TaPP Insight

The Environmental Effects of Digital Trade

How to Monitor, Measure and Mitigate

Summary

UK trade is digitalising fast: more than half of UK exports are now digital, and more than three quarters of services exports are digitally delivered.[1] Yet, the intersection of digital trade and environmental sustainability is complex and underexplored, and the environmental implications of this shift remain a blind spot for policy. [2]

TaPP network held a discussion on 25th April 2025, to explore the environmental effects of digital trade, and how to measure and mitigate them. Our speakers Ingo Borchert, Professor of Economics at the University of Sussex Business School and Deputy Director of the UK Trade Policy Observatory, Vitor Castro, Reader in Economics and Loughborough Business School, and Adrian Friday, Professor of Computing and Sustainability at Lancaster University, spoke about how we assess the impacts of digital trade, what we know about the environmental footprint of the digital world, and our understanding of how the two are interlinked. From a UK government perspective, it is these two priority sectors stand out: environmental goods and services, and digital, where environmental goods and services is currently growing twice as fast as other sectors and digital is seen as a key driver of productivity and innovation. We need a more honest accounting of both the environmental gains and the hidden costs of the digital shift, so that we can find the means to enable digital trade, in a way that doesn't quietly outsource or escalate the carbon footprint. Finding a sustainable way to achieve green and digital growth is essential for UK strategy and ambition to become a global leader.

1. Ingo Borchert – Digital trade and its impacts

Britain has enshrined its commitment to the green transition and net-zero targets in law. Yet the current government remains singularly focused on growth, in particular through growth of new digital technologies. AI and digital services are at the heart of the UK's growth strategy—sectors the UK is backing heavily to drive future prosperity. Trade agreements increasingly reflect this, with chapters calling for the liberalisation of cross-border data flows and a push to accelerate digital services trade. On the surface, this shift seems like a win for the environment: digital delivery means fewer planes in the sky and fewer container ships moving heavy equipment around the world. But the story isn't that simple. While digital trade offers the promise of substitution—doing more virtually instead of physically—it also brings rebound effects. We stream more, consume more, and in many cases, the underlying infrastructure of digital trade is surprisingly carbon-intensive. Remote consulting may replace international flights, but the data centres powering those interactions consume vast quantities of energy.

[1] OECD 2024; [Commons 2024]

[2] While the UK government has been actively pursuing digital trade policies, the environmental effects of digital trade has historically not been considered an area of strategic importance (OECD 2024; UK Gov Digital Trade Strategy 2021).

What is digital trade, and how much of it do we have?

Digital trade—a term that now benefits from a close-to internationally accepted definition—encompasses both the digitally ordered (i.e. goods) and the digitally delivered (i.e. services). But defining is easier than measuring. While trade in goods can, in principle, be tracked by order origin, digitally delivered services remain elusive, with and analysts rely instead on “digitally deliverable” services from balance-of-payments statistics as an upper bound for what may have actually been digitally delivered. (e.g. WTO, 2023).

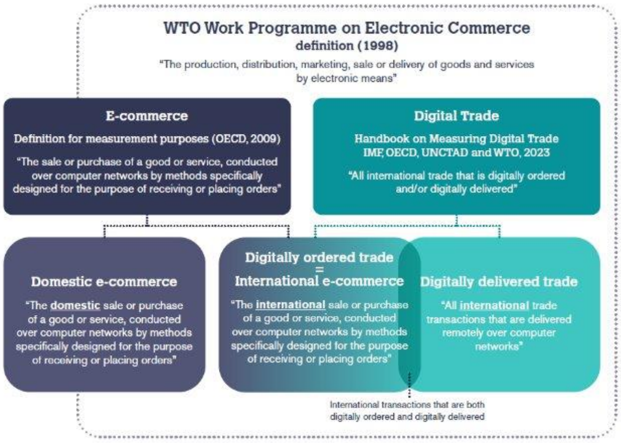

Table 1: Digitally deliverable services
Insurance and pension services
Financial services
Charges for the use of intellectual property
Telecommunications, computer and information services
Research and development services
Professional and management consulting services
Architectural, engineering, scientific, and other technical services
Other business services
Audio-visual and related services
Health services
Education services
Heritage and recreational services
Digital intermediation services provided by DIPs
Digitally delivered services consumed abroad (Mode 2)

The UK’s own accounting of its digital trade is limited. Firstly, digital trade is *not* the same as trade in and by the digital economy - the UK has only officially published stats on the value of goods and services trade by the UK digital sector, a figure far smaller than digital trade. Secondly, cryptocurrencies are excluded from the scope of digital trade – a problem in this context given their significant emissions. Thirdly, so-called “free” services (such as gaming, streaming, AI, etc) are not captured anywhere in official statistics, which is problematic where these might have large environmental impacts. Fourthly, and perhaps most importantly - domestic trade is not included in the definition, although this is the overwhelming share of e-commerce. Roughly 80% of e-commerce is domestic[3], but when it comes to environmental impacts, there little difference between trade transactions that happen intra-nationally as opposed to those which cross international borders. For services, digitally deliverable trade exports of UK services were £340 billion in 2023. Meanwhile, the latest figures for e-commerce are from the 2021 Digital Economy Survey, which indicates that total website sales by UK businesses were £460 billion – this however does not separate goods and services - meaning these figures can’t be added.

Digitalisation – a silver bullet for the environmental impact of international trade?

OECD data and analysis suggest that there is significant variation in emissions intensity across exports, with services having lower CO2 emissions than goods.[4] For example, business services accounts for roughly 40%

[3] Cross-Border Online Shopping Statistics (2025): eCommerce Data
[4] See OECD Data - GHG Footprint Indicators ; and OECD Analysis - Services Trade and Environmental Sustainability

of all UK export value, but only around 15% of CO2. For most goods, the reverse is observed. Could digital trade come to the rescue of UK environmental footprint?

What can policy do?

As the UK seeks to align its trade strategy with its net zero ambitions, attention must turn to how policy instruments can operate along the margins of substitution. This concept focuses not on the aggregate volume of trade but on how trade patterns evolve—between sectors, across modes, and in terms of value-added content. There is growing evidence of scope for *cross-sectoral substitution*—in particular, a shift from goods trade to services trade. This trend holds promise for reducing the emissions intensity of UK exports. However, much of this shift is being driven by the rise of digital intermediary platforms, which are not merely reshaping existing markets but creating entirely new ones – meaning that the environmental impacts of this transformation should be viewed as *additional* to the steady-state emissions trajectory of pre-digital trade. That is, while digitalisation may foster lower-emissions trade, it also contributes to an overall expansion of market activity—with associated environmental implications.

Another important margin of substitution occurs *within* goods trade, through the process of *servicification*—where services are increasingly embedded in traded goods (**Mode 5 trade**). These include design, branding, logistics, IT, and after-sales services. In some specific cases, services are displacing goods entirely—for example, streaming services replacing physical media like CDs or textbooks. While these examples may be small in scale, they represent the shift in how value is delivered and consumed across borders.

The carbon footprint of services trade is not uniform. **Mode 1 trade**—cross-border supply of services via digital means—is considerably less emissions-intensive than other modes, such as **Mode 2** (consumption abroad) or **Mode 4** (temporary movement of people). Facilitating and expanding Mode 1 trade, through regulatory cooperation, digital infrastructure investment, and mutual recognition of standards, could yield substantial emissions savings. Strategic trade policy should prioritise this shift toward lower-emission modes of service delivery.

Secondly, digital technologies such as artificial intelligence and blockchain are not themselves classified as part of "digital trade", they are instrumental in enabling it, and may have a growing indirect role in facilitating cross-border services trade (e.g. via digital platforms and AI-powered logistics). Meanwhile, technologies that remain excluded from formal definitions of trade – e.g. cryptocurrencies have their own environmental footprint (Bitcoin mining alone consumes more energy annually than Finland) (Borchert et al 2023).

Lastly, one of the most critical omissions in current policy discussions regarding trade and climate concerns the treatment of services under carbon border adjustment mechanisms (CBAMs). At present, the EU CBAM, requiring tariffs levied on the carbon content of imports, applies only to a narrow set of high-emissions goods, such as steel, aluminium, cement, and fertilisers. **Services are entirely excluded** from this framework. This exclusion is problematic, given their growing share of global trade and the potential for embodied emissions.

2. Adrian Friday – Digital, but not dematerialised

It is tempting to imagine that the digital economy floats above the material world. But far from being emissions-free, the modern digital infrastructure is increasingly energy-hungry, resource-intensive, and geopolitically entangled.

Estimates show that the ICT sector accounts for up to 10% of global energy consumption, and 2.1-3.9% of global emissions, on par with air travel. (Freitag et al 2021) One of the big driving forces for the growth sector is the rise of AI, particularly deep learning, generative AI, etc, which is adding fresh strain. The sheer complexity of training and inferencing those models is requiring huge physical infrastructure - data centres with more computing and energy intense racks –meaning demand for energy is skyrocketing. Data centres globally are now more energy intense than many countries. Training and maintaining large-scale language models (LLMs) demands enormous computing power - one AI-powered search query can use between 10 and 60 times more energy than a conventional one[5]. So when this is adopted by search engines including Google and Bing, hugely increasing energy demand of every search, we should expect a large environmental cost. AI workloads continue to increase at around 40% a year, and data centre capacity is growing at around 13% a year.[6]

However, ***where*** **computation is carried out** is important for the emissions impact of that computation, as it will depend on the regional energy mix which supplies it. Training a model in Norway, vs training a model in China, can result in some very different emissions outcomes. If the US administration invests in more coal, the energy mix will become dirtier, and the emissions intensity of the big tech giants' computation processes gets worse.[7] Location also matters for other reasons: we are beginning to see *congestion effects,* i.e. datacentres tend to locate near one another and often near to populations, creating hotspots and contention for energy and water (for cooling), especially in sensitive locations where water is already scarce.

This surge in demand is **exposing a structural gap** that could emerge over time. It is far quicker to build a data centre than to expand the energy infrastructure to service it (building nuclear or renewable energy generation takes years or even decades of planning and delivery). How much of our decarbonisation transition energy infrastructure are nations willing to commit towards supplying the rapidly growing digital sector? In Ireland, data centres are expected to consume a third of the country's electricity by 2026, and energy prices are rising. (IEA 2024) A clear phenomenon is emerging: across the sector, data centre and tech companies (e.g. Meta) are engaging in large-scale investment and power purchase agreements to buy greater shares of renewable energy.

Congestion effects, i.e. datacentres tend to locate near one another and often near to populations, creating hotspots and contention for energy and water (for cooling). Water is an emerging issue as this can be in sensitive locations where water is already scarce.

In addition, the growth of AI and decarbonisation technologies is accelerating **demand for rare earth elements**. A fully electrified, AI-powered future will depend on roughly 45 critical minerals – needed for both decarbonising the energy grid, and developing ICT- two demands that will need to be carefully balanced in the longer term. These materials are scarce, environmentally costly to extract, and often entangled in questionable supply chains. They are not easily recycled or recovered from waste. Billions of kilos of electronic waste are dumped, handled illegally, damaging the environment and contravening human rights. The longevity of these rare earth elements is essential, but the circular economy remains largely aspirational. As demand accelerates, we're locking ourselves into long-term dependencies with limited resources. We need systemic thinking: how do we balance the mineral needs of AI and the green transition without undermining both?

While digital trade may appear immaterial, it carries real and lasting environmental impacts. Overlooking its long-term material dependencies risks locking in costly consequences for the future. As we accelerate into an AI-powered, electrified world, we must confront the hard truth: the digital economy is only as sustainable as the physical foundations it rests on.

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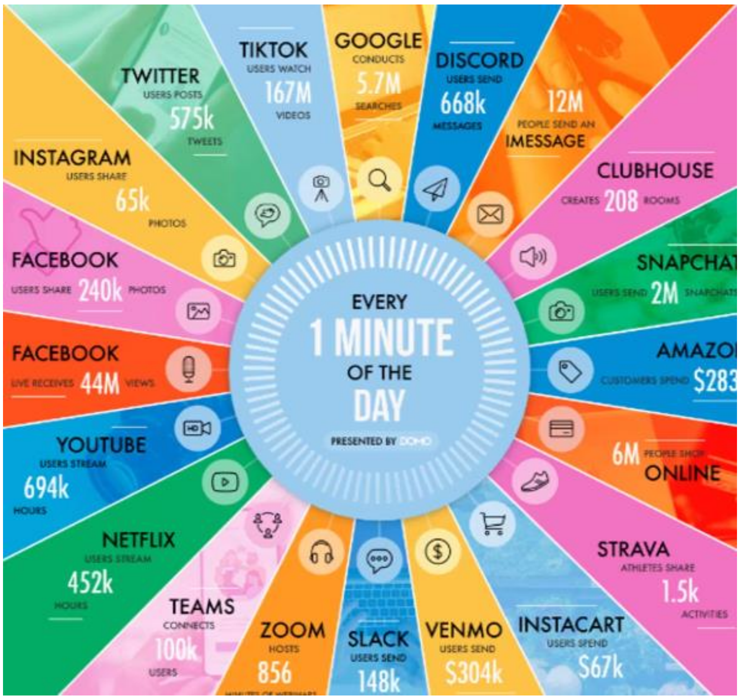
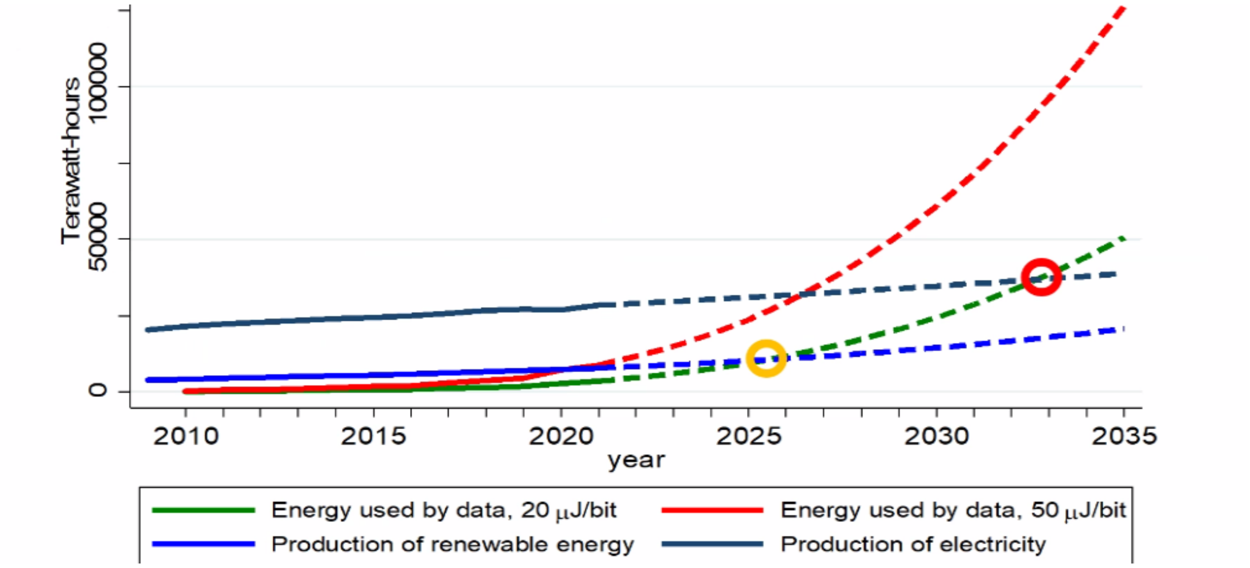
[5] https://www.andrs.nu/your-knowledge-search-comes-at-a-price-google-search-vs-ai-powered-an-energy-comparison/ ; https://arxiv.org/abs/2407.16894 ;
[6] BCG 2025. Breaking Barriers to Data Centre Growth.
[7] See HBR 2024.

3. Vitor Castro - The Tipping Point of Digital Growth



The transition to digital is not a free lunch. The ICT industry emits 2.5-3.7% of global greenhouse gas emissions (more than aviation which is 2.1-2.4%.)(Lavi 2022). But we expect global data creation and storage to explode in the next years. Emails stored for one year in the cloud can contribute to up to 100Kg of CO2 emissions per user per year (Google 2011). These emissions from emails will soon be dwarfed by those from AI, an extremely energy–hungry technology. Another issue is so called “dark data” - stored in clouds with noone using it. Of the information stored by smart technologies in the Internet of Things (IoT), 90% of this is never used. (IBM) This little-known environmental impact is only going to grow.

The rapid growth of data is leaving an increasingly heavy digital footprint. As demand for computing power surges, especially from data centres, a widening gap is emerging between energy supply and demand. These facilities consume vast amounts of electricity, and if growth continues unchecked, we may reach a point where energy production can no longer keep pace. This imbalance could drive up energy prices and strain national power grids. Castro and his colleagues draw attention to ways to solve this problem in a recent paper (Castro et al 2024). According to their estimates, the current trend of expansion in renewable energy production may not be enough to cope with the growing energy demand of digital data. (assuming efficiency gains in the use of data - 20 microjoules per bit (μJ/bit) rather than 50 μJ/bit). Even in a high efficiency scenario, by 2025, if all the energy needed for data was produced by renewables, it wouldn’t be enough to supply the energy demanded by data centres. Indeed, if current trends persist, we could be heading towards a *“digital data doomsday”* by 2033 - where the demand for energy by data outstrips the total supply of electricity, with all electricity needed to service data centres.



Can we avoid this? Castro et al have suggestions: Firstly, investing in increasing energy production (particularly renewables and nuclear). Secondly, supporting technological advances – in computation processes and renewables. And, thirdly, working on efficient use of digital data with more sustainable approaches.

Unfortunately, most people remain largely unaware of the hidden costs of data storage. The vast majority of data produced is never actually used. In fact, up to 80% of on-premise primary business data is considered "dark"—redundant, obsolete, or trivial (ROT). Only about 20% qualifies as critical data that individuals and organizations actively rely on. IBM estimates that 90% of sensor data collected by Internet of Things (IoT) devices also goes unused. Reducing the energy spent storing unused data represents a significant opportunity to redirect resources toward more meaningful and efficient processes.

Decarbonisation of digital trade requires targeting problematic data practices – dark data, unstructured data, data duplication, corporate memory, email, information overload, data growth and IoT, and the "store it all" approach. Digital Decarbonisation propose the below solutions (digitaldecarb.org). The first step is to remove and delete dark data. Then, environmentally conscious data management should consider the potential CO_2 emissions of every step of data on the journey from data acquisition, data assimilation, data transformation, to data exploitation.

Table 2: Digital Decarbonisation's steps to improving data practices

Reuse	**Forecast**	**Develop**
Change habits and data practices management	New projects to be more environmentally friendly	Promote digital sustainability

Individuals and organisations should ask the following six questions in order to include data into a sustainability strategy :

1. Where are existing data being stored?
2. Why are new data & information needed?
3. Which structures enable data codification?
4. Who is responsible for sharing new data?
5. What options are available for data reuse?
6. When are data evaluated & waste disposed of?

Digital trade organisations should recognise that the process is dynamic, and that the emissions of their outputs will also include that of the entire value chain - upstream and downstream (scopes 2 and 3). Resources to calculate and plan their data carbon emissions can be found at digitaldecarb.org.

Discussion

1. **Beyond energy and emissions, what about the nature side - impacts on biodiversity, water, and land use. Can we understand more of this?**
   Environmental impacts of digital infrastructure extend well beyond carbon - Digital trade also has significant implications for biodiversity, water resources, and land use.
   For instance, data centres frequently rely on evaporative cooling systems to regulate their temperature. These systems draw heavily on local water supplies, placing strain on water tables, particularly in regions already facing water scarcity or in proximity to densely populated areas. This pressure can exacerbate existing environmental and social tensions. Moreover, the physical footprint of digital infrastructure can have direct consequences for land use and biodiversity. While these developments may support low-carbon energy generation and digital connectivity, they can also lead to habitat loss, ecosystem disruption, and social dislocation. (E.g. in the Zeewolde, the Netherlands).

   In addition, the growing problem of electronic waste (e-waste) represents a serious environmental hazard. Without adequate recycling and disposal systems—particularly in lower-income regions—hazardous substances from discarded digital equipment can leach into soil and water systems, further threatening both environmental and human health.
   As the UK and other nations seek to position themselves as global digital hubs, it is essential to take a more holistic view of the environmental costs of digital infrastructure. This includes careful consideration of where such infrastructure is sited, how it interacts with local ecosystems and communities, and how its full environmental footprint—including water use, land impact, and waste—is managed.

2. **There is a clear model for gathering and storing data, especially for training AI, but how would you create a business model for removing and deleting data? Are the incentives currently stacked against this?**
   This is an important first step. There is a significant volume of data that is simply stored without being used—referred to as "dark data". The process of identifying and deleting unnecessary data is increasingly necessary. Initiatives such as, Digital Decarbonisation, (as well as some of the big tech companies), are exploring ways to improve the efficiency of AI algorithms and data processing.

   However, we should be wary about framing this an individual choice to delete data, and ignoring the systemic issues business face. It is not simply a matter of individual choice - if it were easy and economically favourable, much of this data would have already been removed. Most organisations would, in fact, like to delete excess data—it represents a liability. But systemic and technical barriers remain significant. What is needed is a restructured system that supports and incentivises responsible data management at scale. Thus, there is also a **key role for government intervention**—particularly through regulation—to change the existing incentive structures. Without regulatory signals, the economics will continue to favour data accumulation rather than responsible deletion.

3. **Can we ensure participatory decision-making around data decluttering (like deleting, moving, or archiving digital data), given its environmental and labour implications — especially when businesses control that process?**
   Decluttering is necessary. A significant share of stored data is never accessed—comparable to "piling newspapers you never read." Unlike physical clutter, digital storage is largely invisible, leading to unchecked accumulation and wasted energy. As individuals, we store massive volumes of photos, files, and data, much of which is never used again. There is certainly critical data that needs to be retained—data that holds historical, organisational, or regulatory value, but organisations must develop clear

data storage strategies that include structured deletion policies to avoid long-term inefficiencies and environmental costs.
However, there could be risks involved if there is not sufficient transparency or oversight. If businesses alone decide what data to delete or move, communities, workers, or regulators may not get a say — or even access to critical information. This raises questions of justice, accountability, and worker/community rights.
There could be a role for **international frameworks** to target this issue. There are precedents - for example, the **Aarhus Convention** ensures access to information, public participation, and access to justice in environmental matters, while the **Escazú Agreement,** includes provisions for environmental rights and participation — especially for vulnerable communities. These emphasise that people should be part of decisions that affect their environment and health — including digital-related waste and data practices. Could it be possible to apply participation through such treaties, not just to traditional environmental decisions, but also to digital processes like data management and tech waste? Such policy frameworks at an international level (and less so, at a domestic level) could play a role by creating legal requirements for corporate transparency, public oversight or participatory data governance, and involvement of workers, waste pickers and affected communities in discussions about digital practices.

International frameworks and policy could help in another way to support transparency, too. There is a significant additional challenge of how to **standardise methodologies** to account for embedded emissions in digital services and infrastructure. In the tech sector, there is enormous variation in what is measured and reported. Entire categories of environmental cost can be excluded depending on accounting approaches. Disaggregating digital supply chains is difficult, but essential if we are to understand and manage impacts.There is a strong case for developing consistent, transparent methodologies for monitoring, reporting, and verification (MRV). Labelling and assessment schemes could also help drive better decision-making across the digital economy.

4. Why aren't consumers being charged for the environmental costs of data storage? Would stronger price signals disincentivise excessive storage and energy use?

Consumers are rarely charged for the environmental costs of data storage — a systemic oversight that fuels excessive energy use and unsustainable digital practices. At present, data storage is effectively "free" or bundled into broader service offerings for many users, which contributes to digital hoarding and overconsumption. The infrastructure required to support this — from data centers to global server networks — is highly resource-intensive, drawing heavily on electricity, water, and land, and generating significant carbon emissions.

If environmental externalities were internalised into the cost of data storage, stronger price signals could help drive behavioural change. Users might become more selective about what they store, while businesses would be incentivised to build more energy-efficient models. Some proposals suggest a form of "digital carbon pricing" for data centres, which would reflect the true cost of digital services in environmental terms. Without these mechanisms, the environmental impacts of the digital economy remain largely invisible to end users and continue to scale unchecked.

However, the lack of pricing is not a simple market failure — it is a strategic feature of the digital economy. Data is not just a tool for current operations; it is a speculative asset. Its value lies in the possibility of future monetisation, especially through targeted advertising, predictive analytics, or training artificial intelligence systems. As such, companies treat data accumulation as an investment — storing everything in anticipation of later profitability. This is especially true in the age of generative AI, where large volumes of stored data are mined and monetised in training models, reinforcing the incentive to retain rather than delete.

Introducing environmental costs into this system is not just a technical fix — it challenges the underlying business model. Deleting data is not merely about saving energy; it risks undermining the entire speculative logic of digital capitalism. In this context, focusing solely on consumer behaviour change is insufficient. Structural change is needed: from regulatory interventions that mandate environmental accounting in digital services, to new norms and legal frameworks that constrain speculative data accumulation.

In short, while stronger environmental pricing could help moderate individual behaviour, real transformation requires addressing the economic structures that reward limitless data retention. The problem is not that storage is too cheap — it's that waste is profitable.

5. **Which countries are taking the lead in managing the environmental impacts of digital trade? What opportunities exist for international cooperation? How can trade policy encourage environmental accountability in digital sectors—particularly for AI?**

The UK government has high ambitions in both the digital and environmental goods and services sectors, seeing them as essential for the strategy for UK growth.
But, at present, few countries are taking a comprehensive approach. Even the UK government, considers perhaps only 10% of digital's full environmental impact. The European Union, through the Green Deal and AI Act, has made more progress—particularly in aligning environmental standards with digital policy. But regulatory fragmentation is becoming a concern: the EU AI Act is setting new standards, while the UK currently relies on voluntary guidelines. The UK could lead by example, and introduce environmental performance requirements for AI products entering its market, but at a risk that such moves increase costs and further complicate compliance for international firms.

At its core, this remains a collective action problem. No one wants to move first, because doing so would raise costs and risk losing competitive advantage. Data centres are highly mobile and industries are price-sensitive. Without coordinated international regulation, meaningful progress will be difficult.

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