AI & Society Institute

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Beyond the Energy Efficiency Directive

Toward Sustainable AI Regulation

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This policy brief was written as part of the Observatory on the Environmental Footprint of AI. The Observatory on AI's Environmental Footprint is a project led by the AI and Society Institute at ENS. Under the scientific direction of **Aurélie Bugeau** (University of Bordeaux) and **Anne-Laure Ligozat** (ensIIE), it aims to advance research on the assessment of the environmental footprint of AI and identify avenues to mitigate its toll.

The **AI and Society Institute** fosters the responsible development and use of AI by studying its interactions with society. It produces analyses grounded in scientific methods to inform policy in France and Europe. It is led by **Constance de Leusse** (Executive Director) and **Hugo Mercier** (Scientific Director).

Published in May 2026

 Suggested citation: Lenoir, T., Valdivia, A., Bugeau, A. and Ligozat, A.-L., *Beyond the Energy Efficiency Directive: Toward Sustainable AI Regulation.* Observatory on the Environmental Footprint of AI at ENS, April 2026.

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Introduction and summary

In November 2025, Google made headlines by announcing an ostensibly bold research program exploring the possibility of placing data centers in space, building an interconnected network of solar-powered satellites equipped with processors to perform computations from space. The initiative underscores both the scale and the urgency of the growing need for technology companies to secure sufficient energy to power the digital infrastructures of the future, in which AI is set to play a central role.

Over recent years, a wealth of evidence has accumulated documenting the environmental impact of AI. AI systems require vast amounts of energy to train and operate, contribute to CO_2 emissions, demand minerals for infrastructure, consume water for cooling computing hardware, and affect biodiversity through the proliferation of data centers worldwide. However, our understanding of AI's environmental footprint remains nascent. This is partly because the technology itself is evolving rapidly, and partly because technology companies continue to restrict access to data that could clarify AI's resource consumption, both at the individual and systemic levels.

This brief highlights key information about the environmental footprint of AI for decision-makers. The first section presents key findings from existing literature and discusses ongoing debates regarding AI's environmental impact. The second section examines current regulations, and in particular the revised Energy Efficiency Directive. Drawing on insights from an expert workshop held at *École normale supérieure* on December 10, 2025, convened on the occasion of the annual conference of the Observatory on AI's Environmental Footprint, we assess the strengths and weaknesses of the Directive. We make three main observations for future regulations:

1. More environmental indicators are needed to go beyond energy consumption.
2. The scope can be wider to include both edge computing and extraterritorial uses.
3. Further regulation will require objectives, raising the difficult question of ICT usage.

We hierarchize the Directive's limitations in the table below.

Table 1. List of limitations, by order of priority and category

Priority level	**Limitation category**	**Limitation**
Priority 1	Indicators	● The sustainability indicators are limited: there is no requirement for reporting of GHG emissions or biodiversity impacts, nor is there consideration of chemical elements used for cooling. ● Embodied emissions are not accounted for. ● The water indicators should account for hydric stress with indicators such as the Water Deprivation Potential (WDP). ● The use of diesel backup generators is not addressed.
	Scope and reach	● The directive excludes extraterritorial digital uses, despite 53% of French digital usage originating outside France. ● The 500 kW threshold may become less relevant over time. ● Planned data centers are not accounted for.
	ICT usage and objectives	● There are no energy reduction targets. ● Digital services are treated as a whole, making it impossible to prioritize which services to maintain if data centers need to be shut down for energy reasons.
Priority 2	Indicators	● End-of-life reporting for servers and other frequently replaced equipment is not required. ● No information on water discharge is required.
	Scope and reach	● The focus is narrow, limited on data centers: user terminals and network are not considered. ● Exceptions may lead to incomplete data. For example data centers built with EU funding can be exempt, regardless of their size.
	ICT usage and objectives	● There are no restrictions on the use of fossil fuels to power data centers. ● There are no GHG reduction targets.

Priority 3	Indicators	• The data is currently unavailable to civil society (requests have to our knowledge been unsuccessful)

The Growing Environmental Footprint of AI

Key Information About AI's Environmental Footprint

There are a number of reviews of key elements about AI's environmental footprint of AI[1]. In this section, we only bring to light a small subset of available knowledge, which we believe is the most important to keep in mind when evaluating AI's rising environmental cost.

AI relies on the computing power of AI accelerators, that is specialized computer chips or microprocessors such as graphics processing units (GPUs) and tensor processing units (TPUs). Over time, advancements in chip technology have enabled faster computations and the processing of vast amounts of data. These microprocessors are housed in data centers. While only a small subset of data centers are dedicated exclusively to AI, most are used for a variety of digital functions, including storing and transmitting data for services like streaming. As a result, the environmental footprint of AI is closely tied to both the chips themselves and the broader data center industry.

Most current global estimates of AI's energy consumption are based on the number of AI accelerators in use. Importantly, many reports project a dramatic increase in AI's energy requirements, driven by the anticipated growth in the number of AI accelerators entering the market. Consequently, AI is poised to become a major energy consumer in the future. It will also further intensify the demand on data centers worldwide.

Here are a few numbers to understand the electricity consumption of AI usage (excluding hardware manufacturing) and put them in perspective:

- In **2024**, the annual electricity consumption of **France** was 450 TWh (RTE, 2024)
- In **2024**, the global annual electricity consumption of **data centers** was 420 TWh, excluding cryptocurrencies. It was 165 TWh in 2014 (IEA, 2025)
- In **2025**, the global annual electricity consumption of **AI accelerators** is estimated to be 100 TWh (Schneider Electric, 2024).

[1] See for example, Sasha Luccioni, Bruna Trevelin and Margaret Mitchell's The environmental impacts of AI - Primer, or Lou Welgryn and Théo Alves Da Costa's *Intelligence artificielle : le vrai coût environnemental de la course à l'IA* (in French).

- In **2030**, the global annual electricity consumption of **data centers** could reach 1500 TWh (Shift Project, 2025)
- In **2030**, the global annual electricity consumption of **AI accelerators** could reach 775 TWh (Shift Project, 2025)
- In **2035**, the global annual electricity consumption of **data centers** (without cryptocurrencies) is projected to be between 700 and 1720 TWh (IEA, 2025)

These numbers represent only a subset of existing estimates.[2] Important variations arise among studies depending on the methodologies used and perimeters (e.g. taking cryptocurrencies into account or not). Due to limited transparency from AI operators and hardware manufacturers, and the lack of standardized methodologies until very recently, these estimates provide useful orders of magnitude, though their precision is limited.

Currently, the energy consumption of AI accelerators is at its lowest. However, as digital businesses and industries increasingly adopt AI to streamline their operations, and as AI-mediated interactions (such as agents assisting users in work, shopping, and daily planning) become more widespread, energy use is expected to rise sharply. In essence, the projected increase in AI's electricity consumption hinges on the assumption that AI adoption will continue to expand rapidly and at industrial scale.

Another important resource needed to train and use AI is water, although less studies document AI's water consumption. Water usage distinguishes water withdrawn (the water taken from a source) and water consumed (the water that cannot be restituted locally after it is used, for example because it is evaporated). A study provides an estimation, quantifying that training the GPT-3 model required over 5 million liters of water, primarily for cooling data centers and generating electricity, though this figure does not account for water used in manufacturing the necessary hardware. During inference, the model's water footprint remains significant. The increased consumption of water for operating data centers is reported by major digital companies in their sustainability report.

AI also affects the environment in several other ways. Its carbon footprint, primarily in the form of CO_2 emissions, varies significantly depending on the energy sources powering data centers. Biodiversity is another concern, as new data center projects can disrupt local ecosystems. Additionally, the hardware required for AI relies on the extraction of minerals through energy- and CO_2-intensive processes. For further details, see the reviews referenced in footnote 1.

Consequences for policy making

The rising energy demand of artificial intelligence raises important questions for policymakers. First, and most evidently, from an environmental perspective, the growth of the data center industry, driven in part by AI, challenges countries' ability to meet their environmental goals. As the Shift Project notes, greenhouse gas

[2] For example, the 2026 IEA report, *Key Questions on Energy and AI*, sees electricity consumption from data centres roughly doubling from 485 TWh in 2025 to 950 TWh in 2030

emissions from the data center industry are projected to increase at a rate of 9% annually until 2030, even though emissions need to decrease by 5% per year to achieve net-zero targets.

Beyond environmental concerns, the voracious energy demands of AI and data centers have sparked conflicts over energy access. In 2023, data centers accounted for 21% of Ireland's total electricity consumption (in a country where many major tech companies have established their European headquarters). As early as 2021, Ireland's national grid operator, EirGrid, warned that the surging energy demand from data centers was placing unsustainable pressure on the electricity system. In response, the Commission for Regulation of Utilities (CRU) imposed an effective moratorium on new data center grid connections in Dublin. The government and energy operators ramped up energy production but had to turn to fossil fuels, the most readily available sources. Much of the new energy capacity was diverted to powering data centers rather than supporting the electrification of other sectors such as transport or industry. Ireland's experience serves as a cautionary example, especially as the EU's AI Continent Action Plan proposes tripling data center capacity by 2030.

The energy demands of AI are posing significant challenges for energy operators. According to the French Competition Authority, it can take between five and seven years for a new facility to successfully connect to the electricity grid. As a result, AI service providers must secure their grid connections well in advance. While France has introduced accelerated procedures for these connections, prioritizing the demands of data centers may require energy providers to turn down requests from other sectors.

One cascading effect of higher electricity demand is electricity price for households. In the U.S., residential retail electricity prices rose by 7.4% between September 2024 and September 2025. This increase is attributed to the current data center frenzy and is outpacing general inflation. It is expected to continue at least through 2026. In parallel, while data centers are consuming more electricity than ever, the prices they pay for that energy have risen only modestly compared to the steep increases faced by residential consumers.

One final point of concern is the emerging competition between AI service providers and traditional energy operators. Data centers rely on backup generators to prevent any interruption in energy supply, as even brief outages can have severe consequences for their services. Additionally, major technology companies are increasingly investing in low-carbon energy sources to power their data centers. For example, in June 2025, Meta signed a 20-year energy deal with Constellation Energy to supply 1.1 gigawatts of nuclear power to its AI data centers in Illinois, starting in 2027. Similarly, Google has partnered with Kairos Power to develop advanced small modular reactors (SMRs) and announced plans to fund three new nuclear power plants in the U.S., each with a capacity of at least 600 megawatts. As a result, AI operators may eventually produce energy surpluses, which they could sell on the market, potentially competing directly with existing energy providers.

Governing AI's Rising Energy Demand

A number of European regulations indirectly address the environmental footprint of AI. The Corporate Sustainability Reporting Directive introduces new transparency requirements for large companies in the

EU. Additionally, the Ecodesign for Sustainable Products Regulation establishes measures to reduce the environmental impact of digital components throughout their life cycles. Among the existing legislative framework, the Energy Efficiency Directive is the most closely related to AI, as it specifically targets the energy use of data centers.

On December 10, 2025, the Observatory on the Environmental Footprint of AI organised its first annual conference, bringing together scholars and experts to discuss the latest research on the environmental impacts of AI. As part of the event, we facilitated an expert workshop with representatives from the French administration and regulatory authorities. The workshop aimed to evaluate the advantages and challenges of potential regulations in this field. The specialised workshop was led by Ana Valdivia, Lecturer in AI, Government and Policy at the University of Oxford. Below, we summarize the key takeaways from these discussions.

The Energy Efficiency Directive

The Energy Efficiency Directive (EED) is part of the European Union's strategy to enhance energy efficiency and reduce overall energy consumption across its member states. Originally adopted in 2012 and subsequently revised in 2018 and 2023, the directive establishes a robust framework for achieving the EU's ambitious climate and energy goals. Its primary objective is to ensure that the EU meets its 2030 target of reducing greenhouse gas emissions by at least 55% compared to 1990 levels, while simultaneously improving energy security and affordability for consumers.

The 2023 Energy Efficiency Directive introduces new regulatory requirements specifically targeting data centers. It mandates that EU member states monitor and report the energy performance of data centers through a centralized EU-level database. This new obligation aims to increase transparency and accountability of data center operators, ensuring that data centers, both large and small, are held to energy efficiency standards.

Data center operators need to integrate energy efficiency considerations into their core operational and investment strategies. The directive's emphasis on the "energy efficiency first" principle means that new and existing facilities must prioritize energy-saving technologies, such as advanced cooling systems, renewable energy integration, and hardware optimization.

The directive primarily targets data centers with an IT power demand exceeding 500 kW. These facilities are required to report their environmental performance at least once a year, ensuring that both large and medium-sized data centers contribute to the EU's energy efficiency objectives. Data centers used for defense purposes are explicitly excluded from these requirements. Additionally, colocation data centers (in which the operator provides the physical infrastructure, while clients retain ownership and control of their own IT equipment) face reduced reporting obligations.

Concretely, starting from May 2024, data center owners and operators must annually report a comprehensive set of energy performance metrics to a centralized EU database. The required data includes floor area, installed power, data volumes, energy consumption, Power Usage Effectiveness (PUE), temperature set points, waste heat utilization, water usage, and the use of renewable energy. Operators are encouraged to follow the best practices outlined in the most recent version of the European Code of Conduct on Data Centre Energy Efficiency.

Data centers with a total rated power exceeding 1 MW are required to utilize their waste heat for heating purposes or other energy recovery applications, unless it is technically or economically unfeasible. In France, the transposition of the EED requires through a decree from December 29 2025 that data center operators reuse 20% of excess heat.

Strengths

The revised Energy Efficiency Directive (EED) introduces key improvements to tackle the growing environmental impact of AI. Notably, the EED establishes essential transparency requirements. During the expert meeting on December 10, participants highlighted the inclusion of a comprehensive set of indicators, covering energy and water consumption and waste heat utilization. The EED is designed to collect information used to evaluate

> *how efficiently [a data center] uses energy, how much of that energy comes from renewable energy sources, the reuse of any waste heat that it produces, the effectiveness of cooling, the effectiveness of carbon usage and the usage of freshwater.* (EED, Recital 87)

The precise information required from data centers is detailed in the Delegated Regulation (EU/2024/1364) of 14 March 2024, which sets out the information and key performance indicators for the reporting obligation (see Annex II of the Delegated Regulation, in appendix).

The EED also provides references to existing methodologies detailed in standards and frameworks to measure 6 of the 24 key performance indicators listed in Annex II. The total energy consumption and the energy consumption of IT equipment can be calculated using CEN/CENELEC EN 50600-4-2 or equivalent standards; the total water and total potable water input using CEN/CENELEC EN 50600-4-9; the waste heat reused using CEN/CENELEC EN 50600-4-6; and the total renewable energy consumption using CEN/CENELEC EN 50600-4-3.

The experts gathered on December 10 2025 also lauded the incentives to reuse the waste heat for data centers with a total rated power exceeding 1 MW. In Sweden, the Stockholm Data Parks initiative partners with local leaders to use waste heat from data centers to warm homes. Similarly, in Finland, a data center region near Helsinki is being built to recycle waste heat to warm the city of Espoo and neighboring areas, potentially becoming the world's largest scheme of its kind. While these initiatives are commendable, experts point out that the reuse of data center waste energy requires significant coordination with city officials, often years in advance of infrastructure implementation.

The EED includes a large number of data centers, as data centers with an IT infrastructure electrical demand of at least 500 kW are subject to transparency and reporting obligations. The 500 kW threshold is relatively low for modern data centers, as most commercial and hyperscale facilities operate in the 1 MW to 50 MW range. Sites above 3 MW might already represent 43% of Europe's data center power market size in 2024.

Finally, the EED aims at making information public. Under the Energy Efficiency Directive (EED), the European Commission is responsible for establishing and maintaining a European database that collects, centralizes, and publishes data on the energy performance and sustainability of data centers. This can be an important resource for future research on data center energy consumption as well as for civil society more broadly. However, only partial and aggregated information is accessible to the general public.

Limitations

More environmental indicators are needed

One important limitation concerns the **indicators** listed in the regulation. Several significant environmental impacts of data centers are absent, as the directive primarily targets energy usage. For instance, while Recital 87 of the Energy Efficiency Directive (EED) states the objective to evaluate "the effectiveness of carbon usage," there is no explicit mention of CO_2 emissions in the directive itself or in the Delegated Regulation (EU/2024/1364), which specifies the key performance indicators to be evaluated by data centers. In addition to CO_2 emissions, other critical indicators, such as biodiversity impacts and the use of chemical elements for cooling, are also overlooked.

Furthermore, some existing indicators could be enhanced. For example, the current water indicators do not account for hydric stress, which could be addressed by incorporating metrics like the Water Deprivation Potential (WDP). Similarly, there is no indicator related to water discharge. The directive also emphasizes the efficient use of resources but does not consider embodied emissions from the manufacturing of IT equipment. This omission is somewhat paradoxical, given that the directive requires Member States to consider the life cycle of buildings. Similarly, the regulation's focus on energy does not require end-of-life reporting for servers and other equipment that are frequently replaced.

Finally, the data collected is not yet available to a wide range of stakeholders including civil society organizations and researchers. This limits the ability of citizens to understand the impact of data centers and make informed decisions.

The regulation's scope can be wider

A second set of limitations arises from the regulation's **scope and reach,** in particular in terms of the location of data centers and their power capacity. The directive excludes extraterritorial digital uses. For example, a January 2025 study by the French environmental regulatory agency Ademe and telecom regulator Arcep estimated that 53% of France's digital usage was hosted in data centers located outside the country. Given Europe's significant reliance on extra-European digital services, both for individuals and organizations, a substantial portion of Europeans' digital activities occurs outside the European Union and thus falls outside the regulation's scope.

In addition, while the 500 kW threshold allows regulators to include a large proportion of data centers, this threshold may become less relevant over time, especially given the rise of edge computing. Allowing computing tasks to be performed on end devices, such as smartphones or personal computers, could be beneficial from an energy perspective, as it would involve the use of less energy-intensive hardware. At the same time, this shift may increase opacity regarding the energy required to run AI tasks in the future. Overall, the fact that user terminals and networks are not considered remains a blindspot for a comprehensive view of digital services' energy consumption. In addition, current exemptions for specific data centers may lead to incomplete data. For example data centers built with EU funding can be exempt, regardless of their size. Finally, the directive does not provide information on planned data centers.

Further regulation will require objectives, raising the difficult question of ICT usage

A third set of limitations concerns the regulation's approach to **ICT usage and objectives**. The revised Energy Efficiency Directive is designed to provide more information about data center energy consumption, enabling Member States to track efficiency. However, it does not establish a binding normative framework for virtuous practices. For example, Article 12 of the Directive states that "Member States shall encourage owners and operators of data centers in their territory with a power demand of the installed IT equipment equal to or greater than 1 MW to take into account the best practices referred to in the most recent version of the European Code of Conduct on Data Centre Energy Efficiency." This provision can be interpreted as an incentive to adopt the Code of Conduct, rather than a mandatory requirement. More broadly, the Directive does not set goals on the use of fossil fuels to power data centers (for example, the use of energy, including fossil fuels, to power back-up generators is not addressed), nor does it set greenhouse gas emission reduction targets for the data center industry by 2040 or 2050. In addition, the directive does not set energy reduction targets for data centers specifically, although it does require energy reductions overall of "at least 1,3 % from 1 January 2024, 1,5 % from 1 January 2026 and 1,9 % from 1 January 2028" (Recital 62)

The question of how to regulate the use of digital technologies emerged as a thorny regulatory challenge in our discussions. Most evidence regarding the environmental footprint of AI points to a sharp increase in technology use caused by undirected growth in usage. It could be the role of public institutions to engage a discussion on the prioritization of specific uses in light of limited energy resources. Beyond environmental considerations, there are also security concerns caused by the lack of information on the types of usage to which computing power in data centers is dedicated. If digital services are treated as a whole, it becomes impossible to prioritize which data centers should be maintained in the event of energy shutdowns. Future legislation could include transparency requirements for the usage of services within data centers. For hyperscalers hosting multiple clients, an initial categorization could be sectoral.

Acknowledgements

The authors would like to sincerely thank all expert participants in the December 10, 2025 annual workshop of the Observatory on the Environmental footprint of AI for their valuable contributions, insightful discussions, and constructive feedback:

- **Marlène de Bank**, The Shift Project
- **Thomas Brilland**, Ademe
- **Aurélie Bugeau**, Université de Bordeaux
- **Jean-Manuel Canet**, Orange
- **Loup Cellard**, LISN
- **Philippe Cordier**, Capgemini
- **David Ekchajzer**, Hubblo
- **Juliette Fropier**, Ministry of Ecological Transition
- **Simon Gosset**, Capgemini
- **Mathilde Jay**, Ecolab
- **Damien Lacroux**, Université de Bordeaux
- **Anne-Laure Ligozat**, ensIIE
- **Tom Nico**, Arcep
- **Benjamin Ninassi**, Inria
- **Aurélien Palix**, DGE
- **Gauthier Roussilhe**, Hubblo
- **Jacques Sainte-Marie**, Inria
- **Fanny Terrier**, Inria

We are particularly grateful to the attendees who provided detailed comments and suggestions on earlier versions of this paper. The views expressed in this report do not necessarily reflect those of the participants and the conclusions are solely those of the authors.

Appendix

Key performance indicators listed in the Annex II of the Delegated Act

1. Energy and sustainability

- *Installed information technology power demand* (‘PD_{IT}’, in kW)
- *Data centre total floor area* (‘S_{DC}’, in square metres).
- *Data centre computer room floor area* (‘S_{CR}’, in square metres).
- *Total energy consumption* (‘E_{DC}’, in kWh)
    - **CEN/CENELEC EN 50600-4-2**
- *Total energy consumption of information technology equipment* (‘E_{IT}’, in kWh)
    - **CEN/CENELEC EN 50600-4-2**

Measurement of energy consumption

- *Electrical grid functions* - peak demand shifting or firm frequency response (FFR);
- *Average battery capacity* (‘C_{BtG}’, in kW)

Measurement of water input and waste heat reused.

- *Total water input* (‘W_{IN}’, in cubic metres)
    - **CEN/CENELEC EN 50600-4-9**
- *Total potable water input* (‘W_{IN-POT}’, in cubic metres)
    - **CEN/CENELEC EN 50600-4-9**
- *Waste heat reused* (‘E_{REUSE}’, in kWh)
    - **CEN/CENELEC EN 50600-4-6**

Measurement of waste heat temperature

- *Average waste heat temperature* (‘T_{WH}’, in degree Celsius)
- *Average setpoint information technology equipment intake air temperature* (‘T_{IN}’, in degree Celsius)
- *Types of refrigerants*
    - Annexes to the Regulation (EU) No 517/2014 of the European Parliament and of the Council
- *Cooling degree days* (‘CDD’, in degree-days)
    - methodology used by Eurostat and the Joint Research Centre or equivalent
- *Total renewable energy consumption* (‘$E_{RES-TOT}$’, in kWh)
    - **CEN/CENELEC EN 50600-4-3**
- *Total renewable energy consumption from Guarantees of Origin* (‘$E_{RES-GOO}$’, in kWh)

- *Total renewable energy consumption from Power Purchasing Agreements* (‘$E_{RES\text{-}PPA}$’, in kWh)
- *Total renewable energy consumption from on-site renewables* (‘$E_{RES\text{-}OS}$’, in kWh)

2. ICT capacity indicators

- *ICT capacity for servers* (‘C_{SERV}’)
- *ICT capacity for storage equipment* (‘C_{STOR}’, in petabytes)

3. Data traffic indicators

- *Incoming traffic bandwidth* (‘B_{IN}’, in gigabytes per second)
- *Outgoing traffic bandwidth* (‘B_{OUT}’, in gigabytes per second)
- *Incoming data traffic* (‘T_{IN}’, in exabytes)
- *Outgoing data traffic* (‘T_{OUT}’, in exabytes)