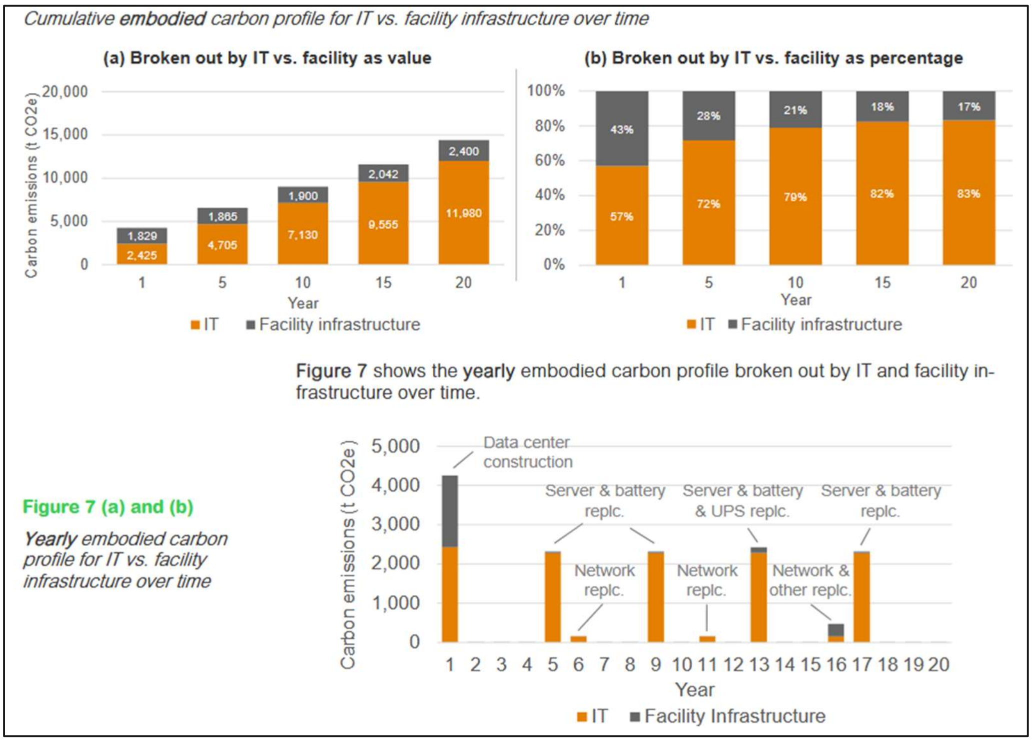


Figure 14 – In the embodied carbon footprint of a data centre, breakdown between infrastructure and IT: shown as cumulative absolute values, as proportions, and with an annual breakdown. Source: (Schneider Electric, 2023)

Next, for processors, globally and at present - this time looking at the energy indicator - **the estimated breakdown of energy consumption is as follows: 80% from use and 20% from manufacturing** (Figure 15) (IEA, 2025a) based on (Boavizta, 2021a; Dell, 2019; Garcia Bardon, M., 2021).

For servers, a few estimation attempts have been made (see Appendix 6, The Shift Project, 2025a) although clearly identifying the share of electronic components - and even integrated circuits - in the embodied carbon of manufacturing IT equipment for a data centre remains a challenging exercise[47] :

[46] For the same model data centre as in footnote 38 above.

[47] The problem lies in a lack of scientific rigour in the available data, which prevents any attempt at reproducibility: unclear scope, unreported methodology and emissions factor database, results left unexplained, no uncertainty ranges, etc.

- According to the Boavizta calculator (Boavizta, 2021b)[48], components with a high density of electronic chips (RAM, CPU, and SSD) can, depending on server configuration, account for between 75% and 95% of the manufacturing footprint, not including AI components;
- Based on available server PCFs[49] that include, at a minimum, a breakdown of the carbon footprint by component[50], the motherboard, expansion cards, and SSD together account for between 70% and 90% of the manufacturing footprint, again excluding AI components.
- From the PCF of the NVIDIA HGX H100 board with 8 GPUs (Nvidia, 2025), and this time including AI components, memory and integrated circuits account for around 70% of the manufacturing footprint[51].

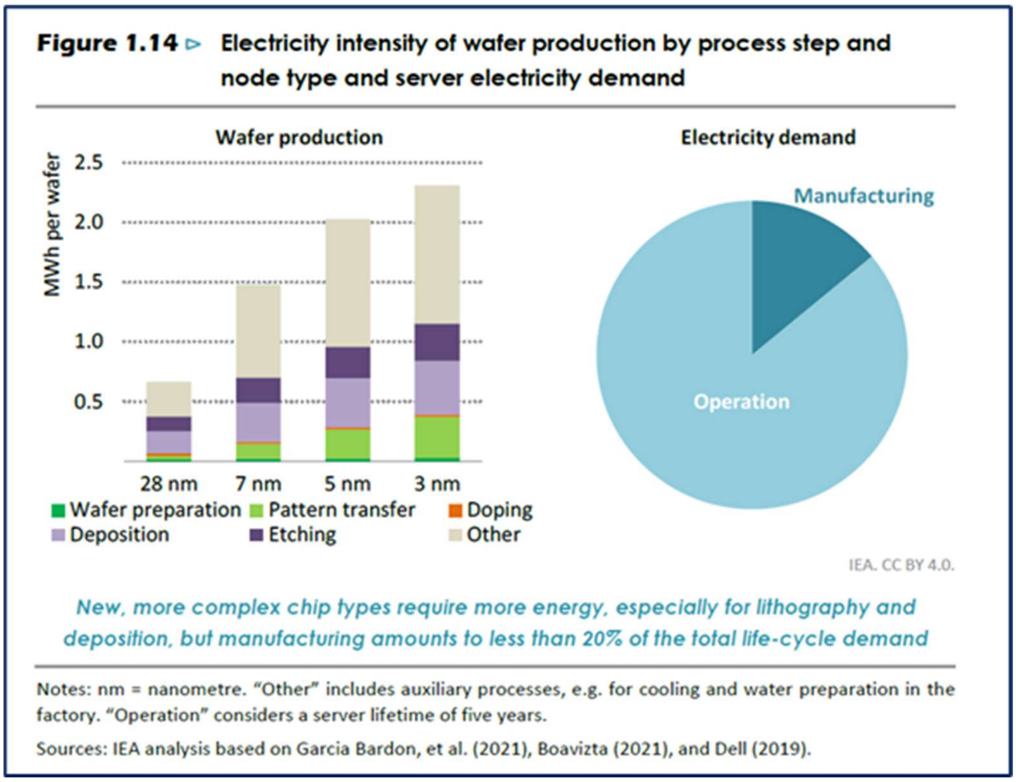


Figure 15 - Energy used in processor manufacturing: share and possible trends.
Source: (IEA, 2025a)

As for the future trajectory of the embodied carbon footprint, a data centre dedicated to computing relies on servers with numerous and diverse electronic components: according to ADEME, more than 50 metals are used in the composition of digital equipment (ADEME, 2024c). Since each component involves specific manufacturing processes and raw materials[52], this multiplies the factors likely to cause their embodied carbon footprint to vary - either upwards or downwards (see Table 1 and the table at the end of the (Roussilhe G., 2025) article).

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[48] Based on a public methodology itself drawing on data from the (Agence fédérale allemande pour l'environnement, 2021)(Agence fédérale allemande pour l'environnement = German Environment Agency = Umweltbundesamt)

[49] Product Carbon Footprint

[50] 4 HPE Proliant servers (see Appendix 6 (The Shift Project, 2025a))

[51] Compared with a server, a GPU board contains large cooling components that on their own account for 73% of the remaining 30% of the manufacturing carbon footprint. Somewhat counter-intuitively, adding GPUs to a server could reduce the relative share of the carbon footprint attributable to integrated circuits.

[52] In a 2024 study, ADEME reported the presence of more than 50 metals in digital devices (ADEME, 2024c).

In particular, the reduction in technology node size[53] leads to higher greenhouse gas emissions, and increased primary energy and water consumption per cm² (Figure 15[54], Figure 16).

If combined with projections of wafer demand[55], corroborated by the historical trend in total die area produced, this would outline a trajectory of increasing carbon footprint from the manufacturing of computing infrastructure - another way of assessing the rise in absolute global impacts from manufacturing electronic components for AI (industriAll Europe, 2025; Roussilhe G., 2025; SemiAnalysis, 2022).

However, the complexity of the value chain and the way the industry operates make it difficult to project the sector's future footprint, even though such estimates would be useful for forecasting trends in the carbon impact of data centres. This footprint will depend in particular on the carbon intensity of raw material extraction, the pace of decarbonisation across supply chains, and the chip specifications adopted (die area, node size, transistor density, etc.) (see Table 1).

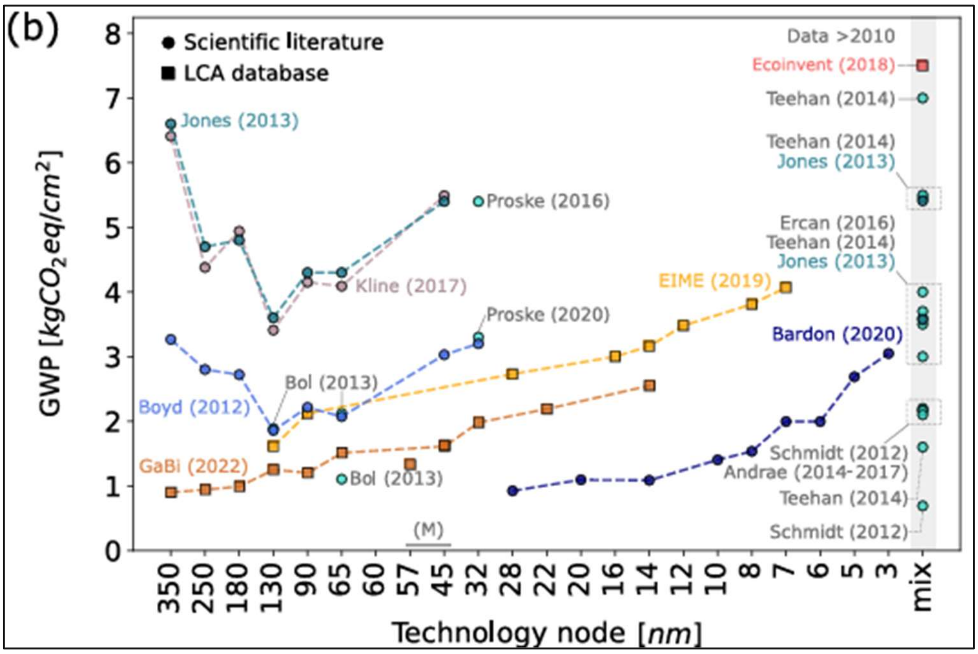

Figure 16 - Change in the production carbon footprint of a printed circuit according to technological node size, historical trends, Source: (Pirson T., 2022)

This review of the embedded carbon footprint makes it possible to draw several conclusions:

- The balance between the use phase and manufacturing must always be considered in relation to the carbon intensity of energy and its decarbonisation trajectory; as this advances, manufacturing accounts for an increasing share.

[53] A technology node, measured in nanometres (nm), refers to a generation of semiconductor manufacturing. It is associated with transistor size and density.

[54] When expressed per unit of die surface (the die surface being the area, often in cm², of the piece of silicon wafer that is processed to form the main element of an integrated circuit or electronic chip), the trend in GHG emissions appears to increase as node size falls below 130 nm (Figure 16).

[55] A semiconductor wafer (silicon in particular) used in electronics.

- Given current trends (such as the reduction in node size) and the absence of a clear decarbonisation strategy, a favourable trajectory for the manufacturing footprint (per FLOP, per hardware unit, or per data centre) remains uncertain.
- Strategies that reduce the embodied carbon of manufacturing should focus on electronic components (memory, processors, AI accelerators, etc.), which often represent more than 70% of the total, as well as on data centres (lifetime, replacement rates, and asset management), and even across the sector as a whole (end-of-life, recycling, etc.).
- Improving the quality of data on manufacturing impacts (reliability, transparency, reproducibility, etc.) is still a prerequisite for effective decarbonisation strategies.

Area	Factor	Trend	Comment
Raw materials	Deposit concentration	Increase	The more a deposit is exploited, the more it becomes depleted, and the more energy is required to extract the same quantity of metal.
Raw materials	Optimisation or efficiency of extraction processes	Decline	
Raw materials	Use of recycled materials	Increase or decline	The use of recycled materials is encouraged in order to limit reliance on extraction. However, recycled materials are not always less carbon-intensive than primary materials: this can depend on the recycling process, the quality of the feedstock available for recycling, and other factors.
Raw materials	Level of purity	Increase	The required level of purity depends on the desired physical properties. In general, the higher the level of purity, the greater the amount of energy needed.
Manufacturing process	Physical characteristics of the chip	Increase or decline	Technological advances, chip architectures, transistor density, etc.
Manufacturing process	Carbon intensity of energy	Decline	As transport systems are decarbonised, the emissions linked to chip manufacturing are expected to decline.
Manufacturing process	Threshold and scale effects	Decline	When expressed per unit produced, the carbon footprint of manufacturing decreases as the number of units produced increases
Assembly process	Carbon intensity of energy	Decline	For example, the components required to assemble digital equipment may be sourced from far afield. With the decarbonisation of transport, the emissions associated with chip manufacturing are therefore expected to decline. One can also point to the decarbonisation of the electricity mix at the assembly location.
Assembly process	Threshold and scale effects	Decline	Same as above
Transport	Carbon intensity of transport modes	Decline	With the decarbonisation of transport, the emissions associated with chip manufacturing are expected to decline.
Transport	Distance travelled	Increase or decline	The longer and more frequent the journeys, the more energy they require.

Table 1 - Minimum set of factors to examine when assessing changes in the carbon footprint of data centre manufacturing.

VI. Accelerated servers and generative AI: key drivers of the data centre sector

While data centres are used for a **wide range of purposes** (website hosting, cloud services, video-on-demand, online gaming, social networks, storage, and enterprise data processing), from 2015 they also began to be deployed for the first professional applications of so-called **"trad AI"** (image processing, machine translation, and recommendation engines). Then, at the end of 2022, came the emergence of generative AI (**"Gen AI"**) for general use, followed by the progressive rise of **agentic AI**.

The purpose of this section is to analyse the contribution of AI, and in particular generative artificial intelligence, to the increase in energy demand and greenhouse gas emissions from data centres worldwide.

Figure 17 brings together several existing projections[56] of estimated electricity consumption by artificial intelligence[57]. When set against projections of total electricity consumption across all data centre uses, they highlight two notable points:

- **A noticeable share of artificial intelligence in overall data centre uses by 2025** (around 15 %[58]);
- **A major rise in this share by 2030** (around 55 %[59]).

This shift in AI's share of total data centre use (from 15% to 55% in five years), and the absolute scale of its contribution (880 TWh for AI in 2030) (Schneider Electric, 2024) calls for closer examination of the main drivers of AI's energy impact, through two lenses: the "usage effect" and the "supply effect" (see Figure 1):

- **Estimate of available computing *supply***: an approach based on the total computing capacity provided by all AI accelerators in stock to assess the impacts of artificial intelligence[60]: presented in the section "Estimating energy-carbon trends based on computing capacity and accelerated server trends.
- **Estimate of *demand* for AI applications**: an approach based on the volume of training and inference models to assess the impacts[61]: presented in Section **Erreur ! Source du renvoi introuvable.** "Forward-looking scenarios based on AI applications".

The computing supply approach enables an assessment of **accelerated servers - the factor identified by the IEA in its "Base" scenario as accounting for 50% of the increase in electricity consumption**

56 Projections from academic and non-academic publications, whose methodologies have limitations discussed later in the report.

57 This refers only to consumption linked to AI, not to the total consumption of data centres and their uses.

58 Electricity consumption from AI uses in 2025 is estimated by (Schneider Electric, 2024) at 100 TWh, and total data centre consumption at 500 TWh by the IEA in its "Base" scenario (IEA, 2025a) excluding roughly 150 TWh for cryptocurrencies.

59 Electricity consumption from AI uses in 2030 is estimated at 880 TWh by (Schneider Electric, 2024) in its "Abundance" scenario, and total data centre consumption at 1,260 TWh by the IEA in its "Lift-off" scenario (IEA, 2025a) to which about 300 TWh for cryptocurrencies must be added.

60 This approach carries a source of underestimation: some inference tasks may not be performed on accelerated servers, but instead on other types of servers, or directly on computers or smartphones. There is also a source of overestimation: accelerated servers are also used for high-performance scientific computing, not only for artificial intelligence.

61 This is the approach used by (Schneider Electric, 2024) to build its various scenarios, while also distinguishing between different applications of artificial intelligence.

between 2025 and 2030 (Figure 18). In addition, the impact of accelerated servers is also highlighted in the IEA's comparison between the "Base" and "Lift-off" scenarios.

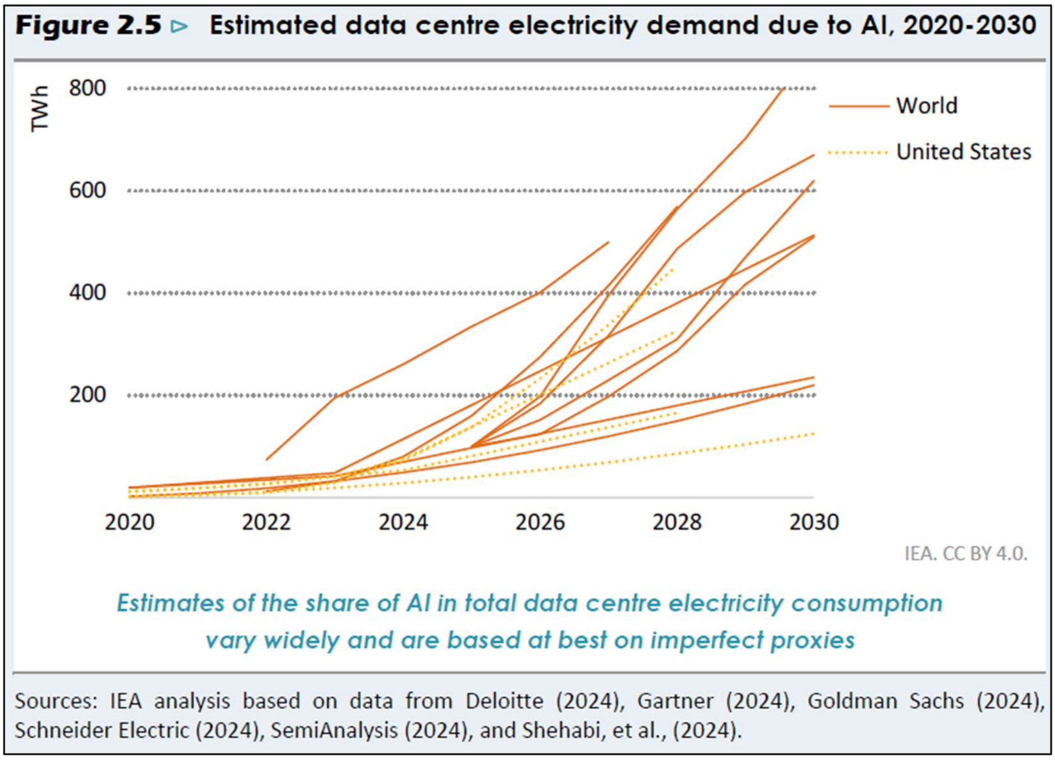

Figure 17 - Estimates of global electricity demand from data centres driven by AI. Source: (IEA, 2025a) based on (Deloitte, 2024; Goldman Sachs, 2024; LBNL et al., 2024; Schneider Electric, 2024)

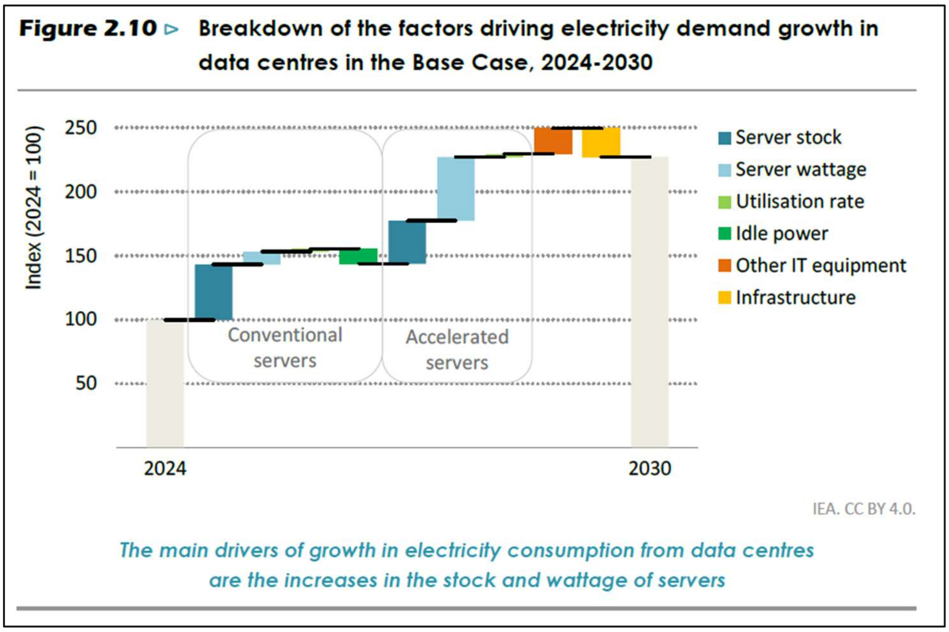

Figure 18 - Drivers of global data centre electricity demand (Base scenario). Source: (IEA, 2025a)

A. Estimating energy-carbon trends based on computing capacity and accelerated server trends

Taking a bottom-up approach from the infrastructure side - that is, the number of AI accelerators[62] in stock and the likely evolution of their technical characteristics - we developed a projection to 2030 showing:

- **Electricity consumption of 774 TWh**: compared with 1,480 TWh for all data centres (Figure 10)[63], accounting for 49%.
- **Greenhouse gas emissions of 255 $MtCO_2e$**: compared with 600 $MtCO_2e$ for all data centres (Figure 2), accounting for 43%[64].

This approach, described in detail in Appendix 6 (The Shift Project, 2025a), is highly sensitive to:

- The projected number of AI accelerators in 2025 and their growth by 2030, based on extrapolating the trends of the past 5 years in total computing power available for Nvidia: 9 million AI accelerators in 2025 (Epoch AI, 2025) and 61 million in 2030 (our estimate, see Appendix 7 (The Shift Project, 2025a));
- Trends in the energy efficiency of AI accelerators (Epoch AI, 2024).

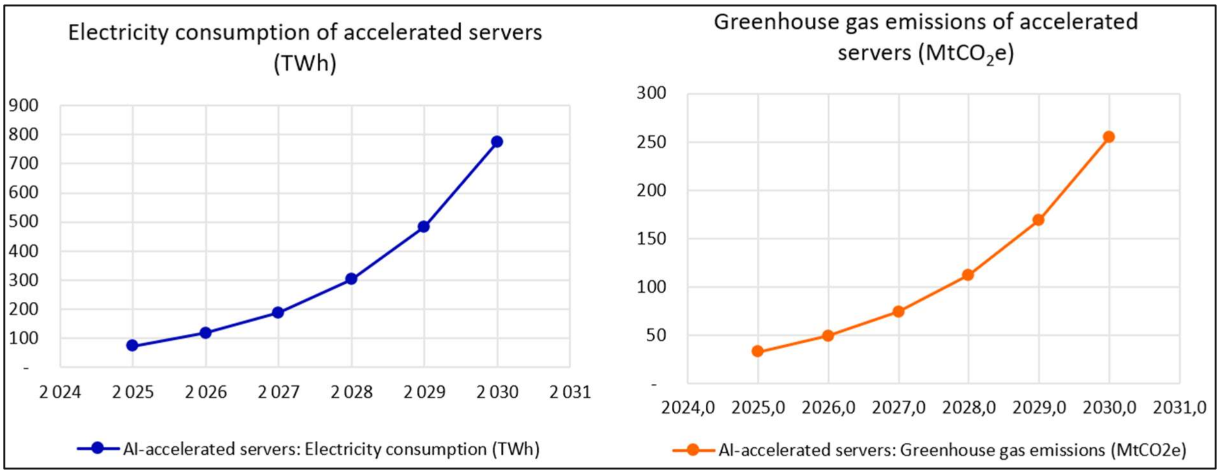

Figure 19 - Global electricity consumption and global greenhouse gas emissions for all accelerated servers (TWh and $MtCO_2e$) Source: (The Shift Project, 2025a)

[62] Specialised components that make model training much faster, such as GPUs. Servers equipped with these accelerators are referred to as accelerated servers.

[63] In the exploratory scenario of undifferentiated deployment of computing capacity and its widespread adoption.

[64] At this stage, the manufacturing-to-use carbon footprint ratio in this calculation is about 6% lower than the usual orders of magnitude of around 25–35% (see "The carbon footprint of manufacturing across the value chain can no longer be overlooked"). In this calculation, the share of data centre infrastructure compared with accelerated servers is not included, which may explain part of the gap. Another factor may be the electricity intensity of the activity and the high material efficiency of accelerated servers, based here on a 67% utilisation rate and a six-year lifetime. This point will require further investigation in the future.

Technological improvements are therefore taken into account, but potential supply issues for AI accelerators are not considered - an important point given the production challenges faced by TSMC, the main supplier of Nvidia and Google for AI GPUs and TPUs (de Vries-Gao A., 2025).

Thus, the main factors shaping the impact of AI when viewed through the lens of accelerated servers are:

- The speed at which new generations of AI accelerators are introduced
- The rate at which AI accelerators are replaced
- The lifespan of an AI accelerator
- Gains in computing performance with each new generation of AI accelerators
- Gains in energy efficiency with each new generation of AI accelerators
- The effective utilisation rate of AI accelerators (which may differ between training and inference phases, and depending on whether they are used privately by AI service developers or deployed through a public cloud).
- The environmental performance of AI data centers, including their location and the carbon intensity of the electricity they use.

B. Forward-looking scenarios based on AI applications

In its 2024 "Artificial Intelligence and Electricity: A System Dynamics Approach" report, Schneider Electric presents an alternative method for estimating the energy consumption of the global AI system. This systemic model also follows a bottom-up approach, but instead uses expected AI applications (the number of inferences and the number of models trained per year) as input variables, and seeks to translate these usage needs into the accelerator infrastructure required to meet them.

Similarly, the two approaches (this one, developed by Schneider Electric, and the supply-side method developed for this report by The Shift Project) can be compared over an equivalent scope:

- The supply-based approach examines the impacts that would be generated if all available infrastructure were used.
- The usage-based approach examines the impacts that would be generated if all expected uses were fully deployed in new infrastructure.

In its approach, Schneider Electric presents four scenarios for how energy consumption could evolve by 2030 and 2035 (Schneider Electric, 2024) :

- "Sustainable AI" scenario: measured growth of AI, where technological progress is balanced with the management of energy resources, with AI data centres installed on renewable energy systems.
- "Limits to Growth" scenario: AI development is limited by energy and demand constraints. Energy availability, the production capacity of AI accelerators, the depletion of training data, costs, and lack of return on investment lead to slower, more controlled growth.
- "Abundance Without Boundaries" scenario: strong, unrestrained growth of AI, where efficiency improvements trigger rebound effects, driving increased use and, in turn, higher overall energy consumption.

- “Energy Crunch” scenario: overly rapid expansion of AI that outpaces available energy capacity, creating imbalances, local shortages and a wider energy crisis, requiring regulatory intervention and improved energy planning.

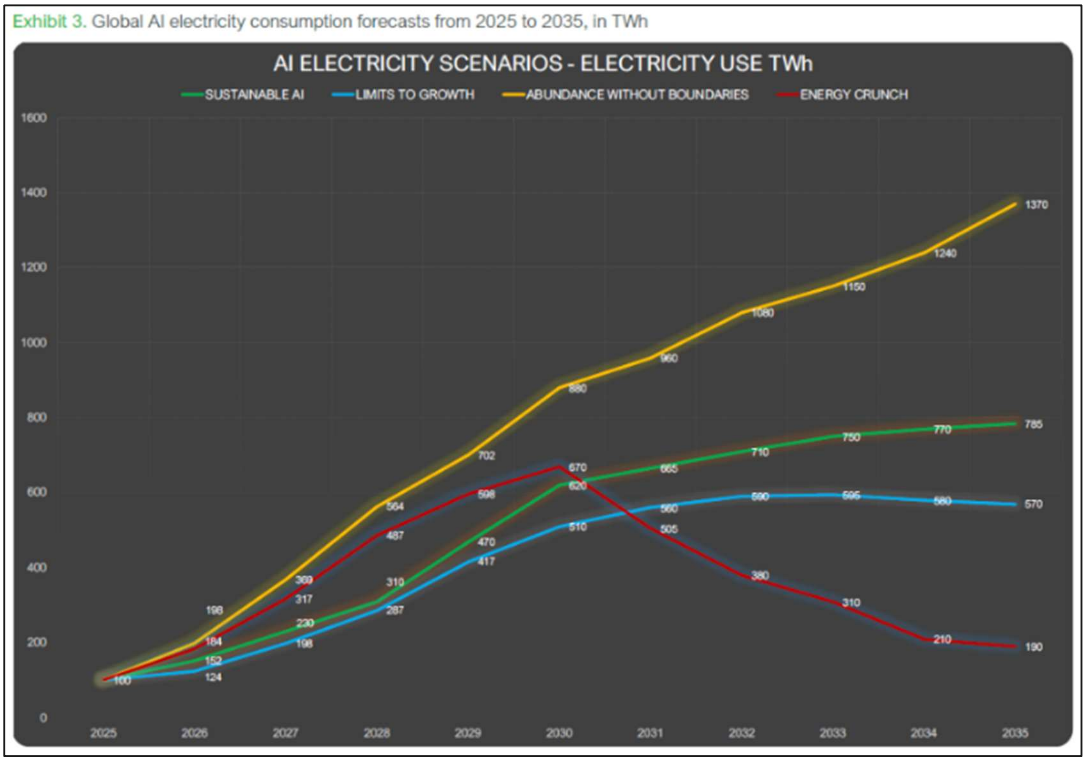

Figure 20 - Global electricity consumption for AI uses (TWh) across four forward-looking scenarios: “Sustainable AI”, “Limits to growth”, “Abundance without boundaries”, “Energy crunch”.
Source: (Schneider Electric, 2024)

By taking the « Sustainable AI » and « Abundance Without Boundaries » scenarios as references:

- **In 2025, AI electricity consumption amounts to 100 TWh** (Figure 20), comparable with the 77 TWh in our estimate (Figure 19),
- **In 2030, electricity consumption amounts to between 620 TWh and 880 TWh** (Figure 20), bracketing our estimate of 774 TWh (Figure 19).Compared with 1,480 TWh[65] for all data centres, this would account for 40% to 60%.

[65] For all data centres (Figure 10) under the exploratory scenario of undifferentiated deployment of computing capacity and its widespread adoption.

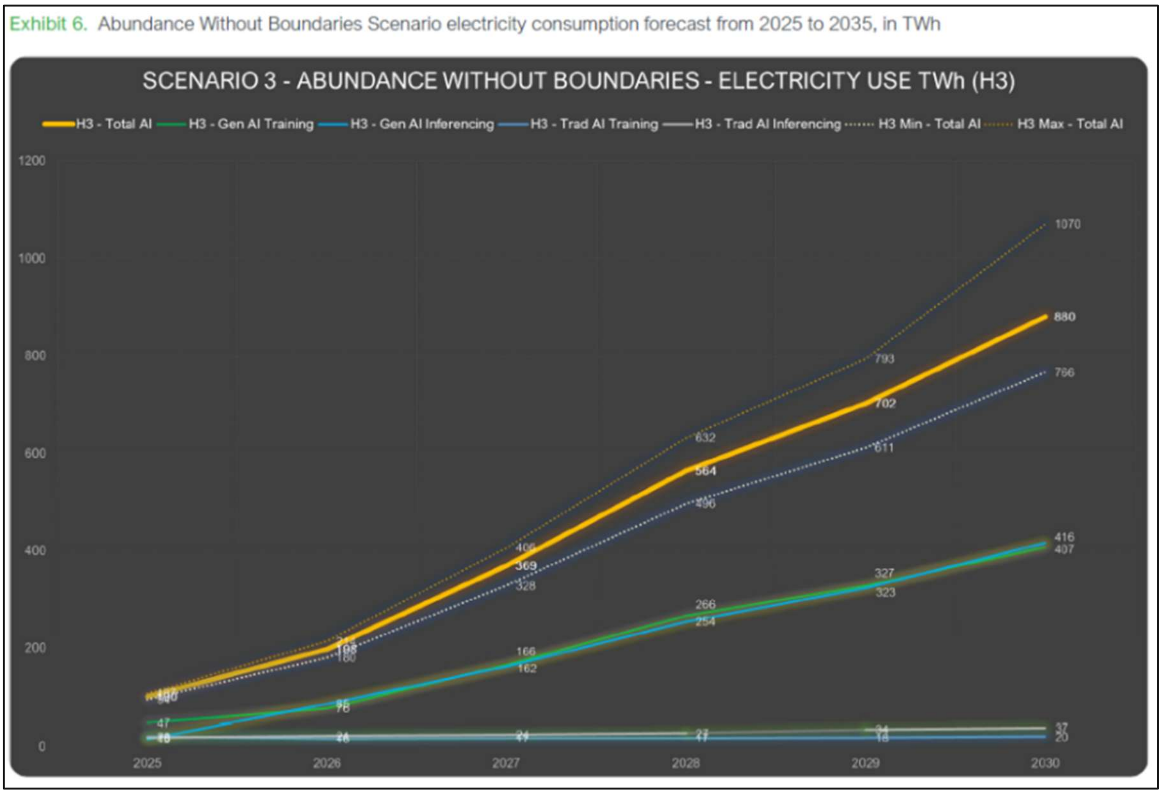

Figure 21 - Electricity consumption by AI use ("Trad AI" vs "Gen AI") and by phase (training and inference) (TWh). Source: (Schneider Electric, 2024)

This analysis separates the energy use of traditional AI from that of generative AI. While the consumption linked to traditional AI remains broadly stable between 2025 and 2030, the consumption from training and inference in generative AI each rises tenfold, making them almost entirely responsible for the increase in AI's overall energy use.

In 2025, 38% of AI electricity consumption is from traditional AI, but by 2030 this drops to just 6%.

Conversely, in 2025, 62% of AI electricity consumption will be related to GenAI, rising to 94% in 2030, with 47 points attributable to the inference phase.

C. The growth of the data centre sector is now largely driven by generative AI

The different approaches confirm several key conclusions:

- Data centre energy consumption is rising at a particularly rapid pace, driven by AI (Figure 20) ;
- Within AI uses, generative AI in particular will be the main factor shaping the rise in energy demand over the coming years (Figure 21) ;

- Between 2025 and 2030, under the "lift-off" and "abundance" scenarios, and assuming current trends in computing power continue, at least 700 TWh would be added worldwide[66].

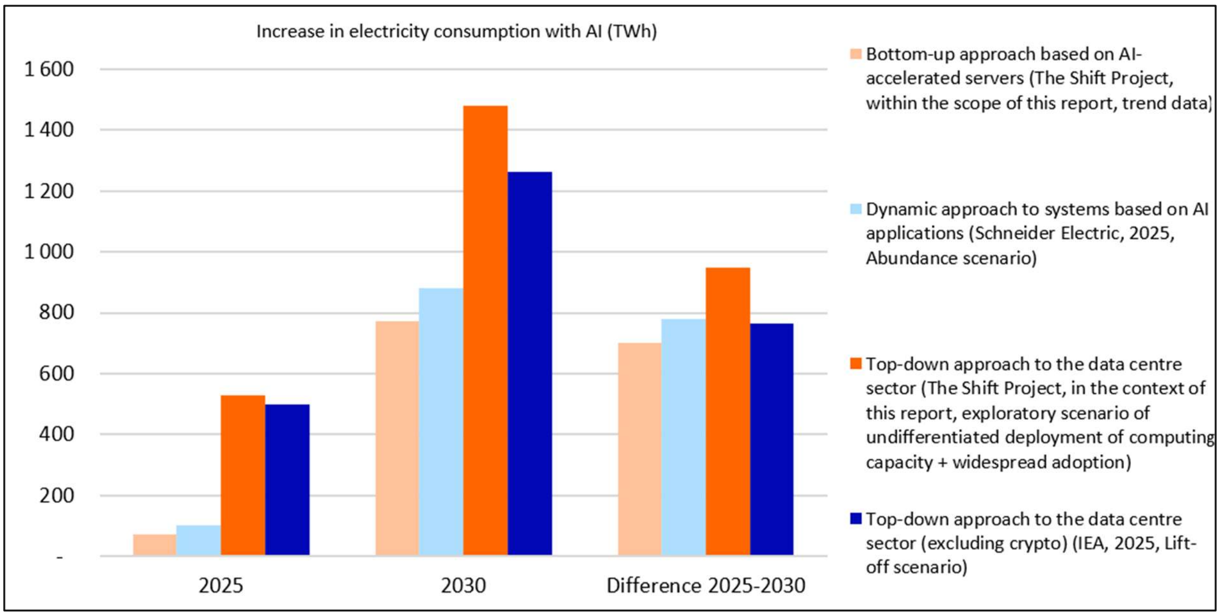

Figure 22 - Increase in electricity consumption with AI between 2025 and 2030 (TWh). Source: (IEA, 2025a; Schneider Electric, 2024; The Shift Project, 2025b)

VII. .... Beyond data centres: early signs from devices and networks?

Data centres are not the only part of the digital system affected by the consequences of artificial intelligence: the other two thirds are also affected, but less directly and, for the time being, less quantifiably.

The impacts of AI on devices and networks can be described through a "consequential" approach: what new system sizes and technical specifications in digital infrastructure will be generated and driven by the deployment of AI services? This approach has the advantage of examining the issue from the perspective of application, service and usage roll-out (the usage effect), while linking these to the infrastructure projections that are meant to support them (the supply effect) (see Figure 1).

In the same way that these studies look at the effects of AI deployment on the distribution of computing capacity (edge or centralised) or on the large-scale configuration of data centres, **"consequential" approaches help to identify and shed light on the possible effects on device capacities or network specifications that AI may call for in the medium to long term.**

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[66] In Figure 23, only the top-down approach for the data centre sector (Figure 11) produces a result of around 900 TWh. It is the only scenario that also factors in a continued trend-based deployment of cryptocurrencies (see Trends in data centres are pushing use phase electricity consumption onto an uncapped trajectory").

A. What impacts will AI have on devices?

As devices are the preferred tools for human interaction with digital technology, they play a significant role in the supply effect.

The move to offer local, embedded, and offline[67] AI services, together with greater local capacity, could accelerate the **obsolescence** and **replacement of devices** (whether driven by marketing, technology, psychology, etc.)[68] offsetting attempts to extend their lifespan[69]. The technological intensification of certain devices - in terms of capacity and complexity - could also **increase their carbon footprint from manufacturing,** undermining efforts to achieve **energy efficiency gains (during use) and in production processes.**

The usage effect brings to light both **indirect impacts** (for example, the rise in the number of inferences once an interface becomes more accessible) and **lock-in effects** (the creation of dependency on AI-based technologies once adopted, and the difficulty of moving away from them once AI solutions are embedded in the essential activities of an organisation or of society).

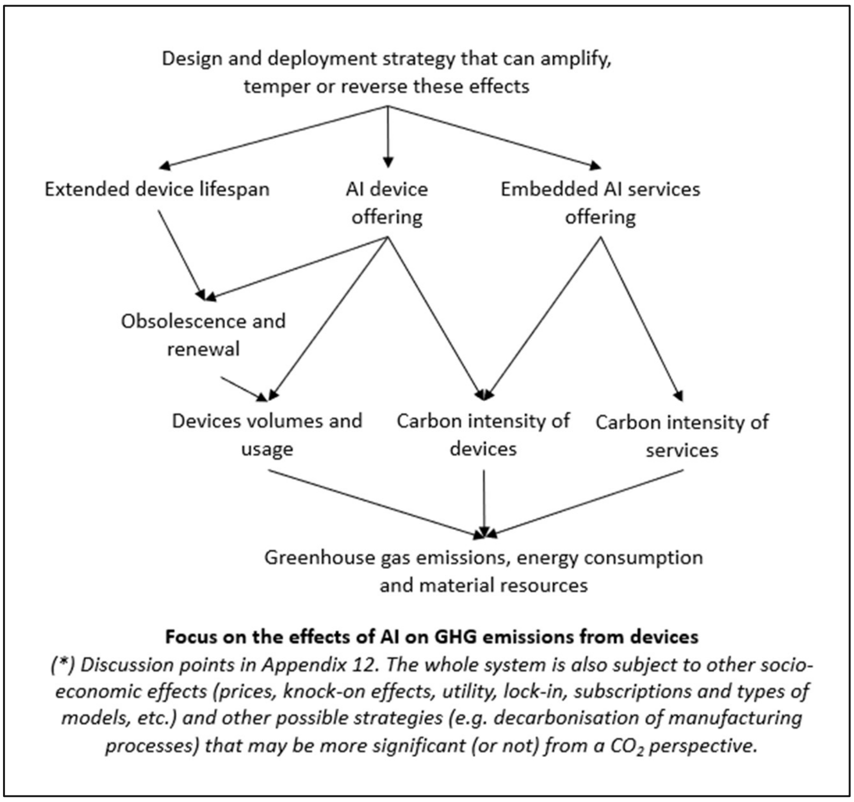


Figure 23 - Simplified overview of the different effects and impacts of AI on devices. See Appendix 12. Source: (The Shift Project, 2025b)

[67] Even though, to date, most AI services are hosted in data centres.

[68] A similar question arises with 5G. As of now, in France, out of 83.8 million SIM cards in service, 24.3 million are active on 5G networks (Arcep, Arcom, 2025).

[69] This finding does not apply to a comparative analysis between remote and embedded computing. An analysis of this kind would require a dedicated carbon comparison and potentially consideration of other externalities, such as the fact that embedded computing can improve efficiency while reducing dependence on cloud services – a dependence that costs the EU €264 billion a year (even though other strategies could help reduce this €264 billion bill) (Asterès & Cigref, 2025).

Over time, the production volumes of AI-enabled devices could increase, leading to lower prices and, in turn, faster growth in demand and AI use. This positive feedback loop, amplified by the wide availability of free or low-cost AI services, needs to be identified if its trajectory and its energy and climate impacts are to be kept in check - although pricing could eventually rebalance the trend through monetisation strategies for services and equipment (once the market is captive). Without a short-term shift in approach, certain AI needs are likely to become established, creating a captive market, which would raise the difficulty and cost of scaling back in the future.

For an organisation (company, IT department, laboratory, government, etc.), managing these impacts requires creating indicators to measure and monitor obsolescence effects, as well as supply and demand for computing power, in order to manage the **fleet management effect**, i.e. to **reconcile *seemingly* opposing strategies of extending the lifespan of devices and rolling out, at scale, services that demand ever greater computing capacity.**

B. What impacts will AI have on networks?

Analysis and projections of network traffic trends show that the current upward trend driven by video streaming (+30% per year from 2020 to 2024 (Ericsson, 2025)) is expected to continue, with volumes in 2033 projected to be between 5 and 9 times higher than in 2023 (Nokia, 2024) (see Appendix 13 (The Shift Project, 2025a)). An approach that separates direct AI traffic from indirect AI traffic suggests that growth is expected to be driven primarily by **indirect AI traffic, linked to the large-scale creation of hyper-personalised content** (see Figure 24) (Ericsson, 2024; Nokia, 2024).

However, some nuances must be considered: these studies are produced by players whose commercial interests are linked to increased traffic, and they do not take into account either the adaptations and improvements that may be introduced in the future or changes in usage patterns.

In addition, Arcep also identifies that “training AI models requires very high-bandwidth, low-latency interconnections between data centres, making the network a determining factor performance” (Arcep, 2025).

At this stage, we can only suggest that a number of issues be addressed in greater depth:

- Today, AI-related traffic (direct or indirect) needs to be monitored using public and accessible data;
- The indirect effects of recommendation algorithms (and therefore of AI) on traffic and networks need to be better documented;
- Could AI and digital technologies in highly decentralised applications, for example, give rise to further network expansion - or not?

Among the many applications related to AI, several could place significant demands on networks, particularly mobile networks:

- in geographical coverage (connectivity requirements for autonomous actuators in rural areas, for example);
- in latency (high responsiveness requirements for mobility applications, for example);

- in upstream traffic[70] (sending traffic to increased AI services).

The effects of these service proposals must be documented systematically, for each usage case, in a comprehensive and systematic manner, in order to understand and predict their impact on infrastructure.

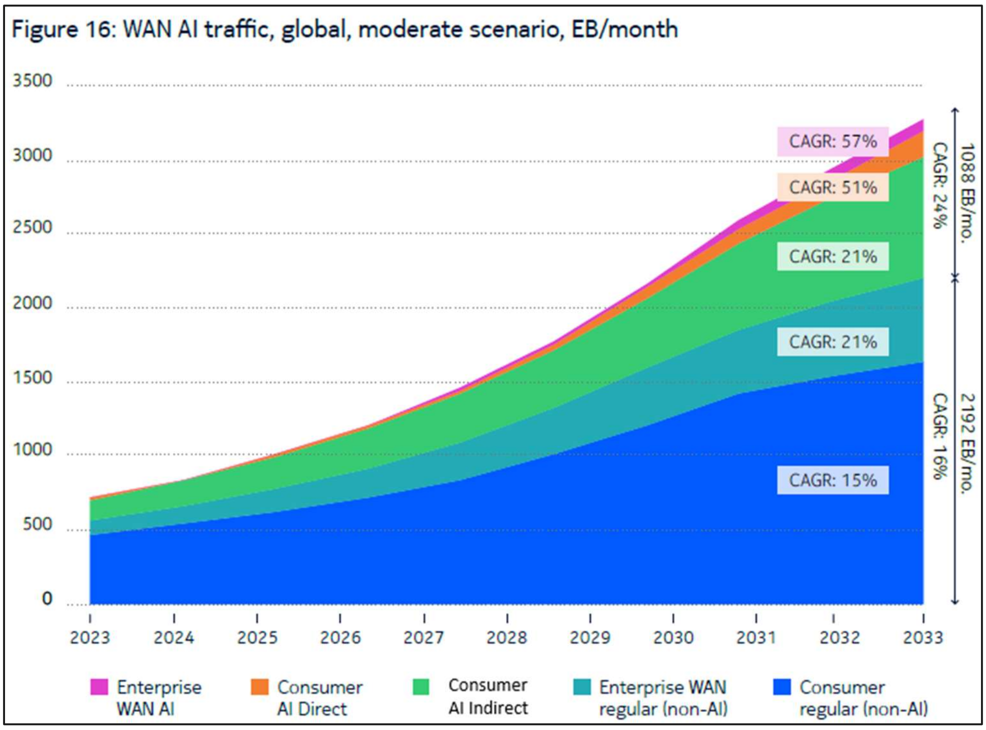


Figure 24 - Projected internet traffic in 2033 according to Nokia in its "moderate" scenario, broken down into direct AI traffic (traffic directly attributable to a product or service explicitly associated with AI) and indirect AI traffic (traffic generated by the use of AI products or services). Source: (Nokia, 2024)

[70] Whereas today network architecture, mainly mobile, is designed for more downstream than upstream traffic.

Chapter 2

Climate and energy trajectories of data centres in France and Europe: steer or endure?

While the previous chapter described global dynamics shaping the data centre sector and set out their climate consequences, **this chapter explores their practical implications for France and Europe, both in terms of climate and energy.**

The reliance of the US on gas to power its data centres (see "The data centre sector is increasing reliance on fossil-based infrastructure") and the case of Ireland with which we begin this section, illustrate the **growing pressure exerted by digital technologies** - and artificial intelligence in particular - **on electricity systems and the energy transition**. Understanding current and future levels of digital energy consumption, especially that of data centres, will be a prerequisite for developing energy plans consistent with climate goals and, ultimately, for ensuring the success of the energy transition.

VIII. Data centres in Europe: contrasting situations today, but a common trend

At the EU level, it is useful both to observe what is happening in other countries - in particular the alignment between different policies (fiscal, commercial, industrial, digital, climate, energy, etc.) - and to manage energy consumption and greenhouse gas emissions across the region.

A. The Irish case illustrates the pressure that data centres exert on electricity systems and the energy transition.

Ireland has positioned itself as one of Europe's digital leaders, with highly proactive policies (particularly fiscal) to attract investment. In recent years, major challenges have emerged around expanding electricity infrastructure to support the rapid growth of data centre deployment while staying on track with the country's carbon targets and maintaining the supply-demand balance of the grid.

Excluding data centres, electricity demand in Ireland has remained relatively stable in recent years. When data centres are included, demand rose by 24.7% between 2012 and 2022 (shown in orange, Figure 25).

According to Ireland's national energy authority (SEAI), data centres already account for more than 20% of electricity use, exceeding that of urban residential areas. In just eight years, data centre consumption has matched industrial consumption (Central Statistics Office (CSO), 2024; The Journal, 2024).

Some projections suggest that the data centre sector could reach around 30% of the country's total electricity consumption by 2028, and could become the largest electricity user under certain scenarios, exceeding the industrial and services sectors within a few years (IEA, 2024a; Prof. Hannah Daly, University College Cork, 2024).

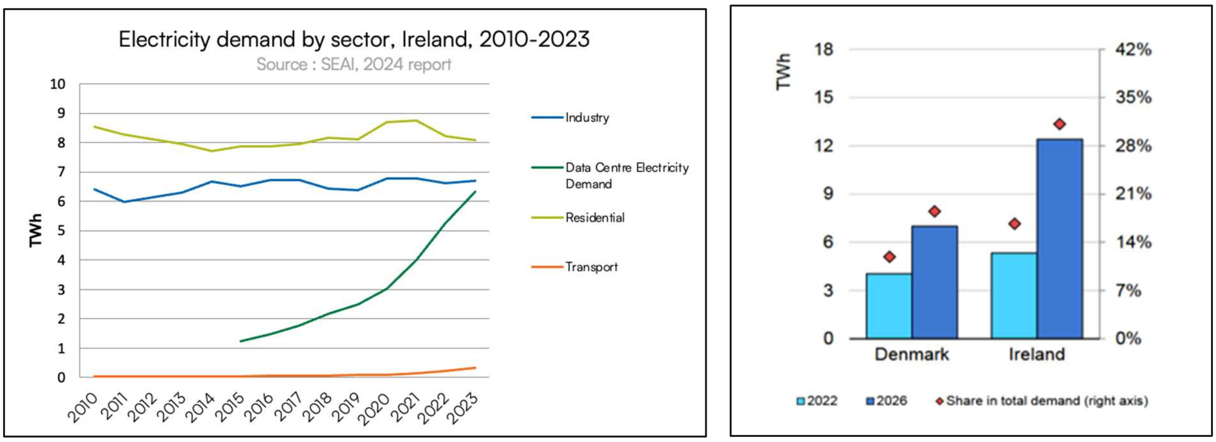


Figure 25 - Electricity demand by sector in Ireland between 1990 and 2023 (left). Source: (SEAI, 2024) and estimate of data centre electricity consumption and its share of total electricity demand in Ireland. Source: (IEA, 2024a)

The development of low-carbon electricity capacity in Ireland, initially planned to support the development of the overall energy mix, was designed in a context of moderate growth in electricity demand from data centres. In practice, planning has proved insufficient to meet the growth in installed capacity and electricity consumption with low-carbon electricity.

These strains on energy access have created a bottleneck for the development of new projects and led the authorities to tighten the criteria for granting permits for new data centres. In 2021, EirGrid, the national grid operator, announced a moratorium on new applications for sites in the Dublin region - where the majority of data centres are located – until 2028 (Data Center Dynamics, 2022). In 2024, South Dublin District Council cited "the insufficient capacity of the electricity grid and the lack of significant renewable energy on site to power the data centres" as grounds for rejecting a project proposed by a major player in the sector.

To sustain their growth, data centres have turned to natural gas for power, in particular by using on-site backup and emergency generators running on fossil fuels. In 2023, the EPA - Ireland's Environmental Protection Agency[71] - granted 13 licences to data centres in Dublin for the operation of backup generators, illustrating the use of fossil fuels as a backup to electricity supply (The Journal, 2024).

Four years after the announcement of the moratorium, Microsoft - which already operates 17 centres, mainly in the Dublin region - stated that the lack of access to electricity in Ireland is pushing the company to redirect its data centre investments towards Nordic countries. In this competitive sector, pressure is mounting on European countries on the grounds that "European regulations and planning procedures are very slow, and everything takes 18 months longer than anywhere else" (Data Center Dynamics, 2025d).

Yet the shift towards the Nordic countries - often seen as energy havens thanks to their abundance of renewable resources - does not necessarily offer a sustainable solution. **In Iceland too, production capacity has reached its limits, highlighting that even regions once considered highly attractive can**

[71] In charge of issuing industrial permits for facilities with a capacity above 50 MW.

quickly come under strain given the data centre sector's exponential demand (Le Figaro, 2025b; Le Monde, 2021).

B. Analysis of energy trends in Europe shows contrasting situations, but a common trend in the data centre sector.

This phenomenon is not unique:

- **In the Netherlands,** data centre consumption - currently about 9% of the country's total electricity use - has led the government to impose a moratorium on the construction of new sites in Amsterdam until 2035. Two grid operators have called on policymakers to act now to prevent the national electricity system from becoming progressively overstretched (DutchNews, 2025).
- **In Italy,** pending grid connection requests reached 42 GW in March 2025, up from 30 GW at the end of 2024 (Reuters, 2025).
- **In Belgium,** grid connection requests represent a potential future consumption of 45 TWh, compared with current national consumption of 80 TWh across all sectors (L'Echo, 2025b). By 2050, electricity demand from data centres in Belgium is projected to be three to ten times higher than today, depending on the scenario (L'Echo, 2025a).
- **In the United Kingdom,** the installed capacity of UK data centres is expected to reach 3.6 GW by 2029, nearly double its current level. Around 80% of this capacity is clustered in London. The National Energy System Operator (NESO), the UK's public system operator, forecasts a fourfold increase in electricity use by data centres by 2030, presenting it as an investment that "will support the development of a smart energy system" (Data Center Dynamics, 2024c). Nvidia's CEO has also warned the UK Prime Minister that the country is lagging behind global rivals in developing AI infrastructure (Financial Times, 2025).
- **In the United Kingdom, from the fossil fuel side**, 2.5 GW of feasibility studies for gas power plants to be built directly on data centre sites have been submitted to the British gas transmission network, "to provide stable supply given the long lead times required to connect directly to the UK electricity grid" (Financial Times, 2025).

This data reveals a paradox: public policies aimed at promoting the establishment of data centres can actually become counterproductive if they are not backed up by coherent and long-term energy and climate strategies.

This observation is shared by several analysts:

- Gartner and Epoch AI now view energy as a key limiting factor for the development of data centres. According to their projections, more than 40% of AI data centres could face operational constraints due to energy shortages as early as 2027 in Gartner's view, and by 2030 in Epoch AI's (Epoch AI, s. d.; Gartner, 2024).
- In the IEA's *Energy and AI* report, the "Headwinds" scenario projects a slowdown in data centre deployment, driven in particular by slower than expected adoption of AI and by additional constraints such as electricity supply bottlenecks. The emergence of local bottlenecks and a strained supply chain ares slowing the growth of installed capacity compared with the sector's most ambitious projections (IEA, 2025a).

This raises another question about waiting lists for grid connections: do they reflect actual demand once consolidated? Some of these requests may overlap, with companies placing multiple pre-orders in different European countries to maximise their chances of securing sufficient installed capacity. Coordination on this issue between national grid operators in Europe could help refine projections and avoid overestimates that might lead to poorly targeted investments.

Lastly, these trends are amplified in certain areas (see

Figure 26), with the following projections for 2022:

- **Two-thirds of data centre energy consumption is attributable to four countries**: Germany, France, the Netherlands, and Ireland, even though they account for only 40% of the European population.
- **The twelve main markets account for around 95%** of data centre **energy consumption**;
- **The share of national electricity consumption varies greatly**, reaching 18% in some countries such as Ireland, 5.6% in the Netherlands, 4.9% in Luxembourg and 4.6% in Denmark.

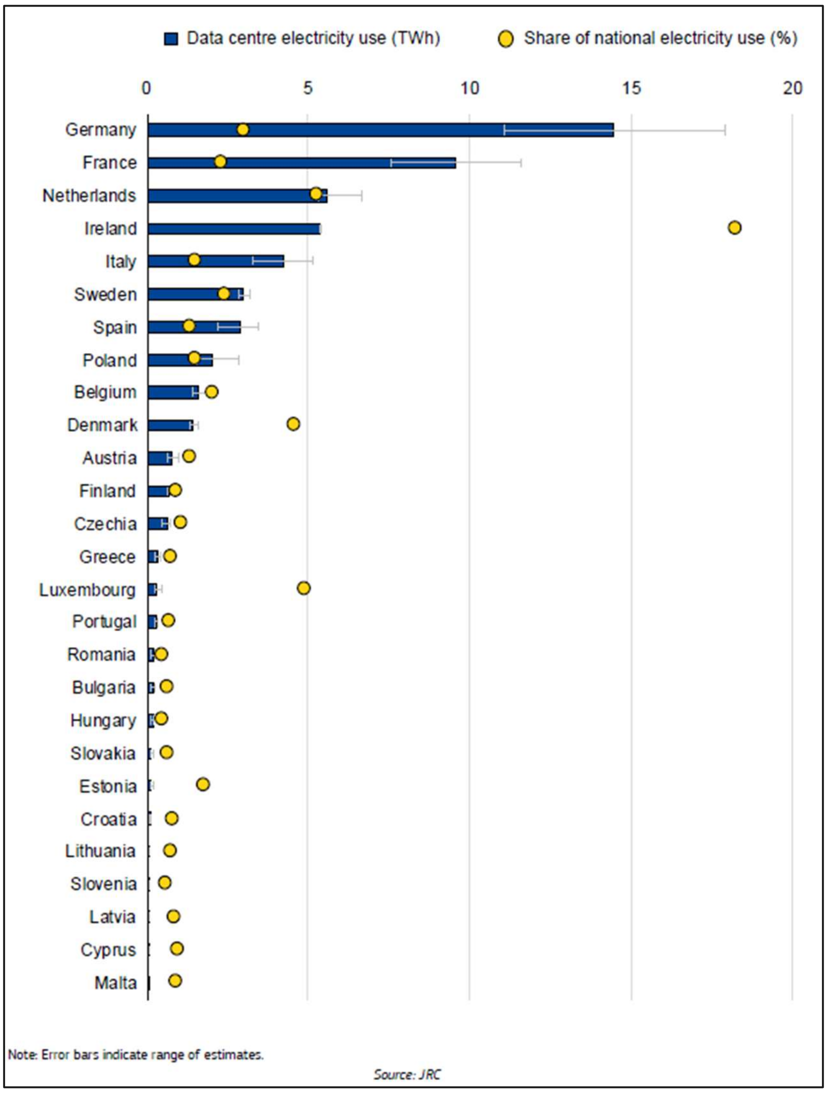


Figure 26 - Estimated data centre electricity consumption by country in the EU27 in 2022 TWh. Source: (European Commission, Kamiya G., Bertoldi P., 2024)

C. Initial scenarios indicate that the trends in the European data centre sector are not sustainable

Even more so than in the US, the electricity consumption of data centres in Europe[72] has been the subject of few quantitative studies, whether historical or prospective:

- In 2020, commissioned by the European Commission, the Borderstep Institute developed a model that fed into scenario work carried out by the Commission on the cloud and on data centres (Figure 27) (European Commission, 2020). According to this model (quite similar to the one used by the Lawrence Berkeley National Laboratory in the US), EU data centres (EU28) consumed 77 TWh of energy in 2018, representing 2.7% of total electricity consumption[73].

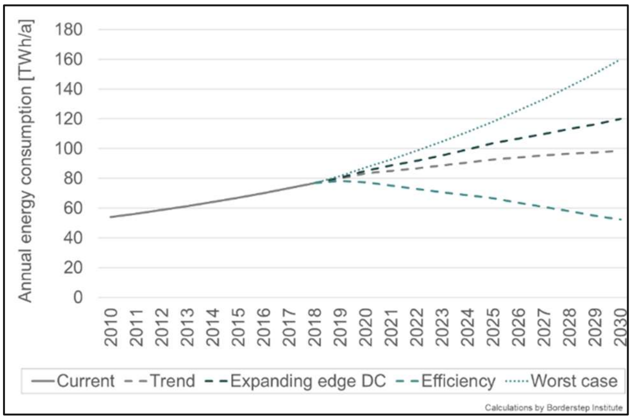
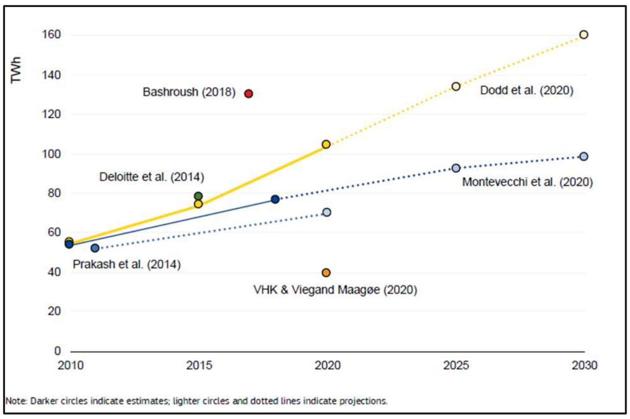
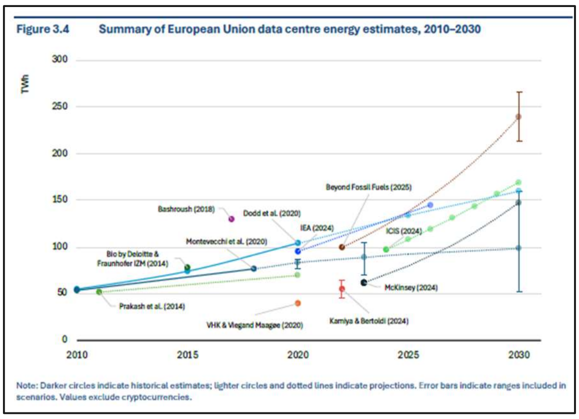


Figure 27 - Possible scenarios for the evolution of data centre energy demand in the EU28 to 2030. Source: (European Commission, 2020)

- In 2024, the European Commission carried out a study on the energy consumption of data centres in Europe (EU27) (see Figure 28) (European Commission, Kamiya G., Bertoldi P., 2024). According to this report, data centres in the EU27 used between 45 and 65 TWh of electricity in 2022.
- According to the European Commission, this consumption is set to rise significantly by 2030 (+28%, reaching 98 TWh) if the trend identified in 2020 (excluding the impact of generative AI deployment) continues, and could account for 3.2% of total electricity consumption (European Commission, 2024).





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[72] The geographical scope needs to be clearly defined depending on the study. For example, EU27 since January 2020 following the United Kingdom's withdrawal from the European Union for European Commission analyses, and EU28 before that or in global analyses where Europe is considered as a whole. Another example: including cryptocurrencies for analyses based on server volumes, excluding cryptocurrencies for figures taken from other analyses (e.g. the IEA's 66 TWh figure in 2025).

[73] Based on server volumes, this modelling includes cryptocurrencies.

Figure 28 – Overview of different estimates and scenarios for data centre energy consumption in Europe. Source: (EDNA, Technology collaboration programme by IEA, 2025; European Commission, 2020)

Several recent studies have taken the impact of AI into account, but report significantly different figures from one another - even though all point to strong growth:

- In 2024, the International Energy Agency estimated an electricity consumption of 100 TWh for Europe in 2022, with a projection of 150 TWh for 2026 (IEA, 2024a).
- In 2025, the International Energy Agency shared new figures: 66 TWh for Europe in 2023, with a projection of 113 TWh for 2030 (IEA, 2025a). These figures, unlike the previous ones, do not include cryptocurrencies, but this factor (around 3-7 TWh in 2023[74]) is not enough to explain the discrepancy.
- For its part, strategy consulting firm McKinsey proposes a reference scenario in which consumption rises from 65 TWh in 2023 to 150 TWh in 2030 for Europe (EU27 + United Kingdom). This growth is attributed in particular to hyperscalers (70% of projected demand between now and 2028) and colocation data centres. According to McKinsey, 25 GW of IT capacity might need to be deployed by 2030, representing 15-25% of total new net European demand between now and 2030 ((McKinsey & Company, 2024)
- According to DCByte, a specialist website that provides an up-to-date database of around 7,500 data centres worldwide, installed power capacity in Europe[75] was 5.5 GW in 2019, rising to 10.3 GW in 2024 and expected to increase to at least 20.2 GW in 2029, a fourfold increase in ten years (DCByte, 2025).
- ICIS analysts forecast consumption at 96 TWh in 2024, rising to 168 TWh in 2030 and 236 TWh in 2035 (ICIS, 2025).

This list highlights both the lack of statistics and methodological differences, which are generally not explained (see the difficulties on this issue outlined in this report at global and French levels).

One of these difficulties concerns how company data centres are accounted for: according to the European Commission, they represent around 35% of consumption, while McKinsey and ICIS[76] put the figure closer to 40%. In fact, data on enterprise centres are even scarcer than for large data centres (in particular colocation centres and hyperscalers).

At the EU level, the Energy Efficiency Directive (EED) - the EU directive that underpins regulations promoting energy efficiency and reducing energy consumption - has been revised and now requires data centre operators to report their key performance indicators, such as electricity consumption, computing performance, and the bandwidth required for networks (European Commission et al., 2025; Journal officiel de l'Union européenne, 2024)[77]. The aim of this update is to increase transparency in the sector by establishing a European database of relevant information on the energy performance

74 Approximate range: 3-5 TWh according to (ICIS, 2025). If 5 % (Harshrate Index, 2025, 2025) of global cryptocurrencies, with a total global consumption of 150 TWh, this would amount to 7.5 TWh.

75 In fact, this refers to the EMEA region, but installed capacities in the Middle East and Africa are an order of magnitude lower.

76 And (Dodd N. et al., 2020) estimated a 56/44 split in 2020 and foresaw a 66/34 split in 2025.

77 Commission européenne = European Commission ; Journal official de l'union européenne = Official Journal of the Europeann Union, 2024

(and water footprint) of data centres, while also promoting new designs and developments in efficiency.

With the delegated EU regulation on the data centre rating system, the European Union will be able to collect information on data centres and assign sustainability indicators - a first step (in July 2025, the survey conducted reported only 14 TWh of consumption for the whole EU (European Commission et al., 2025)) but still insufficient to reverse the trends in energy consumption and greenhouse gas emissions.

In any case, the growth in electricity consumption by data centres in Europe appears all the more worrying given the incompleteness and lack of reliability of the data needed to make informed decisions.

Based on information from DCByte (DCByte, 2025) and using a simplified version of the modelling we developed for France (described in Appendix 7 (The Shift Project, 2025a)), we estimate that **electricity consumption by data centres in Europe (European Union, United Kingdom, Switzerland, Norway) is expected to rise from 97 TWh in 2023 to [165–200] TWh in 2030 and [290–369] TWh in 2035** (see Figure 29) (see Appendix 15 (The Shift Project, 2025a)).

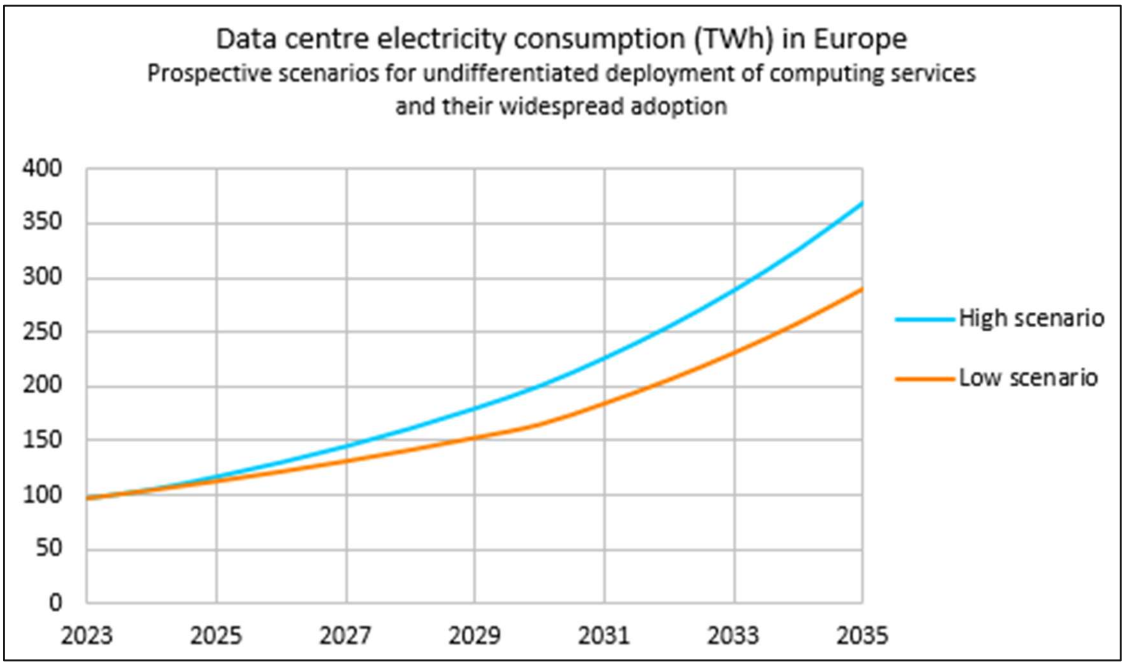

Figure 29 - Electricity consumption of data centres in the use phase (TWh) in Europe (EU27, United Kingdom, Switzerland, Norway) in our exploratory forward-looking scenarios of undifferentiated computing capacity deployment and widespread adoption Source: (The Shift Project, 2025a)

In other words, if the trajectory set by the data centre industry is implemented, data centres would account for around 7.5% of electricity generation in Europe by 2035[78]. This figure is close to the lower end of Lawrence Berkeley National Laboratory's [6.7% - 12%] estimate for the United States in 2028 (LBNL et al., 2024) and therefore appears, paradoxically, relatively moderate - even taking into account

78 Compared with 4390 TWh: the projected electricity generation for the EU27 in 2035 under the IEA Stated Policies (IEA, 2024b), to which the 2024 electricity production of the United Kingdom, Switzerland, and Norway is added (Our World in Data, 2025).

the “time lag” that traditionally exists between the two regions. It could even turn out to be an underestimate if the number and pace of new site openings were to accelerate as a result of incentive measures announced by the Commission and by Member States.

In any case, this increase in consumption of more than 200 TWh (Figure 29) **is, to our knowledge, not taken into account in energy planning scenarios aligned with climate objectives.**

Yet it represents around half of the reduction in gas[79] electricity generation that is expected to have taken place by that time (Figure 30) (IEA, 2024b)**, thereby jeopardising Europe’s ability to meet its climate targets by roughly 100 MtCO₂e annually in 2035[80]**, considering only the use phase of data centres.

Conversely, it is thus crucial to integrate data centres (and digital technology more generally) into energy planning, using them as a management tool and adapting Europe's industrial strategy to make it inherently compatible with its climate commitments.

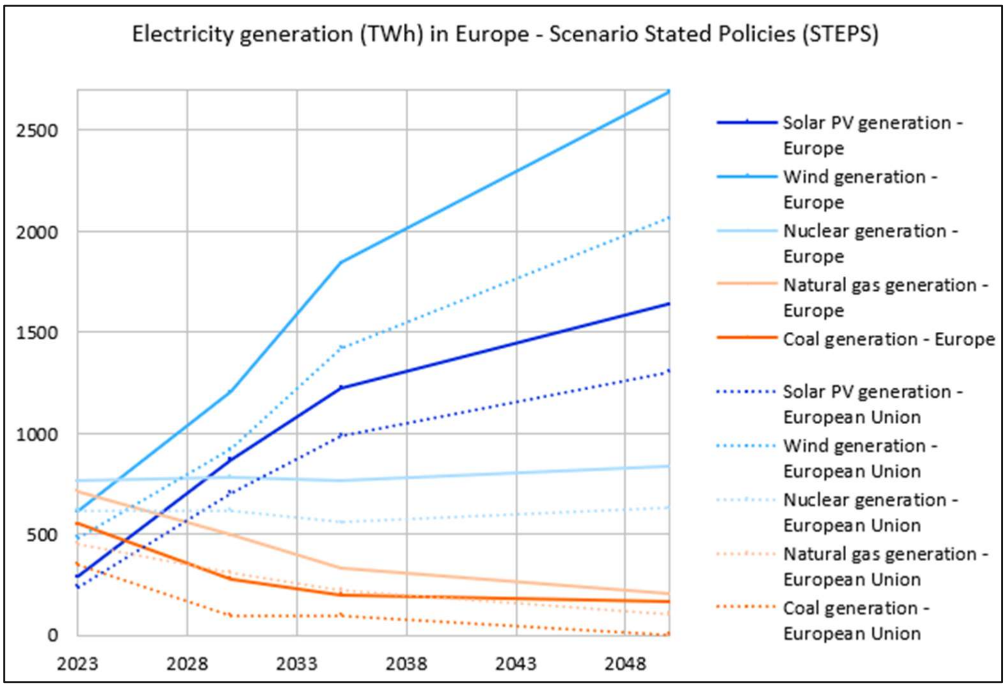

Figure 30 – IEA Stated Policies Scenario (STEPS) for electricity generation in Europe and the EU27 (TWh). Source: (IEA, 2024b)

79 The EU has stated its “intention” to buy US liquefied natural gas (LNG), oil, and nuclear products worth an estimated US$750 billion (around €700 billion) over the next three years (Contexte, 2025; Le Monde, 2025d).

80 Without accounting for manufacturing-related greenhouse gas emissions, this would add between **97 and 136 MtCO2e** of greenhouse gas emissions in 2035 compared to 2020 (depending on the low or high scenario). This calculation uses an emission factor of 500 gCO2e/kWh. This reflects today’s use of gas (Electricity Maps, s. d.), and also represents the upper range of emission factors for natural gas, in order to capture the imports now being introduced (Contexte, 2025; Le Monde, 2025d) of american LNG from shale gas, whose liquefaction and regasification are energy-intensive (Connaissance des energies, Joly A., 2022)

When including manufacturing-related greenhouse gas emissions, this would add between **130 and 184 MtCO2e** of emissions in 2035 compared to 2020 (depending on the low or high scenario).

The calculation assumes a 75/25 split between use and manufacturing, which is realistic today when electricity averages around 500 gCO2e/kWh (see “The carbon footprint of manufacturing across the value chain can no longer be overlooked”).

IX. Data centres in France: avoiding resource conflicts

A. Climate: overview of greenhouse gas emissions from the data centre sector

The carbon footprint of digital technology (data centres, networks, devices) in France **for 2020** was estimated at **17 MtCO2e**, excluding imported emissions from data centres overseas that serve French users (ADEME & Arcep, 2023).

An update published in January 2025 revised this estimate for **the year 2022** and including imported emissions from data centres, bringing the carbon footprint of the digital sector to **29.5 $MtCO_2e$ in 2022** (ADEME, 2025). **For 2022, the carbon footprint of the digital sector therefore accounted for 4.4% of France's total carbon footprint, with 46% attributable to data centres**, taking into account imported emissions linked to the use of data centre services abroad. However, as ADEME itself points out, this estimate of 29.5 $MtCO_2e$ is likely underestimated, as it does not account for the recent rise of generative artificial intelligence, the imported share of data exchanges over networks outside France, or a detailed update of French data centres.

This update, which has almost doubled the result, mainly due to a change in scope, highlights the need for frequent and reliable measurements of the carbon footprint of this rapidly evolving sector.

In terms of forecasts, the 2023 ADEME-Arcep study also estimated territorial emissions in 2030 and 2050 for their exploratory business as usual scenario[81] and several normative scenarios[82].

Carbon footprint of the digital sector ($MtCO_2e$)	2020	2030	Empreinte carbone du numérique ($MtCO_2e$)	2020	2050
Business as usual scenario	17,2	25	Business as usual scenario	17,2	49
Sobriety scenario	17,2	14,4	Frugal generation scenario (S1)	17,2	9,4
Moderate sustainable design scenario	17,2	20,7	Regional cooperation scenario (S2)	17,2	22,8
Widespread sustainable design scenario	17,2	18,1	Green technologies scenario (S3)	17,2	48,7
			Restoration gamble scenario (S4)	17,2	81,1

Table 2 - Carbon footprint of the digital sector in business as usual and forward-looking scenarios for 2030 and 2050 from the ADEME-Arcep study. Source: (ADEME & Arcep, 2023)

[81] Exploratory scenarios look at today's situation and trends, then set out a logical chain of events leading to a possible future. The aim is to make clear what consequences may follow.

[82] A normative scenario sets out a defined set of objectives to be achieved, whose combination provides a picture of a possible future.

B. Energy: clarifying uncertainties about the current state of electricity consumption in the data centre sector across France

In France, electricity consumption by the digital sector was estimated at 51.5 TWh in 2022, representing 11% of national electricity use (ADEME, 2025). When electricity consumed by data centres abroad hosting French usage is also taken into account, total consumption rises to 65 TWh.

For data centres in particular, over the past five years, estimates of current regional consumption and projections have continued to rise:

- In its 2022 study *Energy Pathways to 2050 (Futurs énergétiques 2050)*, RTE reported electricity consumption of 3 TWh in 2019, with projections of 5 TWh for 2030 and 9.5 TWh for 2050. In this study, data centres are included under the "tertiary sector" category, and only colocation centres are taken into account (RTE, 2022).
- In 2023, ADEME-Arcep, in its *Assessment of the environmental impact of digital technology in France and prospective analysis* study (*Evaluation de l'impact environnemental du numérique en France et analyse prospective*), modelled electricity consumption of 11.6 TWh for 2020, taking into account several types of data centres: colocation centres, HPC (high performance computing), and conventional facilities for public-sector bodies and companies. The study does not account for the impact of generative AI or for French usage hosted in data centres abroad. In its business as usual scenario, the study projects data centre electricity consumption of 16.4 TWh in 2030 and 39 TWh in 2050. In the remainder of this report, this scenario will be referred to as the "former business as usual" (ADEME & Arcep, 2023).
- In 2023, the Hubblo consultancy modelled 11.59 TWh of consumption in France and 11.3 TWh of cloud consumption abroad for 2020, reminding us that the carbon footprint of French digital services hosted abroad is just as significant (Hubblo & Fourboul E., 2023).
- In December 2023, in its *Forecast Report 2023–2035* (*Bilan Prévisionnel 2023-2035*), RTE estimated consumption at 10 TWh for 2020 and projected between 23 and 28 TWh for 2035 based on current demand, again under the "tertiary sector" category (RTE, 2023).
- In 2024, RTE, in its network development plan[83] (SDDR), studied 8 GW of data centre demand based on its current grid connection[84] reqests. These 8 GW translate into 25.3 TWh in the Ile-de-France region and 3.8 TWh in Marseille by 2040 (RTE, 2024).
- In February 2025, during the Summit for Action on Artificial Intelligence, several commercial and strategic announcements were made simultaneously. However, it is difficult to predict the implementation rates of these projects:
    - EDF (state-owned French electricity utility) put forward four sites on its land for 2 GW and announced two new sites to come (DCMag, 2025b; Le Figaro, 2025a),
    - The Elysée (French presidency) put forward three 1 GW sites (Le Monde, 2025a, 2025b; L'usine digitale, 2025a),

[83] Unlike the *Energy Pathways* (*Futurs énergétiques*) and the *Forecast Reports* (*Bilans Prévisionnels*), the SDDR is not a forward-looking document.

[84] In September 2024, RTE reported having signed 4.5 GW of grid connection offers for data centres, with "an equivalent volume" under review (LeMagIT, 2025).

  - The government has announced 35 ready-to-use sites mapped at the regional administrative level, including 15 that can be connected to the high-voltage grid and can reach a capacity of 750 MW (DCMag, 2025a; LeMagIT, 2025)[85],
  - Some are in the process of being finalised, including 1.4 GW in the Ile-de-France region, which is scheduled to be operational in 2028 (L'usine digitale, 2025b).
- In March 2025, data centres appear this time under the "industry" category in factsheet no. 5 of the SDDR published by RTE (RTE, 2025c). Since 2016, RTE has connected eight data centres with a total capacity of 800 MW, and by the end of 2024 these were operating at a maximum power of 120 MW (around 15% of the contracted capacity) (RTE, 2025b). Furthermore,
  - 25.5 GW are currently under review,
  - 10 GW are at the technical and financial proposal (TFP) stage, of which 5 have already been signed by manufacturers,
  - 0.6 GW are at the connection agreement stage,
  - 0.8 GW are already connected.
- In June 2025, Enedis (French electricity distribution operator) reported changes in electricity consumption in some of its data centres between 2019 and 2024 in the *French ecological transition observatory* (*L'observatoire français de la transition écologique*), with 2.34 TWh in 2019 and 2.9 TWh in 2024 (Enedis, 2025)[86].
- In July 2025, the census carried out by the European Commission under the EED directive reported electricity consumption of only 14 TWh for the EU as a whole, based on data from just 36% of eligible data centres. The result is therefore partial, with no public indication of the share attributable to France (European Commission et al., 2025).
- For autumn 2025, a study using complementary census methodologies is to be carried out in order to consolidate the scope and create a database listing active data centres in France (energy, water, and land consumption), as well as a prospective study for 2060 taking into account the phenomenon of generative AI (Hubblo, ADEME, n.d.).
- By December 2025, the CEA (French alternative energies and atomic energy commission), through a multi-partner 2040 prospective study, aims to analyse the life cycle of data centres and to develop forward-looking scenarios that incorporate technological opportunities as well as energy and material requirements (Y. Spot, CEA, s. d.).

This overview highlights significant discrepancies between successive estimates of electricity consumption by data centres in France for the reference year used in the studies: 3 TWh for 2019 (RTE, 2022), 11,6 TWh for 2020 (ADEME & Arcep, 2023), 12 TWh for 2022 (ADEME, 2025), and 10 TWh for 2022 (RTE, 2023). Several factors may explain the divergence in these assessments:

- Some estimates focused on a specific category of data centres only, in a context where identifying data centres remains administratively complex and where the census via electricity distribution operators has not yet been organised or is not yet public.

[85] RTE lists around 50 source substations able to accommodate 250 MW and about 20 able to handle 750 MW, not solely for data centres (LeMagIT, 2025). By February 2025, among its 140 signed projects totalling 21 GW, RTE recorded 40 data centre projects, averaging 130 MW each, or 5.2 GW in total (LeMagIT, 2025).

[86] *Data as of* 20.06.2025 - *Geographical scope: Mainland France, network operated by Enedis. Sources : Enedis, SDES, Local electricity consumption data, ©ADEME-baseOPERAT – Processed by SDES/Enedis*

- To date, data on consumption, installed capacity, or connection request volumes are not systematically shared. This lack of transparency from companies operating these centres prevents a clear view of energy demand for this sector.
- Although projections and scenarios may differ, the underlying assumptions have not always been clearly explicit (e.g. the rate of increase in data centre capacity). Furthermore, these assumptions may change rapidly.

While recent years have seen a gradual build-up of expertise on these issues which could, to some extent, help reduce such discrepancies, **robust mechanisms are still needed to measure and accurately identify capacities and consumption. This includes, for example, ensuring consistent monitoring on a comparable basis and at regular intervals, potentially through an observatory.** It is also important to promote the sharing of this information among relevant stakeholders, to encourage its publication, and, where appropriate, to develop methods of data aggregation that can help overcome confidentiality concerns. This overview also shows a tendency towards upward revisions of projections for 2030, 2035 and beyond.

C. Competing uses: planning ahead to reduce the risk of tensions between data centres and the energy transition

Analyses carried out by RTE as part of the SDDR show that the full connection of all requests received by RTE would result in a theoretical consumption of 45 TWh[87] in 2030, compared with the 15-20 TWh projected in the *Forecast Report 2023* (*Bilan Prévisionnel 2023*). This would contribute very significantly to pushing industrial consumption well beyond the estimate set out in the PPE (multiannual energy programme) (Figure 31).

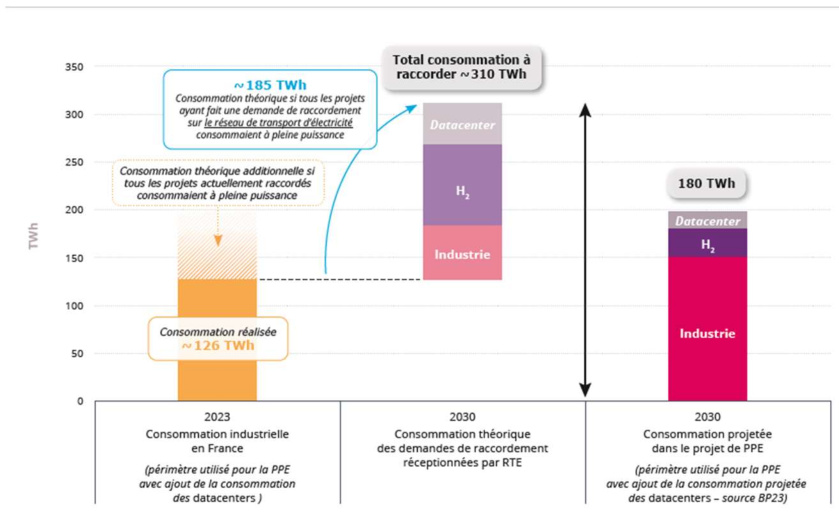

Figure 5.1 – Consommation industrielle actuelle et projetée sur la base des contrats de raccordement signés et comparaison avec les perspectives de la PPE, à l'horizon 2030

Figure 31 - Current and projected industrial electricity consumption according to RTE, based on signed grid connection contracts, and comparison with PPE projections to 2030.
Source: (RTE, 2025c)

[87] See (RTE, 2025c)

Data centres: an opportunity for France and its electricity supply-demand balance?

A recurring issue in a market context characterised by an oversupply of electricity relative to demand is that of negative prices[88], whose frequency has been increasing in France. Before 2022, the Commission for energy regulation estimated a maximum of 102 hours per year (around 1.2% of the time), compared with 235 hours in just the first half of 2024 (5.4% of the time).

Insufficient demand for electricity relative to production has physical and economic consequences for the network, hence the idea and arguments that data centres (which consume electricity) represent an asset for France.

But the data centres whose grid connections are approved today will reach their peak electricity consumption in 2035.

Current annual balances therefore do not allow an assessment of the role of data centres over this timeframe, at a time when their deployment could pose a real challenge for the energy transition, which relies heavily on the electrification of major sectors of the economy (such as transport, heating, and hydrogen production).

Moreover, the extra electricity consumption of data centres in 2035 compared with 2020 would account for between 10% and 23% of the overall increase in electricity use over that period[89]. In other words, part of the newly installed electricity generation capacity would not serve the energy transition (electric vehicles, industrial decarbonisation, electrolysers, etc.) but instead meet the additional needs of data centres.

- Between 2020 and 2030, the growth in data centre electricity consumption is estimated at 5 TWh [90] ADEME-Arcep **representing 6%** of the additional electricity consumption forecast by RTE over the same period, and all this without taking into account the “AI phenomenon” and the resulting acceleration of the data centre sector.
- Between 2020 and 2030, the updated assessments in RTE’s forecast report, published in the midst of the “AI phenomenon”, estimate the increase in data centre consumption at 10 TWh[91], equivalent to **13 %** of the additional electricity demand projected by RTE in its 2024 forecast report[92].
- Between 2020 and 2035, the updated assessments in RTE’s forecast report, published in the midst of the “AI phenomenon”, estimate the increase in data centre consumption at 18 TWh[93], equivalent to **12 %** of the additional electricity demand projected by RTE in the forecast report[94].

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[88] When the spot market price of electricity (day-ahead delivery) falls below zero, it reflects the different behaviours of market players depending on their ability to adapt or disconnect. During periods of low demand, such as Sundays or summer months, instances of negative wholesale electricity prices on wholesale markets are becoming increasingly frequent.

[89] Breakdown of the figures below

[90] 16.4 TWh in 2030 compared with 11.6 TWh in 2020. This is shown by the orange curve Figure 32.

[91] 20 TWh in 2030 and 10 TWh in 2020, high case scenario (RTE, 2023).

[92] +76 TWh for 2030 and +156 TWh for 2035: 454 TWh in 2020, 530 TWh in 2030, and 610 TWh in 2035 in the *2035 Forecast Report* (*Bilan prévisionnel 2035)* (fig. 2.9, scenario A) (RTE, 2023). This is shown by the black dotted curve Figure 32.

[93] 28 TWh in 2035 and 10 TWh in 2020, high case scenario (RTE, 2023). This is shown by the blue band Figure 32.

[94] +76 TWh for 2030 and +156 TWh for 2035: 454 TWh in 2020, 530 TWh in 2030, and 610 TWh in 2035 in the *2035 Forecast Report* (*Bilan prévisionnel 2035)* (fig. 2.9, scenario A) (RTE, 2023). This is shown by the black dotted curve Figure 32.

- Between 2020 and 2035, our “new buisness as usual” scenario and its two variants (see “Data centres in France: from current trends to decarbonisation scenarios”) estimate the additional consumption in 2035 compared with 2020 at 24 TWh, or even 37 TWh, representing **15% to 23%** of the additional electricity demand projected by RTE in its forecast report[95].
- Between 2020 and 2050, the ADEME-Arcep trajectory (ADEME & Arcep, 2023), set out before the “AI phenomenon”, projects an additional 27 TWh over the period for data centres, equivalent to nearly **14%** of the additional electricity demand projected by RTE in its *Energy Pathways* (*Futurs énergétiques*) report[96].

The current pace of data centre deployment raises questions about the availability of electricity in France[97], both in terms of generation and interconnections. **It also highlights the issue of competing uses by 2035 between the data centre sector and those sectors whose full decarbonisation depends entirely on electrification, such as transport, industry, and hydrogen production through electrolysis.**

These questions are all the more justified given that no additional consumption is allocated to data centres in RTE’s long-term *Energy Pathways to 2050* scenarios (*Futurs énergétiques 2050*) published in 2022 - neither in the “Reference” scenario nor in the “Strong reindustrialisation” scenario. In the latter, France’s total electricity consumption in 2035 is 45 TWh higher than in the "Reference” scenario, broken down as: 16 TWh more in industry, 24 TWh more in electrolysis, and 5 TWh more in the energy sector.

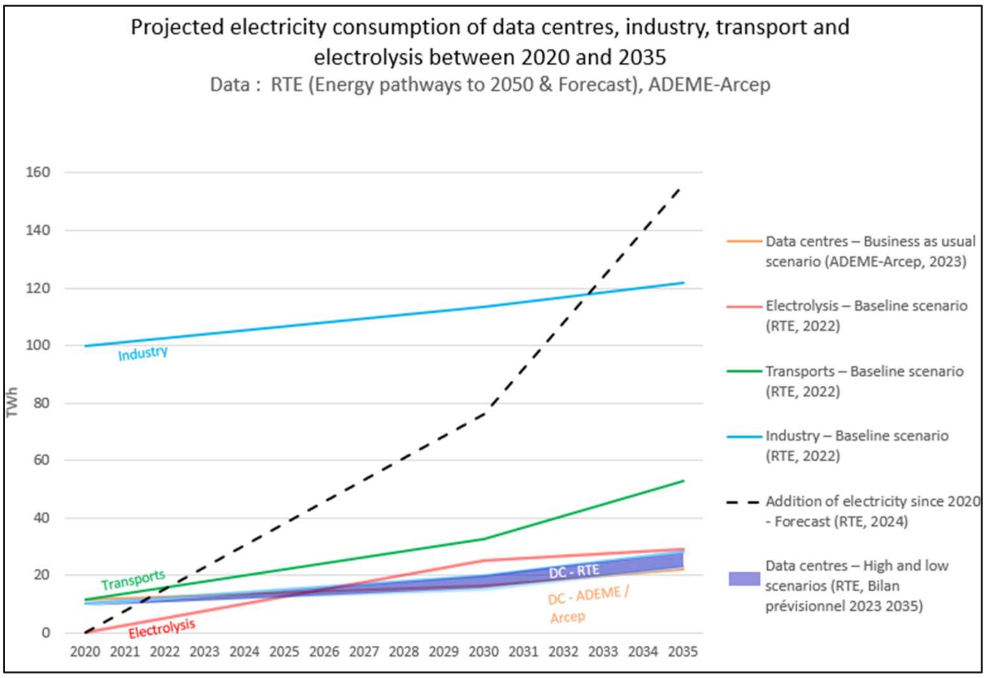

Figure 32 - Projected total electricity consumption and data centre electricity consumption between 2020 and 2035. Sources: based on (RTE, 2022), (RTE, 2024), (ADEME-Arcep, 2023) and (The Shift Project, 2025)

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[95] +76 TWh for 2030 and +156 TWh for 2035: 454 TWh in 2020, 530 TWh in 2030, and 610 TWh in 2035 in the *2035 Forecast Report* (*Bilan prévisionnel 2035)* (RTE, 2023). This is shown by the black dotted curve Figure 32.
[96] +191 TWh: 454 TWh in 2020 and 645 TWh in 2050 in the *Energy Pathways to 2050* (*Futurs énergétiques 2050*) (RTE, 2022)
[97] As well as the balancing role of neighbouring grids (in the United Kingdom and Germany), especially during winter.

Comparing the electricity consumption projected for data centres (RTE, 2023) with that projected for industry in two of the *Energy Pathways (Futurs énergétiques*) scenarios (RTE, 2022)[98], Figure 33 shows the share of data centre consumption not factored into industrial consumption. On the left, this is shown as a proportion of total industrial consumption (rising from 10% in 2020 to over 20% in 2035), and on the right as a share of additional consumption since 2020 (which could reach up to 58% in 2035)

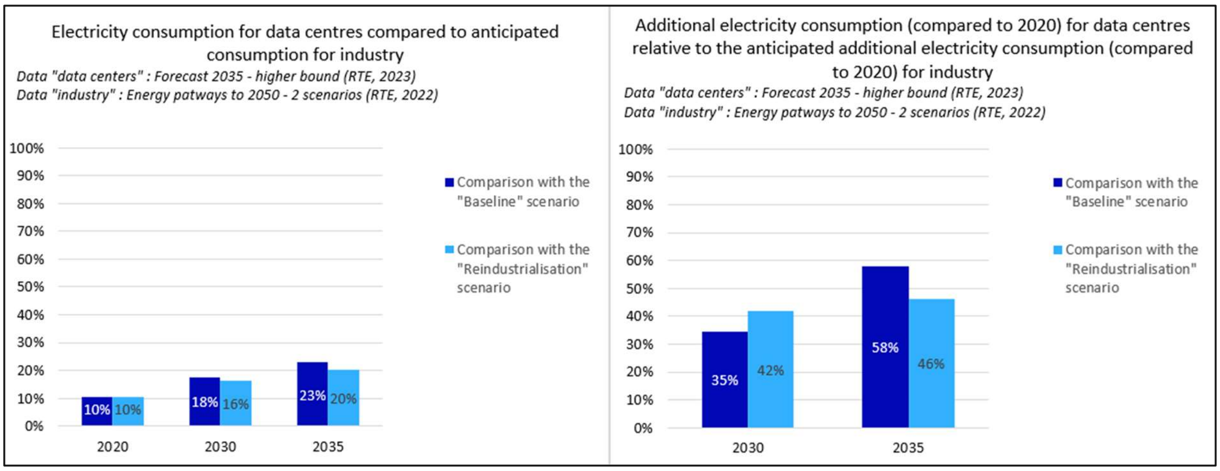

Figure 33 – Electricity consumption for data centres compared with projected industrial electricity consumption: total values on the left, additional consumption since 2020 on the right. Sources: (RTE, 2023) for data centres, (RTE, 2022) for industry

This competition needs to be carefully guided and managed, to avoid the large-scale rollout of data centres putting other transformations at risk unintentionally. One of the most direct forms of competition concerns industry: the major 'AI' data centre projects announced at the AI Summit compete directly with large-scale industrial projects that are central to France's reindustrialisation and decarbonisation strategies (decarbonised steel production, e-fuel production, hydrogen production via electrolysis, etc. (The Shift Project, 2022)) (see Figure 33). This competition, already visible in the overall electricity available, will affect individual sites, the location of certain large projects, infrastructure development, and access to the very high-voltage grid[99]. These pressures need to be planned for now, as the **grid connections approved today will drive consumption that will only reach full capacity in about ten years.**

Finally, two further questions need to be raised concerning both sobriety policies and choices, and the expansion of electricity generation capacity across France: what level of interest and what credibility would policies promoting energy sobriety in housing, for example, have if the electricity saved were instead used for data centres? And how might citizens react if such generation capacity - whether low-carbon or not - were taken up by data centres?

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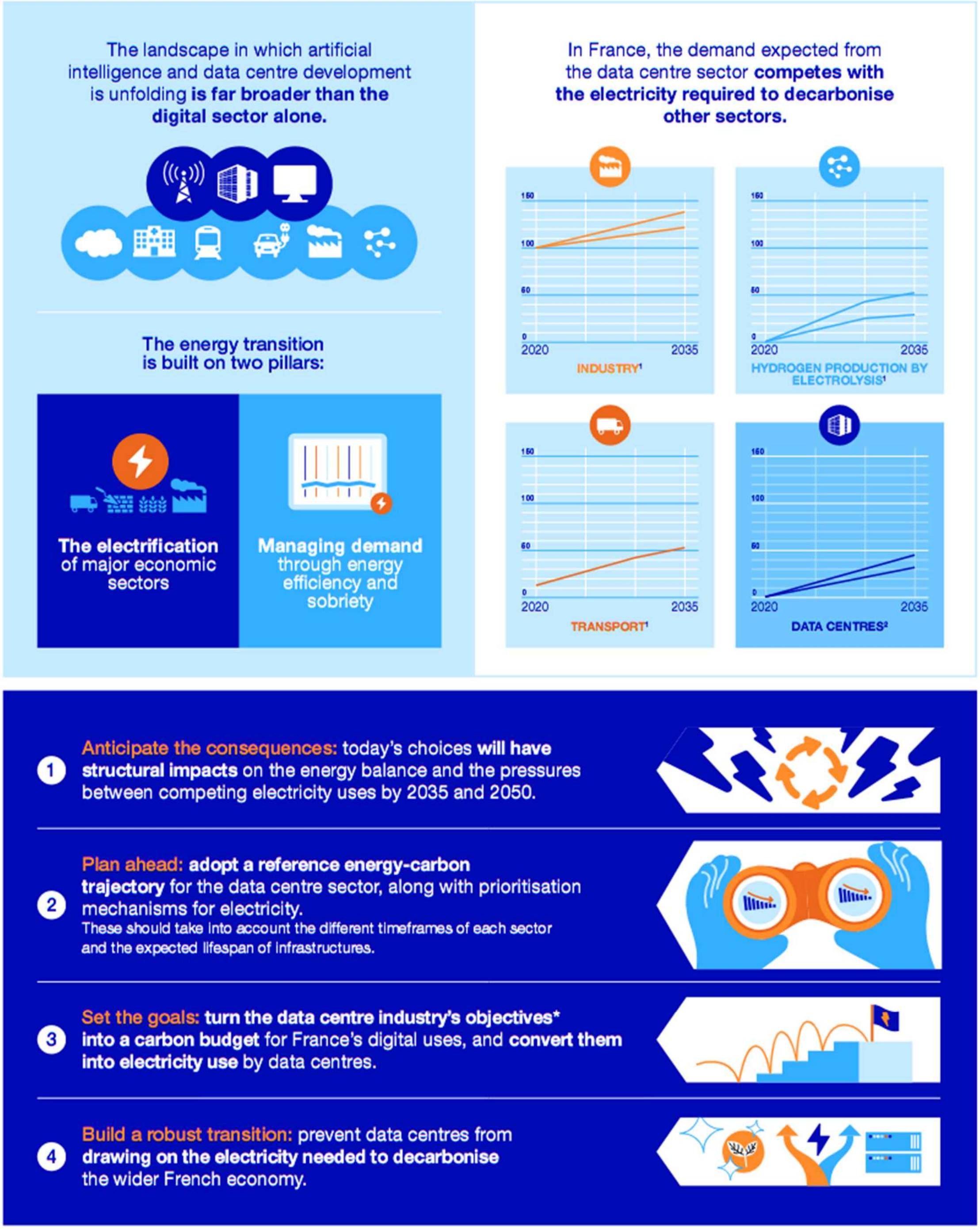
[98] Even though in these scenarios, electricity use by data centres was barely considered (5 TWh in 2030 for services, 0 TWh for industry).

[99] These future trade-offs are all the more foreseeable today as the Energy Regulatory Commission (CRE) has just approved a "fast track" connection procedure for linking large power consumption sites to the extra-high voltage grid (400 kV) (Commission de Régulation de l'Energie, 2025) (Commission de regulation de l'énergie=French Energy Regulatory Commission).

Managing competing uses: planning ahead to reduce the risk of pressures between data centres and the energy transition



1. RTE, 2022: Futurs énergétiques 2050
2. The Shift Project, 2025: as part of this report, France "New Business as Usual" scenario
*For example, -45% between 2020 and 2030 (SBTi, 2022), -90% between 2020 and 2050 to approach net-zero scenarios.

X. Data centres in France: from current trends to decarbonisation scenarios

This section examines the impact of data centre deployment in France on electricity consumption, greenhouse gas emissions, and the country's decarbonisation objectives. It focuses on two key elements: the capacity of these centres (installed capacity and its scaling up) and their use (changes in load factor and PUE).

With regard to capacity, i.e. the power of the facilities, several factors influence its development:

- The current state of installed capacity,
- The amount of capacity requested (by industry players from grid operators RTE and ENEDIS for connection),
- The progress of these requests along the process from inital application to completed connection: exploratory studies, technical and financial proposal (PTF), connection agreement, connection made available,
- The actual pace of deployment of capacities currently awaiting connection.

With regard to the use of connected capacity, this will depend on:

- The actual pace at which already connected capacities are ramped up: how long does it take for a data centre to reach its maximum power?
- The maximum power actually installed compared with the initially announced capacity (which represents a theoretical maximum),
- The initial PUE[100] and how it evolves over time,
- The initial load factor and how it changes over time: how much of the installed capacity is actually used?

These are some possible variations of these elements and answers to these questions that lead to the detailed scenarios below. Information relating to modelling is available in Appendices 8 and 9[101] (The Shift Project, 2025a).

A. Scenarios studied

In this report, three scenarios were examined:

- **The "new business as usual" scenario**, which describes what would happen if the projects corresponding to the capacities currently reserved[102] in RTE's pipeline were completed. It is

100 Power Usage Effectiveness : an energy efficiency indicator used to measure the efficiency of a data centre. It is the ratio between the total energy used by the entire facility (including cooling, air handling, uninterruptible power supplies, etc.) and the share actually used by the IT systems it operates (servers, storage, network).

101 A key point is the chosen assumption for the growth of French uses in data centres outside French territory: starting from a 2020 baseline model (Hubblo & Fourboul E., 2023), we modelled a trend that keeps the same share of electricity use in France.

102 Those for which a technical and financial proposal (PTF) has already been issued.

presented in two variants, reflecting either the full achievement or, conversely, the non-achievement of the objectives set at the AI Summit. These are exploratory scenarios[103].

- **The "former business as usual" scenario**, which does not come from our modelling but from earlier prospective analyses carried out by ADEME-Arcep and published in 2023 (ADEME & Arcep, 2023).
- **The "target" scenario**, in which we assess the feasibility of meeting several greenhouse gas reduction objectives. This is a normative[104] scenario. Two objectives have been set out:
  - In 2030 compared to 2020: -30% territorial emissions and -45% emissions for French usage abroad, targets proposed by The Shift Project in its 2023 analysis note (The Shift Project, 2023).
  - In 2050 compared to 2020: -90% emissions (territorial and French usage from data centres located abroad), a figure reflecting a carbon-neutrality strategy for 2050 (Commission européenne, 2019)[105].

B. Climate-energy sustainability: defining the conditions for compatibility

By 2035, data centre consumption in France could reach 7.5% of total electricity consumption, compared with only 2% today.

Electricity consumption in the "new business as usual" scenario is very high: between 33 TWh and 45 TWh in 2035, depending on whether or not the announcements made at the AI Summit are implemented. This represents between 5.5% and 7.5% of the consumption projected by RTE for 2035 (around 610 TWh) (RTE, 2023) and up to a third of industrial consumption[106,107].

The comparison between the "new business as usual" and "former business as usual" scenarios highlights the difficulty of predicting growth in the sector and the risks involved.

Comparing these results (Figure 34) with those of the "former business as usual" scenario (as a reminder, the ADEME-Arcep study published in 2023) provides a clear picture of the difficulty of forward-looking analysis, given both the sector's rapid momentum and the lack of transparency in key data. First, with respect to the current situation, the uncertainty is significant: 8.3 TWh in the "new business as usual" scenario versus 11.6 TWh in the former[108]. By 2030, the business as usual scenario has increased by 50%, rising from 16.4 TWh to 23.3 TWh in this modelling exercise.

The lack of transparency regarding operational data centres has led to an energy deadlock in the US (and a dismantling of decarbonisation scenarios for the electricity sector); in France, it poses a real risk to multi-year energy planning.

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[103] Exploratory scenarios start from today's situation and trends, then set out a logical sequence of events leading to a possible future. Their aim is to clarify the consequences that could follow.

[104] A normative scenario sets out a defined set of objectives to be achieved, whose combination provides a picture of a possible future.

[105] Commission européenne = European Commission

[106] Comparison of industrial consumption in the reindustrialisation scenario (RTE, 2022)

[107] Same conclusion as in the section "Competing uses: planning ahead to reduce the risk of tensions between data centres and the energy transition" with the data from this scenario.

[108] With a large share of company data centres. See explanations above on the consolidation of figures from different sources: why they differ, and so on.

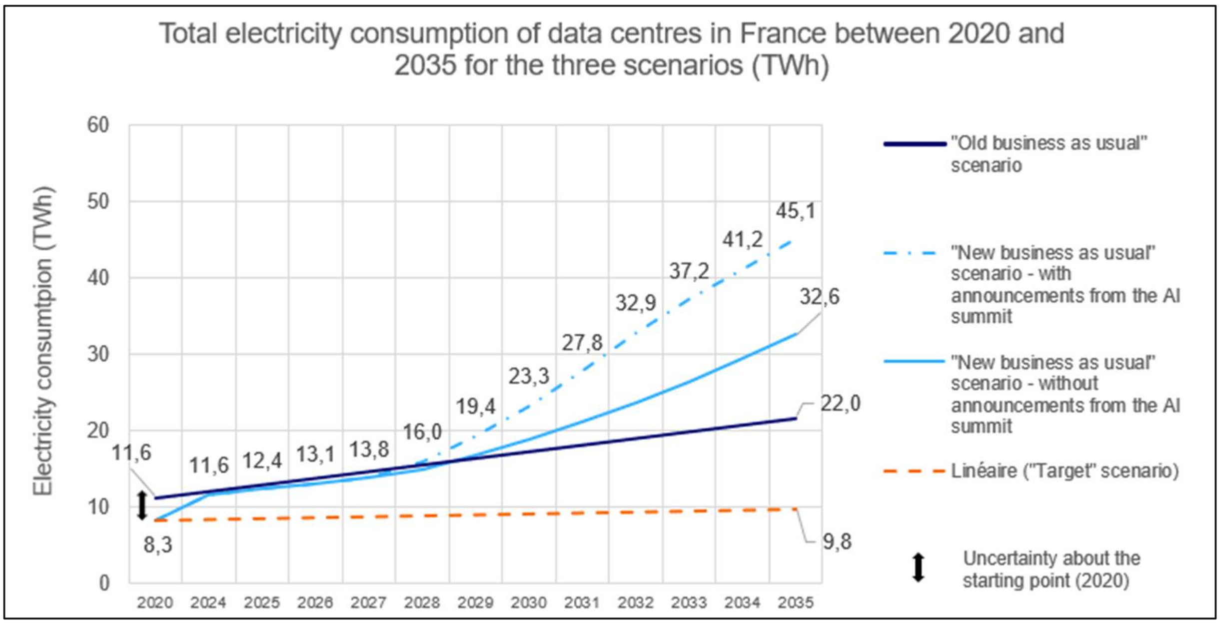

Figure 34 - Data centre electricity consumption in France between 2020 and 2035 across the three scenarios. Source: (The Shift Project, 2025b)

Continuing with the "new business as usual" scenario is completely incompatible with achieving the 2030 targets.

Figure 35 shows the greenhouse gas emissions footprint of data centres in the scenario with the AI Summit announcements. The dotted line shows the footprint target for 2030, which is clearly not being met.

Maintaining the current trajectory would make it impossible to achieve the sector's 2030 decarbonisation targets, both in terms of the national inventory and the carbon footprint.

If the current trend in the sector continues and the announcements made at the AI summit are implemented, the sector's territorial emissions in 2030 would be 1.5 MtCO2e, representing a 67% increase compared to 2020 instead of a 30% reduction. In order to meet this target scenario, consumption in the sector in France would need to be limited to 9.3 TWh in 2030, i.e. virtually unchanged, whereas the "new business as uaual" scenario would lead to at least a doubling (18.9 or 23.3 TWh in 2030 depending on the variant).

In terms of carbon footprint, as a reminder, we are aiming for a 45% reduction in emissions from our consumption in data centres located abroad by 2030: these are the SBTi targets. Taking into account the reduction in the carbon intensity of global electricity, in order to meet these targets, consumption by foreign data centres would need to be 12.4 TWh, compared with 13.3 TWh[109] today.

109 (ADEME, 2025)

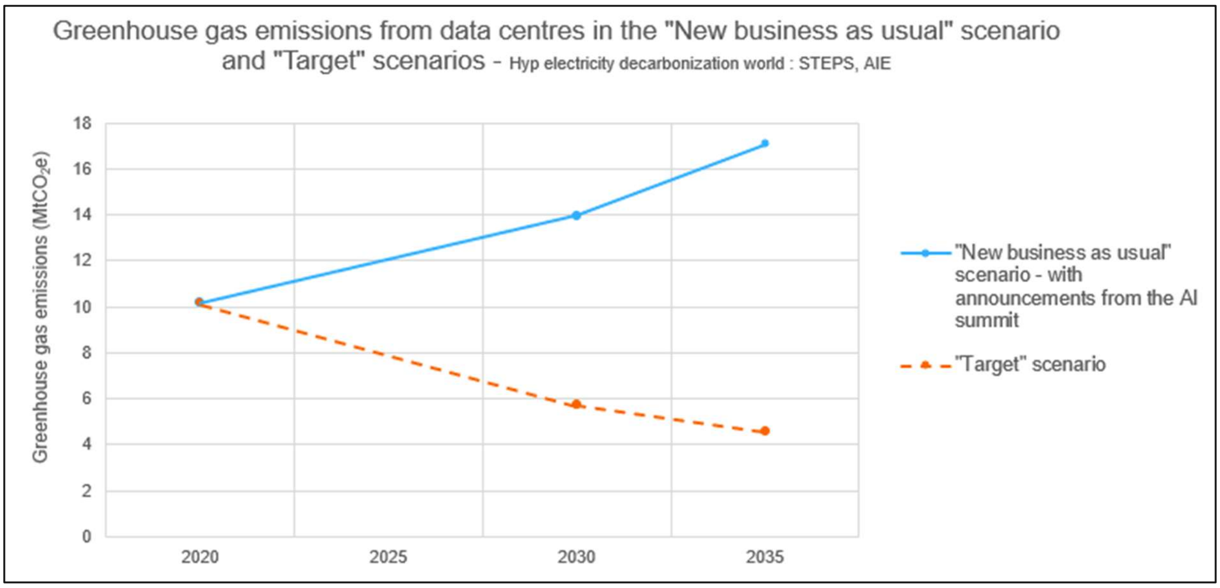

Figure 35 - Carbon footprint of the data centre sector under the "with AI summit announcements" variant of the "new business as usual" scenario, compared with the target.
Source: (The Shift Project, 2025b)

Even if electricity consumption by data centres abroad serving French demand remained constant, achieving the 2050 targets would still be impossible.

In 2050, despite the continued reduction in electricity emission factors, the target of a 90% reduction in the footprint compared to 2020 is unachievable: emissions from current consumption abroad alone would exceed this target.

The argument that electricity in France has a low emission factor is sometimes put forward to justify a strong policy of attracting construction projects.

If we take the hypothetical scenario of 3 TWh of electricity consumption for French uses of data centres located abroad, then meeting the 2050 targets would mean accepting a maximum of around 40 TWh on French territory in 2050[110]. The chart in Figure 36 generalises this scenario by varying residual electricity consumption in data centres located abroad between 0 and 13.3 TWh[111]. Moreover, meeting this international greenhouse gas reduction strategy would require a strict policy obliging companies to use cloud services in France.

In light of current trends, this consumption will already be exceeded by 2035 according to the "new business as usual" scenario (45 TWh for national consumption).

Achieving the 2050 target can therefore only be done by limiting the installation of new data centres in France, even though our electricity is relatively carbon-free. This cannot be done without considering the structure of the data centre sector's supply and its business models.

[110] Including re-imported consumption.

[111] How to read figure 36: If electricity use from French activities abroad, estimated at 13.3 TWh in 2020, falls to 3 TWh in 2050, then up to 37 TWh could be used in data centres in France while still meeting a decarbonisation target of -90% between 2020 and 2050. As another example, if this use remains constant at 13.3 TWh, then the targets cannot be met (negative consumption in France, dotted curve).

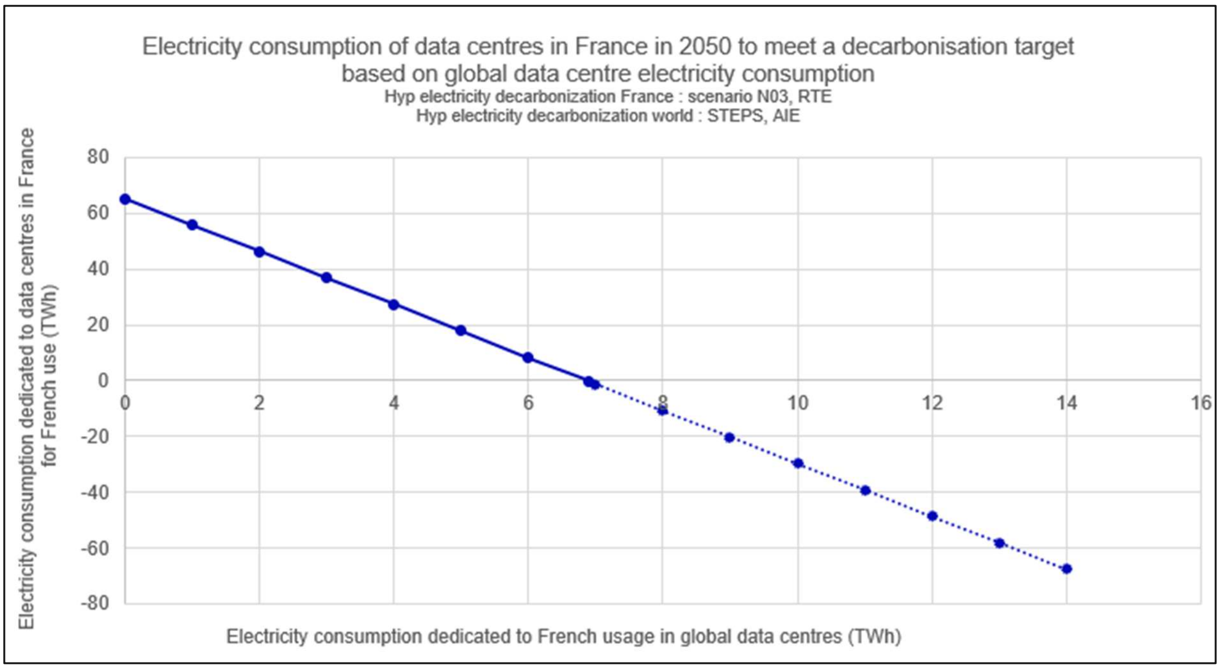

Figure 36 - Remaining electricity consumption in 2050 for data centres in France (or in a country with a similar level of electricity decarbonisation) to stay within a 2050 decarbonisation target (-90% between 2020 and 2050), after accounting for the carbon footprint of French uses in data centres worldwide. Source: (The Shift Project, 2025b)

XI. The integration of data centres - a local issue: water management, public debate, regulatory developments[112]

To enable sustainable long-term development for regions, local areas, and economic sectors alike, these stakeholders will now need to take several key factors into account in their strategies: water management, the **intensification of extreme weather events**, the Zero Net Artificialization (ZNA) objective, the preservation of natural areas, etc.

Although the positive and negative impacts of data centres (such as attractiveness, employment, air pollution[113], and pressures on limited resources including water, land, energy, climate, and the environment) **tend to remain fairly constant in nature, their scale can vary and may even cross critical thresholds. What was seen as a minor impact yesterday could become a significant one tomorrow.**

A. Water management by data centres and the intensification of extreme climate events

Data centres require constant cooling and sufficient humidity levels to maintain server performance and keep them in good working order. Without cooling, temperatures in data centres can reach levels that can damage equipment, cause data loss and reduce efficiency. The cooling system is often one of the main factors driving water consumption in these facilities.

Cooling systems and water consumption:

Direct or indirect consumption:
This consumption can be direct (water is used in cooling circuits) or indirect (to produce the electricity consumed by data centres and to manufacture equipment) (Alkrush A. et al., 2024).

Types of cooling (depending on data centre size and available technologies):

- **Air conditioning cooling.** This system relies on mechanical vapour compression refrigeration provided by an air conditioner. Computer rooms are equipped with devices that direct cold air towards the servers.
- **Free cooling**. This method involves using cold outside air to cool the servers, avoiding the need for air conditioning. It is effective as long as the outside temperature does not exceed 25°C. It is often combined with water evaporation cooling.
- **Liquid cooling:**
  - **Indirect liquid cooling**. This system combines air cooling with liquid thermal efficiency. The liquid does not come into direct contact with the computer equipment, but helps to support traditional air cooling.
  - **Direct liquid cooling.** In this system, a cold liquid circulates through pipes in direct contact with heat-generating components (such as processors or graphics cards).
  - **Immersion Cooling.** This technique involves immersing servers in a dielectric liquid, i.e. an insulating liquid.

[112] Not all of the issues are addressed in this section. On waste heat, see for example: (ADEME, 2024a)

[113] Air pollution was not examined in this report, although participants in the collaborative workshop we organised on 6/03/2025 highlighted its importance. Most of the air pollution comes from backup systems, used both in crisis situations and regularly to test proper functioning. The concentration of data centres (in capacity, GW), and the related backup systems, needs to be monitored for its impact on air quality. In addition, the greenhouse gas impact of backup generators is an issue that requires deeper investigation.

Closed-loop or open-loop

Water is used to remove heat through closed-loop or open-loop systems. In open loops, water is taken from a natural environment (such as a river or groundwater), passes through heat exchangers where it captures heat, and is then released, often in liquid or gas form after heating, via an adiabatic cooling process where the water is evaporated.

Types d'eau

The types of water used in these systems can vary: predominantly potable water[114], but in some cases greywater[115], and in others seawater[116].

Impact assessments are crucial to ensuring the preservation of local water resources and the proper functioning of servers.

Water management in data centres requires a tailored local approach, as it depends on many factors specific to each region.

After construction, the environmental impact of data centres' water consumption should be assessed. A report by Nature Finance estimates that 45% of data centres worldwide are located in river basins where water availability poses a high risk (Nature Finance, 2025). The report therefore suggests that environmental impact assessments of data centres' water consumption should be carried out, particularly in regions where water is a scarce resource. Key indicators include baseline water availability, water pollution, and drought risk.

Thus, a first step in implementing Article 33 of the SREN (National digital strategy, *Stratégie nationale pour le numérique*) (Légifrance, 2024) could be to **make the disclosure of water abstraction and consumption by existing data centres mandatory**: volumes, sources of supply, and water management methods. For data centres still at the project stage, **impact assessments should be mandatory**, covering :

- In terms of **water availability:**
  - Is there a risk of the source drying up?
  - Is there a risk of water stress for local ecosystems, to residents, or to other water uses, particularly agriculture?
  - What changes in water availability are expected in the area where the project will be implemented?
  - Is the water used competing with other uses (agriculture, households, etc.)?

- Regarding **Water quality:**
  - Is the water released from the cooling systems of lower quality?
  - Is the water released at a temperature that is safe for aquatic ecosystems?

- At the **points of abstraction and discharge:**
  - Are they the same?
  - If not, what is the risk of drying out in the withdrawal area?

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114 This is the case in Marseille, for example: Digital Realty's data centres are cooled using "river cooling", drawing on a drainage gallery with drinking water quality. The water is diverted through a pipeline network and passes through pumping stations before reaching the data centres.

115 Some facilities use untreated wastewater to cool their servers. This is the case for the Infomart data centre in San Jose (California) and Google's facility in Douglas (Georgia, US), which both use local greywater for cooling (Diguet C. et al., 2019).

116 Beyond seawater cooling, Microsoft submerged a small data centre (800 servers) for two years (futura-sciences, 2020).

Water resource management is also an operational issue for data centres. If water supplies were to run out or temperatures became too high for effective cooling, this would have a direct impact on the way the facilities operate.

The intensification of extreme climate events must be planned for.

Warming trajectories may create new constraints. For example, some areas may be ruled out because they lack the water volumes required for data centres during droughts and periods of extreme heat, or because they may contribute to the creation of urban heat islands, etc.

Accounting for evolving climatic conditions in a given region is essential to ensure the resilience of regions and economic sectors. For example, flooding and storm risks can damage buildings and disrupt cooling systems.

In addition, during droughts or heatwaves, water availability can be severely reduced, which puts added pressure on the resource while increasing cooling needs.

These climate events can also weaken electricity networks: in times of crisis, power cuts may become more frequent, leading to greater reliance on backup systems, which are often polluting and costly.

B. Public debate must take into account the dual carbon constraint

AI, often treated by default in public debate as a driving force for the energy transition as well as for other forms of progress, represents a major digital transformation with significant infrastructural and material impacts (see previous sections on global, European, and French carbon assessments). This technological, material, energy, and climate direction is ultimately a political choice (just like the deployment of video uses and associated networks, such as 5G) (The Shift Project, 2019, 2021), even if it is not explicitly recognised as such. It calls for an informed public debate in which the carbon constraint is factored in, both for the assessment of externalities and for the very definition of sustainability: what progress is expected, and what benefits are hoped for society as a whole, given increasingly complex material, energy and climate trajectories?

To achieve this, the debate must involve a wide range of stakeholders (civil society, citizen representatives, digital planning institutions, the regulator, institutions in charge of carbon, energy, and environmental trajectories, the business community, industry players, etc.) at the most relevant levels to address regulatory issues (France, Europe, or beyond).

C. An overview of ongoing regulatory developments

The installation of data centres in France is encouraged through exemption from the electricity consumption tax (TICFE) for data centre operators that meet certain conditions (Legifrance, 2022)[117].

[117] Electricity used for the needs of real estate infrastructure qualifies for a reduced excise rate, for the share exceeding one gigawatt-hour in a calendar year, provided that the following conditions are all met: […] 3° It includes dedicated systems for controlling temperature, air quality, power supply, and fire prevention. 4° It has an energy management system that is in line with the criteria set out in the second paragraph of Article L.233-2 of the Energy Code. 5° The operator is part of a programme, recognised by a national or international public authority, for sharing best practices in energy management of data centres, covering: a) eco-design of data storage centres;
b) optimisation of energy efficiency;
c) monitoring of energy use and regular reporting;
d) deployment of cooling technologies that meet performance standards. 6° The waste heat it produces is recovered through a district

At the same time, a number of recent regulatory developments could ease the conditions for establishing data centres: the "major national interest project" designation, relaxations of the Zero Net Land Take (ZAN, *Zéro Artificialisation Nette*) framework, and the "fast-track" connection procedure for sites with high energy consumption.

The designation as a "project of major national interest" (PINM)

The draft law on simplifying economic life (Vie publique, 2025), in particular Article 15, stipulates that certain data centres may receive the PINM (Project of Major National Interest, *Projet d'Intérêt National Majeur*) label. For projects awarded this label, the competent authority may allow them to derogate from local urban planning rules on building height, within limits set by decree of the Council of State.

This label applies to "large" data centres of particular importance "in view of their purpose and scale, notably in terms of investment, installed capacity, and support for the emergence of competitive domestic ecosystems." For a data centre awarded the PINM label, the law would make it possible to speed up certain administrative procedures (compatibility of urban planning documents, connection to the electricity grid, recognition of overriding reasons of major public interest - RIIPM (*Raisons impératives d'intérêt public majeur*)) (Vie publique, 2024).

La loi Zéro Artificialisation Nette (ZAN)

As part of the draft law on simplifying economic life (Sénat, 2024)[118] two amendments relating to the Zan (Zero Net Land Take) law have been adopted. The amendments aim to remove the full exemption granted to industrial developments from the calculation of land take by municipalities under the 2021 Climate and Resilience Law (Assemblée nationale, 2025)[119]and to remove the national interim target of reducing land take by half between 2021 and 2031 compared with the previous decade.

On 28 May 2025, during the examination of the draft law on economic simplification, several amendments were adopted (Assemblée nationale, s. d.) including one allowing a 30% increase in the amount of natural land that can be developed without requiring justification, as part of the implementation of the ZAN law. These changes could reshape the framework under which data centres are deployed, and the conditions that apply to them.

The "fast-track" procedure

The data centres announced at the AI Summit and the Choose France event require connection to the extra-high voltage grid (400 kV), for which the French Energy Regulation Commission (CRE, *Commission de Régulation de l'Énergie*) approved an accelerated connection in May 2025 (Commission de Régulation de l'Energie, 2025). This "fast-track" procedure allows connection with no capacity limits for high-energy consumption sites previously designated by the State. In June 2025, the CRE approved the contractual and financial terms for this accelerated connection, enabling project developers to request a rapid connection without restrictions. As a result, installation times for these data centres are much shorter: they are expected to be operational by 2028.

heating or cooling network, or the facility meets a quantified multi-year performance indicator for efficient use of power, set by decree. 7° The water used for cooling is limited according to a quantified multi-year indicator, set by decree. 8° The level of electricity intensity, assessed at the scale of the facility, is at least 2.25%.

[118] Sénat = French senate

[119] Assemblée nationale = French national assembly

The "Use it or lose it" (UIOLI) mechanism

It is often the case that the connection capacities requested by projects from the electricity grid operators RTE and ENEDIS are set much higher than the power that will actually be used. This is because it takes several years to fill a data centre with servers and for those servers to be gradually brought into use. However, in some cases the initial capacity is deliberately set much higher than needed, for various reasons: competition between companies looking to make headline announcements or to secure available connections before their competitors, investment plans being scaled back during the project, etc.

With this mechanism, the connection capacity of data centres may now be taken back by RTE (DCMag, 2025d) when the maximum power drawn by these facilities is lower than the contracted connection capacity. This is the UIOLI ("Use it or lose it") mechanism, introduced by Article L. 342-24 of the Energy Code, which will apply from August 2025 to all facilities, both existing and new. Thus, if the power actually used is lower than that requested, RTE may reduce the capacity allocated. Data centres are not granted any exemption, despite requests from the sector citing their strategic role in digital sovereignty and the gradual scaling up of their activity (DCMag, 2025d)[120].

European regulations

Within the European digital policy framework, several initiatives aim to promote digital transformation while integrating sustainability objectives. The European Energy Efficiency Directive (EED) in particular requires reporting on the environmental footprint of data centres, signalling an effort to improve the transparency and energy performance of these infrastructures. It is more than likely that this directive is only partially applied today, since reported consumption was around 14 TWh in total as of July 2025 (European Commission et al., 2025).

These European measures form part of the Digital Decade project (Commission européenne, s. d.)[121] which sets ambitious targets to be achieved by 2030, such as the widespread adoption of artificial intelligence, cloud computing, and Big Data in at least 75% of companies. This overarching initiative is supported by several legislative instruments, including the Gigabit Infrastructure Act, which aims to strengthen connectivity capacity across the continent. Finally, it should be noted that the AI Act, which plays a central role in regulating artificial intelligence, does not at this stage impose any specific requirements[122] regarding the environmental footprint of AI systems.

[120] "Although the industry lobbied against it, the decree of 14 November 2024 on facilities covered by Article L.342-24 of the Energy Code still applies to data centres. The industry had asked to be left out of the scheme, given the strategic importance of data centres for France's digital sovereignty and the way their needs change over time with client demand. In its public response to the second consultation run by the Energy Regulatory Commission (CRE) on this scheme, Microsoft pointed to the Netherlands as an example. That country also introduced rules similar to the UIOLI scheme but allowed certain clients providing 'essential services', such as data centres, to opt out." (DCMag, 2025d)

[121] Commission européenne = European commission

[122] The recommendations in the codes of conduct, drafted by the AI office, should provide "guidance on measuring and minimising the environmental impact of AI systems, rather than obligations" (Article 95).

Chapter 3

AI & climate: Redirecting our technological choices and strategies towards carbon compatibility

XII. Artificial intelligence: a digital system of uses like any other

A. The unsustainable use of artificial intelligence

Like video services, virtual worlds, and mobile applications, artificial intelligence services form part of a broader digital "usage system" (The Shift Project, 2019, 2024a, 2024b): a set of services, activities, and usage patterns enabled by specific infrastructures, which they both underpin and drive on a large scale.

Artificial intelligence relies on digital infrastructure as a whole, but above all on its backbone: data centres. Yet the dynamics of this sector are compatible neither with climate constraints nor with the energy transition - not today, and not in light of the trajectories the sector is pursuing:

- Data centres are experiencing an unprecedented increase in greenhouse gas emissions (+9 to 13% per year, reaching 0.6 to 0.9 GtCO2e in 2030[123]) which is fuelling climate change in the sector and in regions where they are located;
- With energy infrastructures being outpaced by the dynamics of the digital sector and its players, the massive roll-out of data centres is continuously driving the use of fossil fuels to ensure they can be brought into operation quickly enough[124];
- The demands placed on the energy sector, at least in France and Europe, could jeopardise the availability of electricity for the energy transition if current trends are not called into question[125].

Although not inevitable, the absence of a carbon target for the data centre sector reinforces this situation.

Understanding that digital technologies and AI are now shaped by a supply-driven dynamic (see Figure 2)[126] is a prerequisite **to avoid the mistake of thinking the sector's direction can be corrected later, once data centres are in place**. Not only will demand by then already be shaped by this supply effect, but the impacts of deployment will also take the form of irreversible carbon, energy, and environmental costs (the carbon cost of manufacturing equipment, the environmental costs of building infrastructure, and the costs and commitments linked to electrical networks deployed to connect these sites, etc.).

Given current industry dynamics and dominant business models, the data centre sector and its players are on trajectories that are incompatible with climate and energy constraints[127]. **A shared direction therefore needs to be set for stakeholders: a common pathway defining the carbon and energy budgets within which the sector must build its infrastructure, goods, and services.** This would enable

[123] These GHG emissions would account for 1.1 to 1.7% of global emissions in 2030 across all sectors, and also represent a significant share when compared with the remaining absorption capacity of a low-carbon economy (see section "Current choices are leading to an unprecedented rise in greenhouse gas emissions" and Figure 2).
[124] See "The data centre sector is increasing reliance on fossil-based infrastructure" and Figure 2.
[125] See "Competing uses: planning ahead to reduce the risk of tensions between data centres and the energy transition" and Figure 31.
[126] For example, data centres are often built 1 to 5 years ahead of use, based on growth forecasts and with uncertainty over the demand that will actually arise. This can lead to saturation of grid connection contracts, a risk flagged by RTE (p46, RTE, 2025b).
[127] Several major digital players noted a drift in their carbon trajectories (+30% and +48% over 3-4 years) compared with their climate commitments, driven in particular by the rollout of generative AI (Google, 2024; Microsoft, 2024).

actors to organise and establish a shared framework with clear rules, aligned with today's physical constraints.

B. The many uses of artificial intelligence

The term "artificial intelligence" covers a wide variety of applications and dynamics (see "Why is The Shift Project focusing on artificial intelligence and data centres?").

- Algorithmic applications that have already been in use for several years or even decades;
- Generative AI technologies and applications, whose widespread accessibility to the general public in recent years has created a "generative AI moment";
- Broader developments linked to the intensification, increase, and distribution of available computing power (in computers, smartwatches, CCTV cameras, cars, etc.).

Under the term "artificial intelligence" we can therefore find goods, applications, and services present across all sectors of the economy, for example[128] :

- Analytics in surveillance cameras (traffic analysis, behavioural analysis, deployment in public or private spaces, detection of objects or waste in public areas, etc.);
- Educational conversational assistants (language learning, maths, French, etc.) via written or spoken interaction;
- Customer-facing conversational assistants (customer service, from simple advice to product identification, guiding users through to purchase from a single instruction, etc.) across many sectors (insurance, tourism, retail, fast-moving consumer goods, etc.);
- Recommendation algorithms and content detection tools to help manage platforms and social networks (violent content, AI-generated content, etc.);
- Assistants for generating computer code (producing code in response to specifications, translating from one programming language to another, etc.);
- Tools for modelling and improving high-performance computing capacity in research and applied sciences (chemistry and pharmacology, materials, climate modelling, etc.);
- Assistants for searching within document collections (administrative procedures, legal texts, summaries of technical reports, etc.);
- Applications in energy and in supporting the management of electricity systems;
- Industrial applications for predictive maintenance or logistics optimisation;
- Agentic applications in robotics and automation; etc..

This report cannot predict future technological developments, new technical combinations, or the applications that might follow. The term **"artificial intelligence"** itself is evolving and always tied to a particular technological and temporal context - in other words, it points to a shifting technological horizon rather than a fixed definition. In France at least, artificial intelligence usually refers to the most advanced automation applications at a given moment, in terms of information processing, task complexity, precision, and reliability. Its future scope cannot, therefore, be predicted.

[128] The list is not, and could not be, exhaustive. We chose not to include specific examples in order to avoid highlighting certain commercial solutions over others. As part of the preparatory work for this report, several use cases were examined in greater detail (see Appendix 14) (The Shift Project, 2025a).

It is precisely for these reasons that **this report examines the dynamics of artificial intelligence through its infrastructures**, which have clear definitions and the slow-moving nature of industry, making their development **easier to assess using forward-looking methods.** To analyse the impacts of AI use cases in a robust way, **the approach taken in this report examines how technological choices made at the level of services and solutions affect the underlying infrastructures**.

The possible applications of AI actually include various categories of digital services, depending on their positioning with regard to environmental constraints:

- Applications aimed at reducing environmental impacts (from digital technology itself or other sectors), commonly referred to as "AI for Green', artificial intelligence for environmental objectives (these objectives are only achieved if the net balance between the benefits and environmental impacts of the solution itself is positive) ((EGDC, 2024)[129]);
- Applications with non-environmental objectives: quality of health services, improved productivity, efficiency or profitability of certain activities, improved reliability of certain processes, etc.

AI, and digital technology more broadly, acts as a catalyst within the system into which it is integrated (improving efficiency, speed of execution, productivity, etc.). Deploying it without establishing a reference trajectory and benchmarks to guide its design and infrastructures will therefore inevitably place AI within an overall system model that increases environmental impacts.

In other words, deploying AI use cases without embedding them in a global decarbonisation strategy that is deliberate, coordinated, and consistent means building AI that will remain just as fossil-based as the economy in which it is deployed - both in the resources it consumes for its own functioning and in the trends it will help to drive across the rest of the economy.

XIII. Assessing carbon and energy impacts: AI's technical complexity and diversity

As mentioned above, the term AI refers to many different solutions, services, and uses, going beyond generative AI and covering a wide range of technical diversity. AI methods are often defined as machine learning-based techniques that enable a system to respond to situations it has never encountered before. However, different learning techniques exist (supervised, unsupervised, reinforcement learning, etc.) for different purposes (classification, text or image generation, regression, etc.)

Questioning the relevance of these solutions in relation to carbon and energy constraints must therefore be done methodically, starting with the first step: understanding the possibilities and limitations of assessing the unit impacts of AI solutions over their life cycle (inference phase and training phase).

[129] The net carbon impact of an ICT solution is assessed by comparing the carbon impacts of a scenario with the ICT solution and a reference scenario without it, within the same scope. The total positive and negative carbon impacts of each scenario are included, covering all direct and indirect effects within the assessment scope.

A. Assessing the carbon and energy impacts of the inference phase

There are many different learning algorithms and models, and **their respective carbon footprints can differ by several orders of magnitude.** **For example, during the inference phase:**

- An assessment of the direct carbon footprint of the inference phase (Desroches C. et al., 2025), carried out over the entire life cycle of AI systems and for use cases which are representative of business applications, shows the diversity of the associated impacts, which can vary by several orders of magnitude depending on the size of the model or the structure of the calculation and its phases (calculation and token generation stages). For the inference phase, for example, the measured energy consumption is 50 to 25,000 times higher for a large generative agentic AI model than for a traditional learning model[130](Desroches C. et al., 2025).
- **Some assessments also show a significant difference in consumption depending on the task**, with consumption for image generation, for example, being 50 to 100 times higher than for text generation (Luccioni A. S. et al., 2024).

The level of uncertainty in these measurements are large enough that the orders of magnitude cannot be generalised (Luccioni A. S. et al., 2024): they depend on the measuring tools used and on many parameters, which are currently documented in too few cases to support global analyses. They do, however, give an idea of differences in consumption between models and their applications (Bouza L. et al., 2023; Jay M. et al., 2023), as well as of the main factors driving the increase in their carbon and energy impacts (Desroches C. et al., 2025; Luccioni A. S. et al., 2024) :

- Model size, number of attention layers, weight precision (quantisation), and level of versatility;
- Much higher intensity of generation tasks compared with classification tasks;
- Structuring of computation steps.

At a macroscopic scale, these significant increases in impact across models and applications are far from negligible: some models designed for very specific applications (such as numerical simulation) result in few inferences and therefore relatively low impacts in use, while others are used millions of times a day (see Figure 21 (Schneider Electric, 2024)).

B. Assessing the carbon-energy impacts of the training phase

The same observation can be made for the training phase as well as for the inference phase of the models, with large variations between generative AI models and smaller models tailored to a specific task.

Looking at historical trends, the computing requirements associated with training machine learning models for the same task have increased exponentially in recent years, **despite optimisation strategies aimed at reducing the related energy consumption and carbon impact** (Morand C. et al., 2025).

The strategies implemented by AI stakeholders to improve the energy and carbon performance of models (technological optimisation, reducing the carbon content of the electricity used, etc.) have not

130 From 3.5 mWh per inference for a traditional learning model (Random Forest Classifier) to 96 Wh per inference for a large agentic AI model (table 1, p. 5).

been enough to reduce the impacts of the training phase. Fuelled by the growth in the intensity and volume of computing tasks required, **the impacts linked to the production and use of graphics cards, servers, and data centres have exponentially increased the carbon footprint of model training between 2013 and 2025.**

The energy and carbon intensity of the training phase remains far higher than that of a single inference task, but inference grows directly with the number of times the service is used. For large, versatile models, the training phase can be equivalent to several hundred million inferences (Luccioni A. S. et al., 2024)[131], yet widespread deployments such as today's most popular chatbots tip the balance within just a few weeks.

C. Assessing the carbon and energy impacts of an AI solution: key requirements

As with all digital services - but with strong additional specificities, such as the diversity of applications covered and technical solutions available, their overlaps, and their rapid development - AI is therefore a set of use cases whose assessment of carbon and energy impacts per application is complex, as it depends on many variables specific to each deployment context and design choice. **The requirements for a rigorous and appropriately scoped analysis of the relevance of a digital solution are just as valid for artificial intelligence and its applications.** The assessment of the climate and energy relevance of an AI application or service must therefore be:

- **A systematic assessment**: the relevance of a solution depends largely on the conditions under which it is deployed. There is therefore no one-size-fits-all answer to whether an AI solution is climate and energy relevant[132]: each case must be assessed before deployment is approved, to take account of its specific context (which is a primary factor: the number of uses, its overlap with other services, the demand it creates for new infrastructures, and the real substitutions or savings compared with the initial situation, etc.)
- **A comprehensive assessment, as a "net balance"**: the climate and energy relevance of an AI solution can only be assessed by taking into account all the impacts across its life cycle, including the production phase of the physical components it requires (devices, networks, graphics cards, servers, and data centres). An assessment that considers only the impacts (positive or negative) of the use phase, for example, would not provide information useful for guiding its carbon and energy impact.
- **A systemic assessment:** When assessing the relevance of an AI solution, it is important to account not only for its direct effects but also for its indirect impacts (rebound effects[133], changes in the broader digital systems and uses where the solution is deployed, shifts in non-digital uses, and evolving maintenance needs). Skipping this systemic analysis means taking the

[131] p. 12-13

[132] For example, in the use case of connected lighting (The Shift Project, 2020), the energy-carbon relevance of the solution depends on the type of existing equipment (LED lamps or not), the room's exposure to light, and usage patterns. The same applies to smart electricity meters, which depend primarily on human behaviour (The Shift Project, 2020). Virtual reality meetings are another example (The Shift Project, 2024b), where outcomes depend entirely on context: for instance, real substitution for physical travel only occurs where teleworking is supported by company policy and employees are willing to adopt it.

[133] With different types of effects: financial gains, rebound effects, substitution, optimisation, macroeconomic effects, and societal transformations, etc.

risk that the solution's potential benefits -whether related to energy, climate, or other areas - could be entirely offset by powerful indirect effects that are often underestimated.

This assessment of carbon-energy costs, aimed at informing design and deployment choices for AI solutions, must be part of a broader approach, outlined later in this report (see "Energy and carbon - guiding technology choices to build sustainable AI: key steps").

XIV. .... Assessing the energy and carbon benefits of an AI solution

To assess the relevance of digital solutions based on their environmental benefits, several methodologies currently exist on a French and European level (ADEME, 2024d; Carbone 4 et al., 2024; EGDC, 2024)[134]. These methodologies help to identify the key issues that need to be documented for each major categories of applications, which we specify here for AI use cases:

- For AI applications aimed at reducing energy consumption and carbon emissions:
  - Within this category are certain applications whose objective is to improve the efficiency and performance of processes directly linked to fossil fuel industries and infrastructures. **Even when they help reduce the carbon and energy impacts per application of fossil-based processes, these use cases, sometimes referred to as "AI for Brown," cannot be considered "AI for Green" applications** (Carbone 4 et al., 2024). This category is intended to cover "AI" technologies that support the transition to a sustainable future; **any application that fits within a scenario of maintaining fossil energy is, by definition, not compatible with this scope**.
  - The assessment must be transparent and based on solid evidence - just as with the assessment of the solution's carbon and energy costs, the assessment of its benefits must be as well:
    - **Systematic**: it must not produce generalised findings based on isolated use cases or examples, as they are almost always difficult to reproduce (The Shift Project, 2020) ;
    - **Comprehensive:**
      - It must take into account all phases of the life cycle (including equipment production, not just the use phase);
      - It must not focus only on energy benefits but also consider the "carbon"[135] dimension. Without this, the assessment of the solution's relevance will not be useful for environmental management. The double constraint is therefore only the essential first level of consideration..
    - **Systemic and contextualised:** The relevance of an AI solution depends not only on the indirect effects of its deployment (rebound effects, transformations in certain uses, etc.) but also on the context in which the service is deployed (existing

134 The *General Framework for Frugal AI* (*Référentiel général pour l'IA Frugale*) (AFNOR, 2024) standardises the concept of a "positive-impact AI service".

135 Or even other dimensions, such as the "mineral resources" aspect.

infrastructure already in place, established usage patterns within a group, policies and rules in place within an organisation, etc.). The assessment must consider these limits to avoid extrapolating from poorly documented situations, which could ultimately cancel out the potential benefits of deployment.

- For AI applications that aim to address the energy-carbon challenge through mechanisms other than direct impacts on emissions from human activities (for example, supporting the development of carbon sinks): the carbon–energy cost assessment must be carried out before any deployment, following the same specifications as for other types of application. This is to ensure that the choices made are consistent with the organisation's carbon trajectory, with beneficial effects to be considered only afterwards and on a broader scale (Carbone 4 et al., 2024).
- For applications aimed at environmental objectives other than energy-carbon issues (adaptation to climate change, water, biodiversity, soil pollution, etc.): the carbon-energy cost assessment must be carried out before any deployment, following the same set of requirements as for other types of application. This is to ensure that deployment choices do not harm certain environmental objectives at the expense of others[136].

This assessment must inform technological choices in a way that ensures deployment delivers a net positive energy-carbon impact, and that it fits within an approach whose starting point is the compatibility of the organisation's physical [137] infrastructure and systems with identified energy-climate objectives.

XV. Energy and carbon - guiding technological choices to build sustainable AI: objectives and method

A. Objectives to achieve: setting a course for AI that is compatible with energy and carbon constraints

To align digital technology and AI with a sustainable energy-carbon trajectory, **three objectives must be met simultaneously:**

- Only deploy AI solutions that are viable within a mix of decarbonised, resource-efficient digital goods and services, in a digital sector following an energy-climate compatible trajectory;
- Increase the share of AI solutions designed from the outset for use in a low-carbon world (taking into account transformations in economic sectors, uses and lifestyles, energy and material availability, production and consumption models, etc.), while reducing the share that are not;

[136] Although the methodology set out in this report focuses on energy and climate, and the necessary documentation of other impacts falls outside this report's scope, our methods and recommendations aim to avoid worsening those other environmental impacts and, where possible, help reduce them.

[137] Energy actually used, emissions directly resulting from the activity, etc

- Eco-design and eco-deploy digital and AI products and services to reduce their carbon and energy impacts per application as much as possible, and ensure that their effects on infrastructures, their wider impacts, and large-scale dynamics are not incompatible with the first two objectives

B. A strategic framework to guide the assessment and adaptation of AI services to energy-climate constraints

Meeting these objectives requires following a step-by-step assessment process when making technological choices in the design or deployment of an AI service. This process moves from the functional analysis of the solution (what needs, what functions) to the assessment of its energy-climate impacts. The assessment must consider not only direct effects but also the wider context - both large-scale (infrastructures) and system-wide (indirect effects) :

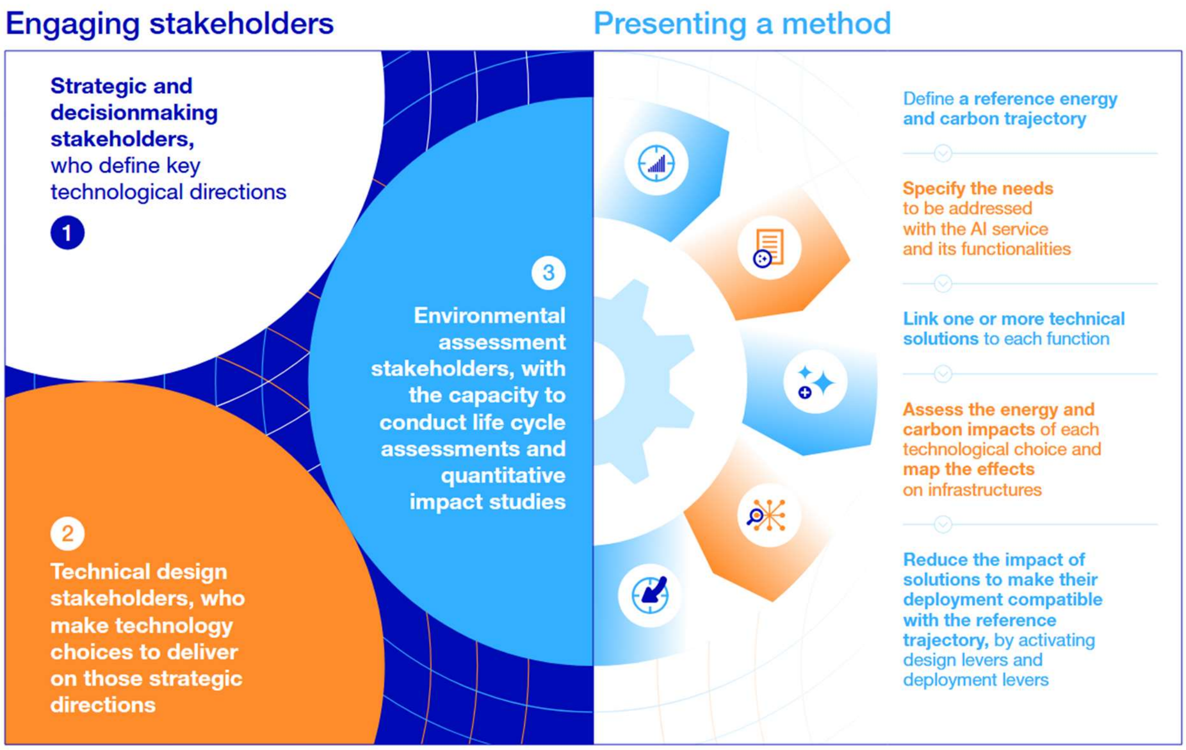
1. **Have a reference energy-carbon trajectory** for the digital system in which the solution would be deployed: this may include the organisation's carbon trajectory, the national sectoral trajectory, SBTi targets, local or regional targets, etc.;
2. **Define the need** to be addressed by the AI application: what specific needs does it meet, and through which functions?
3. **Associate each function with one or more possible technical solutions** to make it operational and address the identified needs: does this require AI (or generative AI), or could more resource-efficient alternatives be used?
4. **Assess the energy and carbon impacts of each technological choice**:
    a. Both by assessing the energy-carbon impacts of an AI solution (see "Assessing carbon and energy impacts: AI's technical complexity and diversity") and, where relevant, by assessing its potential benefits (see "Assessing the energy and carbon benefits of an AI solution")
    b. and by mapping the effects that each technical solution will have, once deployed, on the digital system's physical infrastructure (network and data centre loads, roll-out of new equipment), as well as on broader dynamics (growth in demand, compatibility with a sobriety trajectory, etc.) ;
5. **Minimise the impacts of the AI solutions so that their deployment is compatible with the reference trajectory**, by activating **design levers** (optimisation; modification or removal of certain functions) and **deployment levers** (adapting the scale of deployment, or even not deploying the solution if no scenario remains compatible with the reference constraint once all possible levers have been applied).

Each step must **involve the three stakeholders in the AI service**, and enable an informed discussion between them:

- **The strategic and decision-making stakeholders**, which steer the main technological directions (desired functionalities, business model and conditions of profitability or relevance, deployment/market entry/procurement scenarios, specification of needs, etc.);

- **The technical design stakeholders**, which make the technological choices to address these directions;
- **The environmental impact stakeholders**, which can carry out life-cycle assessments, quantitative impact studies, and/or analyse compatibility with the sectoral or organisational trajectory.

The final decision must therefore be based on the organisation's physical infrastructure and systems, which helps to clarify the viability of a choice while also taking account of other considerations (productivity, marketing, human and HR factors, etc.). **It must also remain explicit about the trade-offs made** (for example, choosing to use part of the carbon budget to meet a marketing need). Being explicit about these trade-offs helps build stakeholder ecosystems that understand both the issues and choices involved, and that can, in the long run, contribute to building a resource-efficient and decarbonised digital sector.



XVI. ....Energy and carbon - guiding technology choices to build sustainable AI: key steps

A. Setting a quantitative benchmark: energy-carbon budgets and trajectories

The first key component for guiding technological choices related to AI is a large-scale, quantitative reference framework:

- Trajectory of the digital sector and the data centre industry at the regional, national, or global level, to ensure compatibility with the dual carbon constraint;
- Carbon trajectory of the organisation and/or its IT system;
- Energy consumption trajectory of an organisation's digital equipment, aligned with its climate objectives; etc.

Without these quantified and large-scale reference points, quantitative assessments of the impacts of an AI application have no framework and are therefore invalid, since the key questions that should guide technological choices would remain unanswered: is the application, in its current design, compatible with our energy-carbon objectives? **At what point are our deployment choices aligned with decarbonisation goals? These trajectories, and the decarbonisation objectives that underpin them, are essential reference points.** They provide the basis for carrying out energy-carbon cost analyses of AI solutions to support technological decision-making.

B. Clarifying the need and technological choices: functional analysis

The analysis of an AI solution that is going to be designed and/or deployed starts with clarifying its function and the needs it addresses. In a world without constraints, one could skip this step. Given today's constraints, however, mapping these functions and needs is essential, as it clarifies the potential and effects of levers related to functionalities.

Numerous tools already exist for carrying out functional analysis of digital services, including AI solutions[138]. The purpose of this analysis is to:

- **Define the need** to be addressed by the AI solution (as recommended in the "frugal AI" specification developed by AFNOR (AFNOR, 2024)) :
    - What specific needs does the AI solution address (technical, productivity, marketing, etc.)? What does it add compared with the initial situation and context into which it will be introduced?
    - What functions does the solution need to provide in order to meet these needs?

- **Link one or more possible technical solutions** to each function:

[138] Including, for example, the initial steps of ADEME's "consequence tree" method (ADEME, 2024d).

- If an AI solution is suggested for a function: is the use of AI really necessary, or are more resource-efficient alternatives available?
- If AI is necessary to make a function possible, are there more resource-efficient AI solutions that can deliver the same service[139])?

This work provides a clear and objective description of the AI solution, together with an overall view of its functional flexibility, which is required for the next stage of the analysis.

When deploying technological solutions, it is of course not possible to foresee all the ways an AI solution might be used, or all the needs it could meet depending on scale and patterns of adoption. If deployment goes ahead without a clearly defined need (for example, the widespread roll-out of a general-purpose technology), it must still undergo an assessment of the associated energy-carbon impacts and their compatibility with the reference budget or trajectory. Where incompatibility is identified, a functional analysis will be required to determine what room for manoeuvre exists to reduce impacts - whether the solution addresses an essential need or not, and through which functionality.

C. From functional analysis to direct energy-carbon costs

Economic analysis alone is not enough to determine whether a solution is resource-efficient or frugal, even when it shows a reduction in its direct energy consumption. The sources of impact are not necessarily direct; they are often shared across infrastructures (networks, data centres, device value chains, sensors, and electronics). Carbon and energy impacts per application are rarely major direct sources of emissions: it is the scale of deployment (expected or actual) and the resulting expansion of national and global infrastructures that determine the true impacts.

1. Qualitative analysis: quickly identifying the major sources of impact

Assessing the energy-carbon impacts of technological choices means linking each technical solution to the demands it places on digital infrastructures. It starts by examining four key questions on the large-scale impacts of each chosen technical solution:

Does the deployment of this technical solution rely on…
... the widespread adoption of new equipment (sensors, user devices, etc.)?
...the expansion of available computing capacity?
...the increase in the volumes of data that can be exploited and/or stored?
...the increase in network capacity (bandwidth, coverage, latency)?

These four questions help to quickly identify the trends in physical infrastructure that a solution would reinforce if deployed. **The more a technical solution contributes to these dynamics, the less likely it is to be viable in a world where digital infrastructure is decarbonised and resource-efficient.**

[139] Non-generative rather than generative AI, for example (see « Complexité et diversité technique de l'IA : comment évaluer ses impacts carbone-énergie ? » for the differences in impacts between AI solutions and the models they use).

The aim is to move beyond a focus on the direct impacts of the AI solution by establishing an initial analytical framework for the digital system as a whole: **in which large-scale trajectory have we implicitly positioned ourselves when making our technological choices, and how does this determine their technical relevance?**

To clarify the definition of possible digital futures (such as the scale of mobile and satellite networks, the capacity and service levels available in cloud and computing infrastructures, and the population's rate of equipment ownership) within which the chosen technical solutions can be used, an analytical framework is provided in appendix 11 (The Shift Project, 2025a)[140]. Inspired by ADEME's *Transitions 2050* scenarios (ADEME, 2021), **it offers qualitative reference points on the structural dynamics of the digital system by projecting them into four broad levels of energy, carbon, and material intensity.**

- **For data centres:**
  - Service levels available (availability, latency, etc.) compared with today;
  - Available storage capacity (data accessible and/or usable);
- **For networks:**
  - The share of mobile uses compared with fixed/WiFi uses;
  - Network capacity in terms of bandwidth and latency;
  - The level of geographical coverage;
- **For devices:**
  - The performance of user devices (smartphones, computers)
  - Deployment of new connected devices (whether new types of devices or entirely new connected infrastructures);
  - The rate of equipment ownership among the population and organisations (screens, TVs, consoles and new devices, tablets, etc.).

2. Quantitative analysis: developing the key indicator for decision-making

This qualitative and simplified approach helps to quickly identify which technological choices will be most decisive in the impact of an AI solution: the closer the minimum scenario in which a technical solution can operate is to the fourth level of intensity (for example, because it requires service levels equivalent to or higher than today's best standards in data and computing), the more it is likely to become a decisive source of both direct and system-wide impacts once the AI solution is designed and deployed.

This initial qualitative analysis feeds into the quantitative phase, which involves carrying out a life-cycle assessment of the AI solution to assess its energy-carbon impact under a design and deployment scenario reflecting what the organisation itself plans. Many methods for conducting quantitative[141] analysis already exist. The challenge today is therefore less about developing new ones than about consolidating those in place and ensuring their deployment:

[140] Many methods already exist to carry out this type of so-called "consequential" analysis, documented in the academic literature. For example, ADEME's *Empreinte projet* (*Project footprint*) (ADEME, 2024b) and ADEME's *QuantiGES* (*Quantification of GHG impact*) (ADEME, 2022).

[141] The life cycle assessment method (ISO 14040 and 14044) and its various adaptations and applications to digital goods and services enable these quantifications, or part of them, to be carried out across different system boundaries. For example, the simplified EcoLogits calculator and the CodeCarbon tool can be used to assess the energy use and direct carbon emissions associated with AI applications, depending on the models, how stages and code are structured, the tasks performed, and so on.

- Data is needed to make the application of these methods robust for AI (life-cycle assessments of AI accelerators and other equipment used, transparency on the technical features and consumption of different models during both training and inference, etc.);
- Classification and standardisation of the methods to be used across sectors and/or types of solutions is essential, in order to align stakeholders in the sector around a consolidated and comparable set of tools.

D. Eco-design and eco-deployment: making AI solutions compatible with the organisation's energy-carbon budgets

Eco-design and eco-deployment bring together the levers available to those designing or deploying AI solutions to **reduce their energy-carbon impacts, with the aim of making them compatible with the reference trajectory** of the organisation, the region, or the sector.

1. Eco-design: a lever for creating digital goods and solutions that are compatible with transition scenarios

Design levers refer to the choices available to those developing AI solutions for deployment:

- **Optimisation**: how to deliver the same functionalities while using as little energy and carbon budget as possible (in both the use and production phases)? **Optimisation levers aim to keep the final service proposition exactly the same**, while acting only on the components of the AI solution that allow this in order to **reduce the carbon and energy impacts per application**: compact models (lighter, more specialised, etc.), software and computing approaches that consume fewer IT resources, hardware with lower production impacts, less carbon-intensive energy, and reliance on equipment that is more energy-efficient but offers the same capacities, etc
- **Adjusting functionalities**: which functionalities can be transformed, modified, or even dropped to reduce the energy-carbon footprint of the service? **Functionality-related levers provide a first level of trade-off** by questioning each function in terms of its essential contribution:
    - A functionality planned at the outset can be modified or even dropped without affecting the core contribution of the AI service;
    - A functionality can be modified or dropped with some reduction in the final outcome, but limited enough for the AI service to remain relevant while reducing its energy-carbon impact.

The use of these levers must be reintegrated into the quantitative analysis previously carried out on carbon and energy costs, in order to define their potential and assess the extent to which they do or do not make the AI service compatible with the reference trajectory. **These levers can also be made available to actors deploying services without designing them, by making the solutions modular**. This allows an organisation using AI services to choose the mix of functionalities best suited both to meeting its needs and to ensuring compatibility with its carbon trajectory.

2. Eco-deployment: a lever to achieve digital sobriety at the right scale

Deployment levers include those available to organisations making purchasing and deployment choices for the AI services offered to them: to what extent should the scale of deployment be reduced (number of uses, locations, or audiences given access to the solution) in order to stay within energy-carbon budgets once the other levers have been activated ? Can the solution be deployed in compliance with the energy-carbon constraint?

A qualitative analysis can first be carried out to assess the different deployment options. An analytical framework to support this exercise is provided in appendix 11 (The Shift Project, 2025a). It sets out four main levels of deployment intensity:

- **Very targeted deployment** to meet a particularly well-defined need very precisely defined activity areas, identified by the essential role the use case will play for them);
- **Targeted deployment,** limited to certain types of sites or sets of use cases;
- **Undifferentiated deployment** (broad deployment without prioritising particular activity areas or sets of use cases);
- **Undifferentiated deployment with widespread adoption** (large-scale deployment combined with sustained momentum aimed at generalising and systematising the use of the AI service).

This analysis, which can be carried out at the level of an organisation, a region, a team, or even a single person, helps to **clarify the main ways in which the new usage system may take shape around the AI solution to be deployed or adopted**: are we creating a pattern of maximum use, one that follows prevailing trends, one that is eco-designed, or one that is both eco-designed and resource-efficient?

This qualitative analysis will help to identify the key factors shaping the planned usage scenarios for the AI service, and will in turn feed into the quantitative analysis. The latter will adjust the assumptions on deployment levels in the initial quantitative assessment of energy-carbon costs, making it possible to assess the extent to which deployment levers do or do not make the AI service compatible with the reference trajectory.

E. Make the AI service compatible with the trajectory - or abandon it

Optimisation levers are usually the first ones used by organisations aiming to reduce the impact of their AI services. They make full use of all available gains in carbon and energy efficiency, without altering the final service delivered.

If optimisation alone is not enough to reduce carbon and energy impacts per application sufficiently for the initial deployment plan of the service to be compatible with the reference trajectory, **trade-off levers become necessary**: either the scale of deployment is adjusted, or certain functionalities initially planned for the service need to be simplified or abandoned. **In some cases, even different combinations of levers may still result in the AI service being incompatible with the reference carbon trajectory:**

- A carbon impact that remains too high even after all possible levers have been activated.
- An AI service made unviable by the level of trade-offs required to bring it into line with the trajectory: deployment is too limited, or the functionalities too compromised to maintain the service's capacity to address the need originally defined.

In this case, the conclusion is clear: the service in its current form is not compatible with the energy-carbon constraint and must therefore be abandoned as a potential option. This can mean either lowering the priority of the need it was meant to address, or finding ways to meet that need without relying on an AI service. **If one or more combinations of levers can align the service with the trajectory, they define the set of physically feasible options for the final decision, taking into account the energy-climate constraint** (alongside the organisation's broader context - see next section).

XVII. .... Energy and carbon - Guiding technological choices to build sustainable AI: a case study of the personal meeting-summary assistant

Here we present a simplified approach designed to raise some of the far-reaching questions around the energy-climate viability of an AI service. The chosen use case[142] is a personal meeting-summary assistant: a service that generates written summaries from users' discussions during an online meeting.

Clarifying the need and technological choices: functional analysis

Its functionalities can have different levels of complexity:

- Recording the spoken discussions;
- Converting the audio into text;
- Summarising the transcript into meeting notes;
- Additional functionalities may include: enhancing the meeting notes with suggestions or extra resources; the assistant participating directly in the chat messages during the meeting to suggest further resources, etc

In our example, which does not take additional functionalities into account, the detailed functional analysis identifies the use of AI to perform two functions (for a total of est un assistant personnel de compte-rendu : ce service permet de rédiger des comptes-rendus basés sur les échanges vocaux des utilisateurs lors d'une réunion en ligne. 250 tokens[143]): transcribing audio into text; summarising the text.

Assessment: From functional analysis to direct carbon-energy costs

The quantification of the energy-climate impact of deploying this service was carried out using a simplified fictitious case characterised by the following specifications:

- Each meeting summary is equivalent to 250 tokens;

[142] Among those that supported the collaborative analysis carried out for this work (see Appendix 14), (The Shift Project, 2025a).

[143] In output tokens for less than one page of reporting. The assumption used in the example is therefore towards the lower end of the range.

- The service is deployed in a company with 1,000 employees, each holding four meetings per working day and using the transcription service.

The quantitative assessment for this illustrative exercise was carried out using the EcoLogits calculator (Ecologits, GenAI Impact et al., 2025), which here allows us to visualise the effects of the different levers[144].

Guiding technological choices: eco-design and eco-deployment

This use case brings together the different sets of levers described in our method:

- **Optimisation levers**: relying on a model whose computing capacity is hosted in a geographical area with lower carbon intensity electricity reduces the carbon impact of the solution without changing its functionalities (the effectiveness of such tools depends heavily on the initial carbon content of the electricity supply);
- **Design levers:** choices regarding the model and its size can reduce the service's carbon impact, at the cost of giving up certain functionalities or performances that are not considered essential to what the service delivers (for example, a model that is less versatile, accurate or fast);
- **Deployment levers**: adopting an eco-deployment policy within the company, which limits the use of this service to a minimum number of meetings where the need is clearly defined, reduces the service's impact across the organisation[145].

Make the AI service compatible with the trajectory - or abandon it

A comparison with a reference threshold will determine whether the measures used are sufficient to make the solution compatible with the energy-carbon constraints, and help assess whether its deployment is feasible

:

- **The reference threshold must be determined on the basis of the organisation's reference trajectory or budget**, translated into its digital[146] systems and services. It is specific to the organisation and to the scope considered for deployment.
- **While this quantitative carbon analysis is not the be-all and end-all of the decision, it remains indispensable.** Deployment decisions must also take into account the risks of potential indirect and systemic effects (rebound effects on the number of documents stored, indirect changes in meeting practices, etc.) and ensure that safeguards are implemented alongside the solution to contain possible harmful effects.

This use case illustrates the approach described above, an approach intended to support digital technologies in aligning with a sustainable energy and carbon trajectory (see "Energy and carbon - guiding technology choices to build sustainable AI: key steps").

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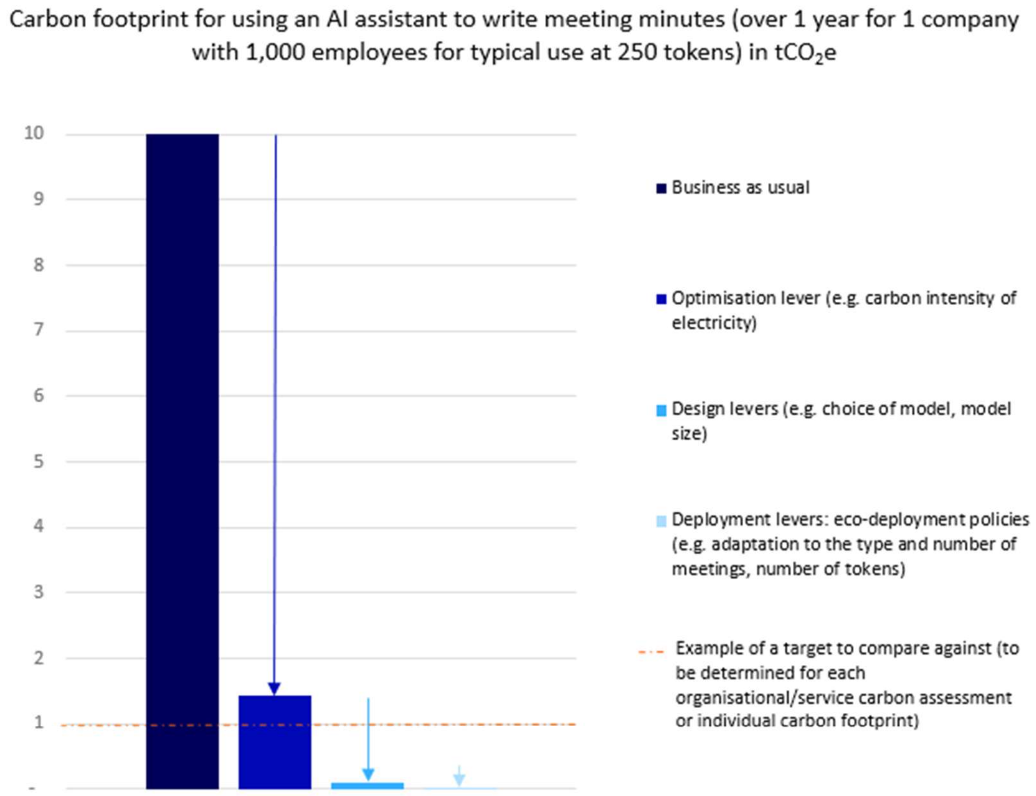
[144] While calculating the service's final impact is essential, the quantitative calculation of each tool's effects to compare them with one another will depend on the order in which they are activated. Their relative effectiveness is therefore not a conclusion independent of the modelling choices.
[145] The length of a standard meeting summary can also be part of this type of policy.
[146] Which can be built on sectoral or national digital targets, such as the SBTi target (SBTi et al., 2020).



This type of approach must be adapted to each specific use, or even to each mix of uses, both by IT departments and by users : https://huggingface.co/spaces/genai-impact/ecologits-calculator.

This approach requires a methodological step back from emission factors (kgCO2e/token), which, at least to date, are marked by a lack of transparency, even when estimated by reliable calculators, and by uncertainties about future emission factors. Furthermore, monitoring usage levels and not just the carbon footprint is a first line of defence against this pitfall. Thinking in terms of scale is a second line of defence: 'What if 1% of the planet did the same thing?', 'What are the main drivers?', etc.

It should be noted that the quantitative calculation of the effects of each lever in order to compare them depends primarily on the order in which the levers are activated.

Figure 37 -Carbon footprint assessment approach using an online calculator for AI services or a mix of AI services. Source: (The Shift Project, 2025b, 2025c)

Recommendations

This report shows that the environmental cost of the current approach to designing and deploying AI is real, well-established, and substantial. The reasons are largely systemic and, to a great extent, the same as those driving the drift in the energy and carbon footprint of the entire digital ecosystem. Addressing them requires the involvement of all stakeholders:

- **Public decision-making and governance actors**: public authorities, public bodies for carbon-energy planning, and public bodies for digital regulation and planning;
- **Companies and organisations using AI services;**
- **Developers and providers of AI services;**
- **Developers and providers of AI infrastructures and components;**
- **Public and private media actors;**
- **The academic sector;**
- **Education and training providers**: initial education and training (universities, engineering schools, vocational schools for digital professions, etc.), and public and private continuing education and training providers;
- **The general public.**

The scale of the shifts needed in underlying dynamics means drawing on every type of lever available to transform AI infrastructures and uses. Technological levers are essential, but insufficient if not combined with societal and organisational levers: **decarbonising digital technologies involves not only technical decisions but also societal and political ones.**

A systemic approach, applying the **four sets of measures** in the right areas and at the right level, will enable artificial intelligence and data centres to transition towards a future compatible with the dual carbon constraint:

- **Measurement and transparency:** without measurement, evidence-based prioritisation is impossible. Without transparency, there can be no measurement and no reliable orders of magnitude;
- **Optimisation**: a complementary lever that is only useful if the level of service delivered remains unchanged, and should therefore be combined with mechanisms that act on service volumes to avoid rebound effects;

- **A collective shift towards sobriety**: a radical transformation of usage systems and organisational-economic models, without which decarbonisation goals cannot be achieved;
- **Information, education and skills**: to enable stakeholders to make well-informed choices in design, use or regulation, with the best possible understanding of the issues (especially energy-carbon and environmental).

The recommendations presented here are not exhaustive. They are intended above all to fill gaps and address blind spots where guidance is still essential, and should be read as a complement to - and in support of - the radical transformations needed to make the digital ecosystem sustainable. These transformations are required to tackle the structural and systemic aspects of the drift we have highlighted in our reports since 2018: volume-based business models, the regulatory framework, information asymmetry, addictive designs, etc.

Finally, we have indicated which stakeholder(s) each of our 20 recommendations is primarily aimed at.

Measurement and transparency
Objective: Ensure public monitoring of the data centre sector
Annually monitor and update the electricity consumption of data centres (including company data centres[147]). Initiating actors: • Public bodies responsible for digital planning and regulation • Public bodies responsible for assessing and planning electricity, energy and carbon trajectories
Communicate quarterly on the status of connection requests for data centre sites. Initiating actors: • Public bodies responsible for digital planning and regulation • Public bodies responsible for assessing and planning electricity, energy and carbon trajectories
Make the national statistical system much more detailed for digital activities, including quarterly monitoring of server delivery volumes. Initiating actors: • Public bodies responsible for digital planning and regulation • Public bodies responsible for national statistics
Provide reliable and transparent data on manufacturing impacts (AI accelerators, components, etc.). Initiating actors: • Public bodies responsible for digital regulation • Public regulatory bodies • Developers and providers of AI infrastructures and components

[147] If needed, through a representative sample of companies

Objective: Ensure transparency of the services provided

Ensure that providers disclose to companies the energy consumption of the services purchased (where necessary through a legal obligation).

Initiating actors:
- Public bodies responsible for digital regulation
- Public regulatory bodies
- Providers of AI services

Ensure that providers disclose to the general public the carbon and energy footprint of the AI services they offer.

Initiating actors:
- Public bodies responsible for digital regulation
- Public regulatory bodies
- Providers of AI services

Objective: Track the effects of AI deployment

Assess the impact of AI development and the deployment of computing power across devices and networks.

Initiating actors:
- Public bodies responsible for digital regulation
- Public bodies responsible for assessing and planning electricity, energy and carbon trajectories
- The academic sector
- Providers of AI services
- Providers of AI infrastructures and components

Optimisation

When it comes to generative AI, prioritise specialised AI (sector-specific) over general-purpose AI.

Initiating actors:
- Companies using AI services
- Providers of AI services

Focus research and development efforts on efficient AI solutions that are compatible with a sustainable trajectory for computing capacity (specialised AI tailored to sector-specific applications, with low demand for computing and hardware resources, etc.).

Initiating actors:
- Research and development actors
- The academic sector
- Providers of AI services
- Providers of AI infrastructures and components

Integrate the general framework for frugal AI (AFNOR) into public actors' purchasing and development policies, as a means of shaping supply.

Initiating actors:

- Public bodies using AI services

For agentic AI, systematically carry out a net impact assessment for the use case in question.

Initiating actors:

- Companies using AI services

Objective: Reduce the impacts of manufacturing (AI accelerators, components, etc.).

Launch, develop, and implement a decarbonisation strategy for the entire value chain (manufacturing, end of life, repair, etc.) in order to reduce manufacturing impacts.

Initiating actors:

- Public bodies responsible for digital planning and regulation
- Public bodies responsible for assessing and planning electricity, energy and carbon trajectories
- Providers of AI infrastructures and components

Collective reorganisation of uses towards sobriety

Objective: Steer the impacts and dynamics of the data centre sector

Develop a trajectory for digital goods and services in France within the SNBC3 (France's third national low-carbon strategy), clarifying the share attributable to data centres, and ensuring it is effectively steered:

- **An upper-limit trajectory for the resources (electricity, land area, water) that digital technologies can consume by 2035 and 2050;**
- **A trajectory for the associated emissions (in terms of both footprint and in inventory).**

Initiating actors:

- Regulatory actors
- Public authorities responsible for planning and regulating digital technologies
- Public authorities responsible for assessing and planning electricity, energy and carbon trajectories

Make the deployment of data centres conditional on compatibility with the reference trajectory (energy, climate, resources), and allow the use of moratoria (national or territorial) in the event of significant deviation from these reference trajectories.

Initiating actors:

- Regulatory public authorities
- Public authorities responsible for planning and regulating the digital sector

Make an environmental impact assessment mandatory for the installation of any data centre with a capacity above 5 MW.

Initiating actors:

- Regulatory public authorities
- Public authorities responsible for planning and regulating the digital sector

Objective: Regulate the deployment of AI use systems

Cap the amount of general-purpose generative AI use within the organisation so that it stays on its trajectory, and prevent AI components from being integrated by default into general-purpose software.

Initiating actors:

- Private companies and organisations using AI services
- Public organisations using AI service

Maintain existing European regulation on digital technologies, including the AI Act, and develop it further by integrating an environmental performance objective.

Initiating actors:

- Regulatory public authorities
- Public authorities responsible for planning and regulating the digital sector

Knowledge, training, and skills

Maintain the resources (human, organisational, financial, etc.) needed to continue initial and ongoing training on energy-climate issues, and do not redirect them into AI training.

Initiating actors:

- Public and private education and training providers (initial and continuing)
- Companies using digital technologies

Encourage a rigorous public debate on the promises and actual impacts of AI (carbon and energy, environmental, social and societal) through information campaigns and independent reviews, including scrutiny of the messages promoted by stakeholders.

Initiating actors:

- Public authorities leading information campaigns or regulating deployment conditions
- Public and private actors in the media sector
- Academic sectors

Hold an informed public debate on the appropriate role of digital technologies and AI in society in 2030 and beyond, on what defines a decarbonised and resilient digital sector, and on which uses should be prioritised in a context of strong resource competition.

Initiating actors:

- Public actors involved in consultation on digital, technological, societal and/or environmental issues
- Public and private actors in the media and information sector

Conclusions

The lack of transparency - even deliberate opacity - among dominant players in AI, combined with the lack of detail and standardisation in available data and the poor documentation of both existing data centres and new projects, particularly in France and Europe, makes it difficult to conduct any quantitative assessment of the energy-carbon impacts of the “generative AI phenomenon,” even for direct impacts.

It is nevertheless possible - and necessary, given the speed at which the “generative AI phenomenon” is spreading - to set out a number of observations, some of which also serve as warnings:

- The energy-carbon footprint of digital technologies was already rising rapidly before the “generative AI phenomenon” emerged two years ago. That phenomenon has since exacerbated the trend, fuelling a drift away from climate goals (see Chapter **Erreur ! Source du renvoi introuvable.**). The large-scale, indiscriminate use of generative AI and large language models as general-purpose technology plays a central role in this. At the same time, feedback from companies often shows that specialised AI (whether generative using smaller models or otherwise) proves more effective. There is an urgent need to dispel the first myth: that the only possible path is generative AI based on gigantic, fully generalist foundation models that, by their very nature, drive an explosion in energy consumption (see Chapter **Erreur ! Source du renvoi introuvable.**).
- Beyond its negative effect on the digital sector’s own footprint, the “generative AI phenomenon” poses a major risk - already clearly evident in the US and in Ireland - of destabilising the electricity system (see Chapters **Erreur ! Source du renvoi introuvable.** and **Erreur ! Source du renvoi introuvable.**). This risk has also been flagged by the International Energy Agency: the growth rate of electricity consumption by data centres is now growing too fast to be matched effectively, whether in electricity transmission or low-carbon generation. Expected consequences range from conflicts of use with other sectors (industry, transport, housing) to the inability (or even refusal) to maintain electricity decarbonisation trajectories. We therefore need to rethink the approach: in France and Europe at least, an energy-carbon budget (with a multi-year trajectory) must be defined for digital technologies (including AI), within which players can develop strategies compatible with our collective objectives.
- Digital decarbonisation solutions ("green digital solutions") do exist - as defined, for example, by the European Green Digital Coalition (EGDC, 2024) - and there are cases where the use of

AI can help reduce the environmental impacts of a system, under certain contextual conditions and once the reference trajectory for comparison has been clearly defined. An initial analysis, however, shows that the AI used in such cases is rarely generative AI. Under these circumstances, there is no basis for claiming that the direct environmental costs of the "generative AI phenomenon" - tangible and directly linked to the use of generative AI - could be warranted by indirect gains which, even when they do materialise, are not attributable to generative AI: there is no evidence for this at this stage, quite the opposite. Moreover, the growth in direct greenhouse gas emissions from the data centre sector alone casts doubt on the ability to neutralise these emissions within a net-zero framework.

- AI - and digital technologies more broadly - acts as a catalyst. Using it indiscriminately within production and consumption models that remain linear and still heavily reliant on fossil fuels will drive emissions up rather than down. The "general framework for frugal AI" developed by AFNOR offers an initial step, as it calls first for questioning the very need for an AI solution and then for meeting that need with minimal technical resources (AFNOR, 2024). The methodology we have developed is designed to support the design and deployment of AI services compatible with the dual carbon constraint (see Chapter “A strategic framework to guide the assessment and adaptation of AI services to energy-climate constraints”).

There is an urgent need to acknowledge the climate cost of the “generative AI phenomenon” and to assess where these dynamics may lead us from an energy perspective. Ongoing analysis of the energy-climate implications of the “generative AI phenomenon” is vital, as is ensuring a well-informed public debate before making choices that could prove harmful. Over the long term, decarbonising the data centre industry and the digital sector will require not only technical decisions, but also societal and political ones.

This is all the more true in France and Europe, where the deployment of AI as promoted by dominant American players is not only likely to undermine the energy transition but also deepen digital and energy dependency. The AI strategy announced on 23 July 2025 by President Trump (Le grand continent, 2025) openly sets out its goal of dominance.

We therefore hope that the insights provided in this report will help build an independent approach of specific development and selective use of digital technologies and AI, one that is resilient and contributes to achieving our climate and energy goals.

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The Shift Project is a French think tank advocating the shift to a post-carbon economy. As a non-profit organisation committed to serving the general interest through scientific objectivity, we are dedicated to informing and influencing the debate on energy transition in Europe.

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