THE FUTURE FOUNDATION

Future Foundation Talk 1

- ICT Impact on the Environment

November 2025

WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

Dr. Behnam Zakeri

- Assistant Professor with the Institute for Data, Energy, and Sustainability (IDEaS) at Vienna University of Economics and Business (WU).
- His main focus area is energy transitions and their environmental impact, including the role of digital tech in such transitions.
- He has been involved in developing energy and climate studies for a dozen countries in different world regions
- He has been scientific advice for international organizations such as the United Nations and Green Climate Fund.

The scene

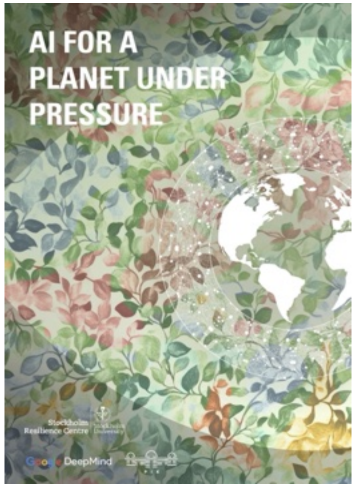
The AI hype has created contradicting views about its environmental impact.


CommonWealth BEACON
POLITICS, IDEAS, AND CIVIC LIFE IN MASSACHUSETTS
OPINION
The dark side of AI: Climate chaos, pollution, and injustice
Massive data centers pose serious risks to Black and brown communities
by DWAIGN TYNDAL

Image from New Scientist


ASK MIT CLIMATE
Climate Portal
Is AI's energy use a big problem for climate change?
AI has created an unexpected surge in energy demand, and with it, climate-warming greenhouse gas emissions. Addressing this will take more computationally efficient AI models, more energy-efficient data centers, and new clean energy to power it all.

CLIENT Climate Intelligence



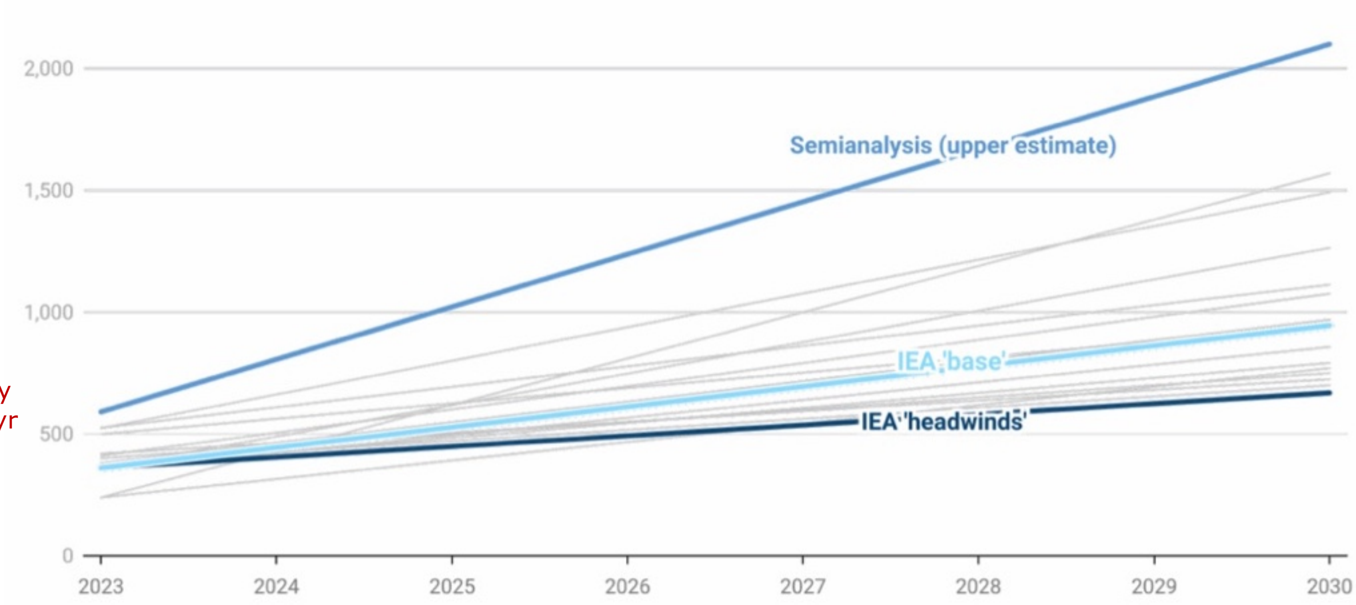
AI for a Planet Under Pressure

Data centre energy demand

By 2030, the electricity demand of data centres will double globally (and four-fold in the worst-case)

Estimated date-centre electricity demand in 2023 and 2030, TWh, according to a range of analysts

Germany's electricity demand: 520 TWh/yr



Source: IEA, Goldman Sachs, Deloitte, Boston Consulting Group, Gas Exporting Countries Forum, Liebreich Associates, Semianalysis, Schneider Electric, International Data Corporation, Jeffries (2024).

CarbonBrief CLEAR ON CLIMATE

IEA: International Energy Agency

The agenda

- Digitalisation and **environmental sustainability**
- **Deep dive:** Energy and carbon footprint of digitalisation
- How can **AI contribute to** environmental sustainability?
- The way forward

What we discuss today:

… the **real** impact (beyond AI) …

… the **real** impact (beyond data centres) …

The problem

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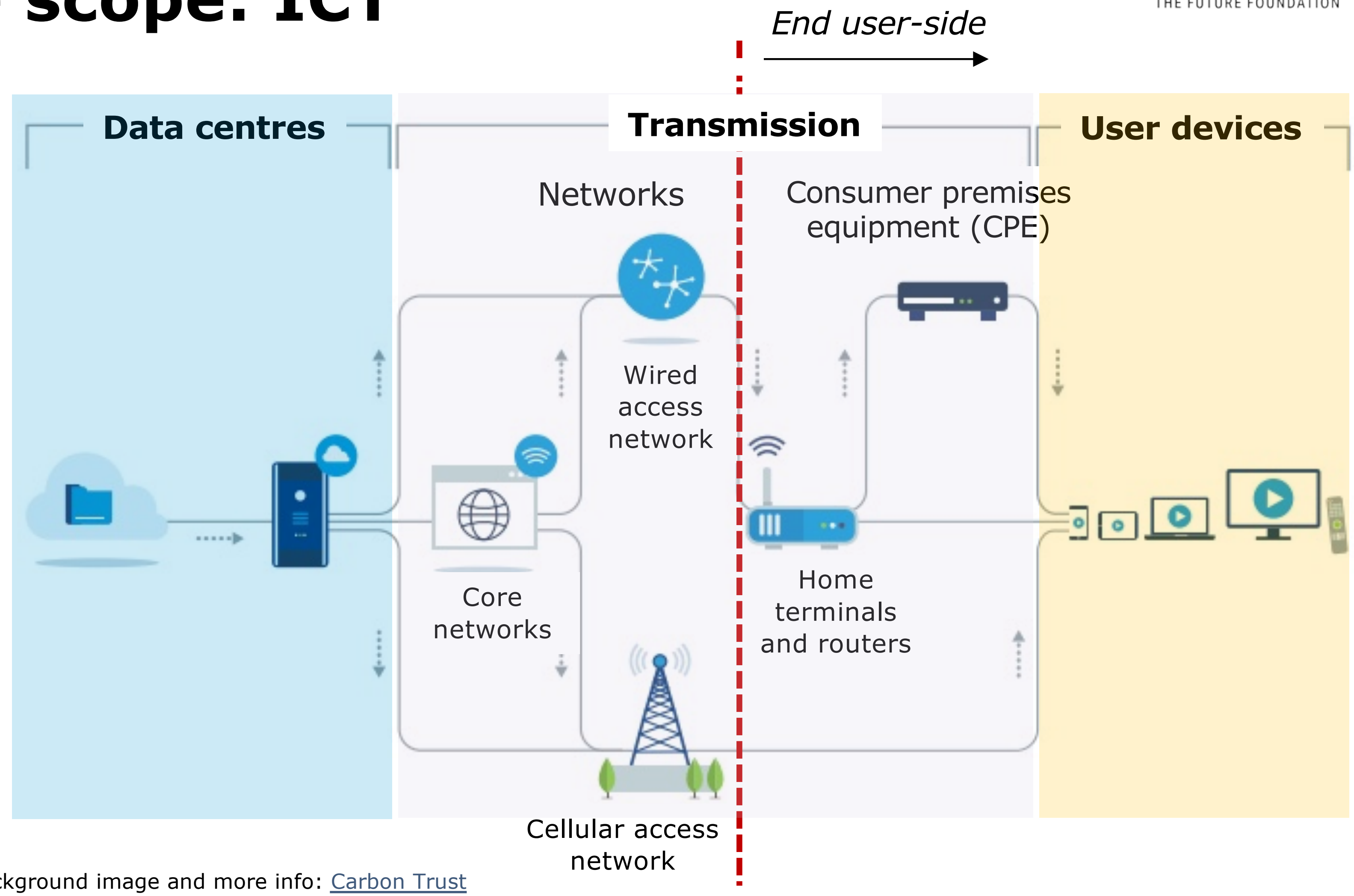
*“The **environment** cannot be improved in conditions of **poverty**. Nor can poverty be eradicated without the use of science and **technology**.”*

Indira Gandhi, then Prime Minister of India
Stockholm Environment Conference, 1972

Image from: livemint

The scope: ICT

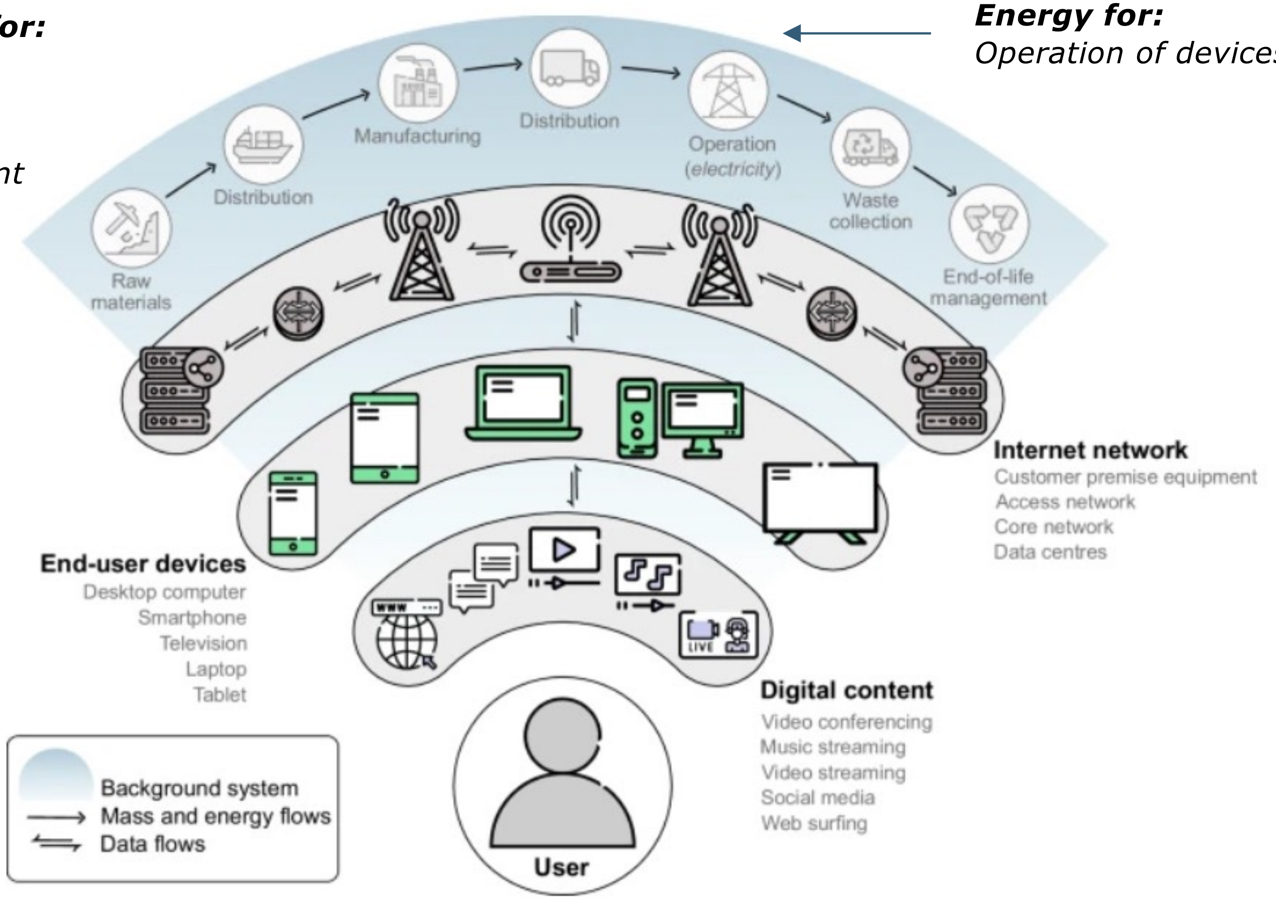


Background image and more info: [Carbon Trust]

The scope: lifecycle environmental impact

Energy, also for:
Mining
Transport
Manufacturing
Waste treatment
etc.

Energy for:
Operation of devices (electricity)

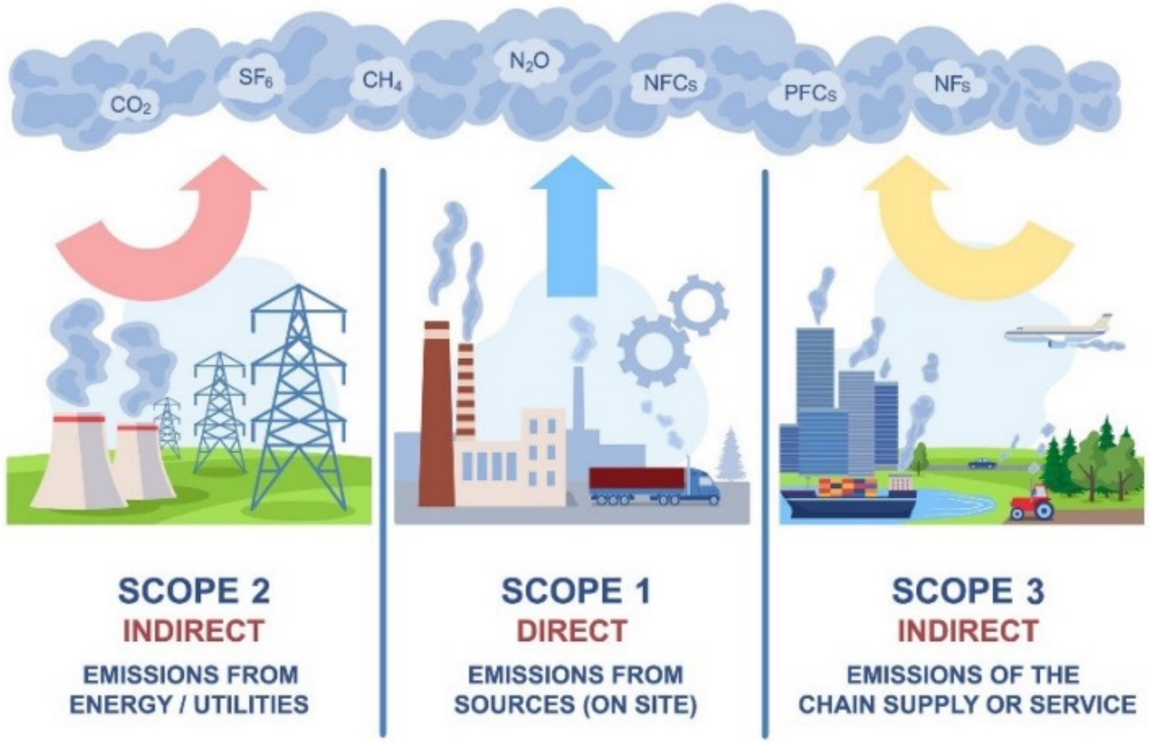


Source: [Istrate et al. 2024]

The "scope" of the impact

Complexity in assessment: Scope 1: onsite → Scope 2: utilities → Scope 3: Supply chain/end-of-life

Example: GHG emissions



Source: ITU, [Assessing AI environmental impact]

The terms: ICT vs. digitalisation

Digital content consumption is only a fraction of the ICT footprint, and that is part of digitalisation

- **ICT (the sector)**
  - Data centres, transmission networks, and end-use devices.
- **Digital content consumption**
  - End users interacting with the internet to meet certain demands (web surfing, texting, video-streaming, video conferencing, etc.)
- **Digitalisation**
  - Economy-wide, including impacts on other sectors (health, food, energy, etc.).
  - Impacts can be both positive (enablement) and negative (rebound effects)

Digitalisation & environmental sustainability

@Getty: Daniel Reiter

The direct environmental impact of ICT

Rapid growth and scale of digitalisation:

- expanding rapidly (more processes/use cases)
- connecting billions of devices: massive resource use throughout the ICT sector

- **High energy consumption (including its impacts)**
  - Water, air pollution, land use, GHG emissions, etc.
- **Water withdrawal and resource extraction**
  - From water to rare earth and critical metals with major sustainability issues (mining, equality, supply-side concentration, etc.)
- **E-Waste, air pollution, water eutrophication, etc.**
  - Short lifespan of devices and low rate of recyclability
- **Climate impact**
  - Both for the manufacturing and operation

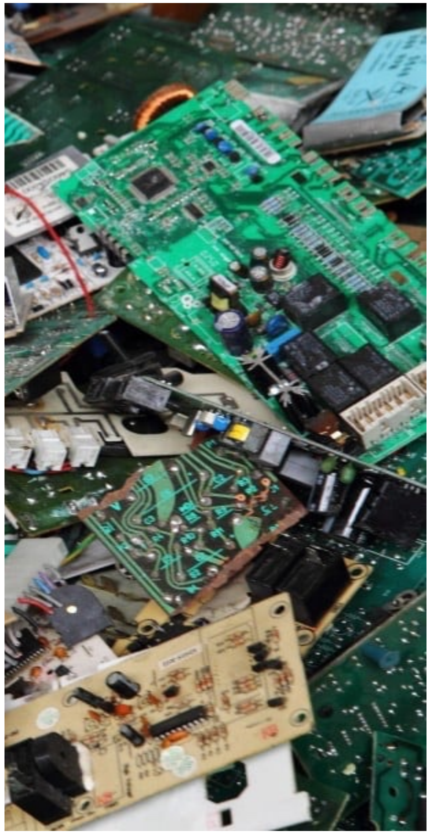


Image from: scmp

For a full list of environmental impacts, see [Istrate et al. 2024]

ICT and freshwater use

AI’s water withdrawal globally could reach as large as half of the UK by 2027

- Under growth scenarios, AI could drive 4.2–6.6 billion m^3 of water withdrawal by 2027 (Li et al. 2025)
- Water for cooling (Scope 1) and mostly water for electricity (Scope 2, ~60%)
- Water consumption in **the semiconductor industry** is **~10 times data centres** (Sandhu et al. 2025)

➔ **Imbalance:** More than 70% of data centres in the US are built in areas with high water stress

Annual Water Consumption (gallons)

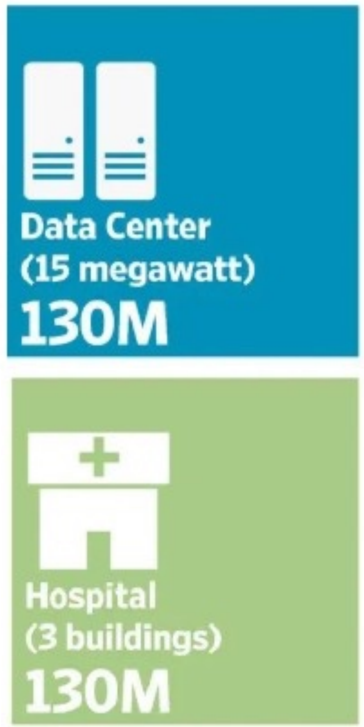
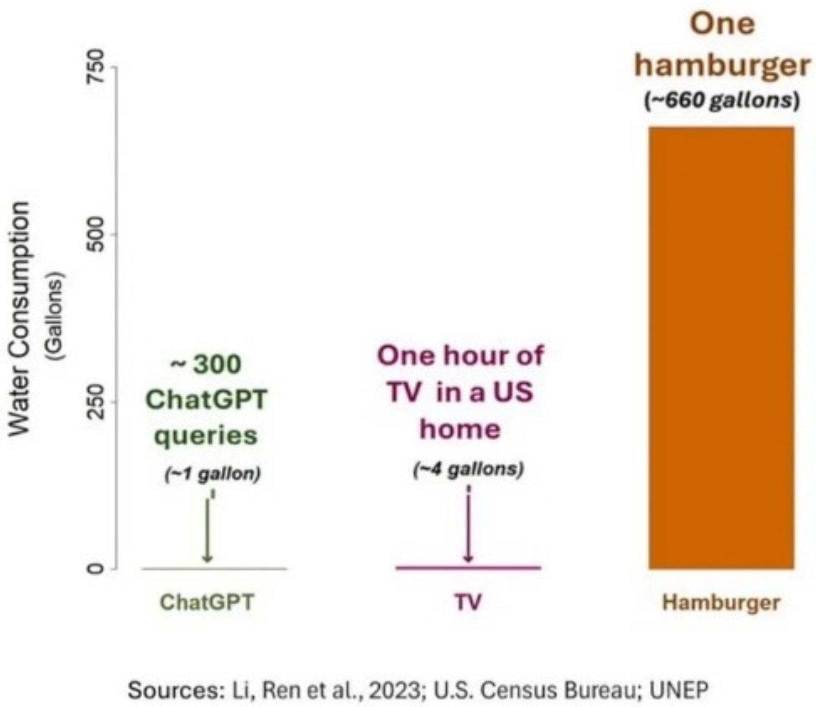


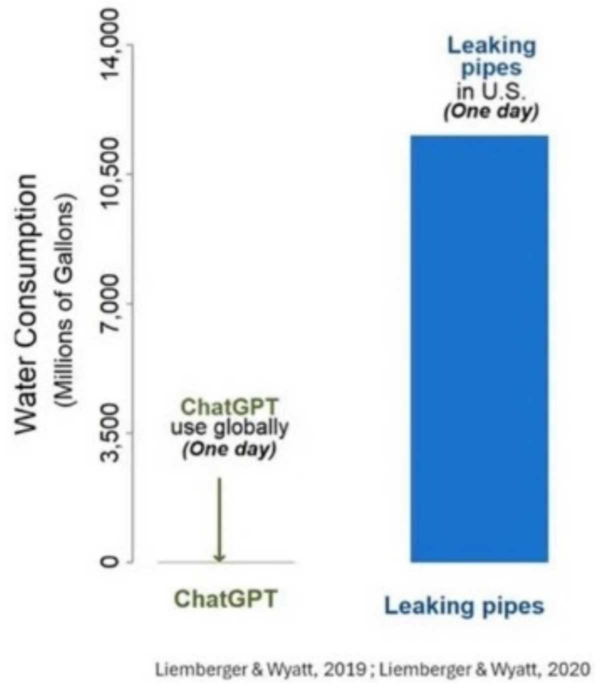
Image from: David Mytton

The water use of LLMs vs. other activities

A conversation with ChatGPT uses 5 times more water than a Google search

Context is useful, but it should be used carefully: because we use/waste a lot of resources elsewhere, we shouldn't forget AI!



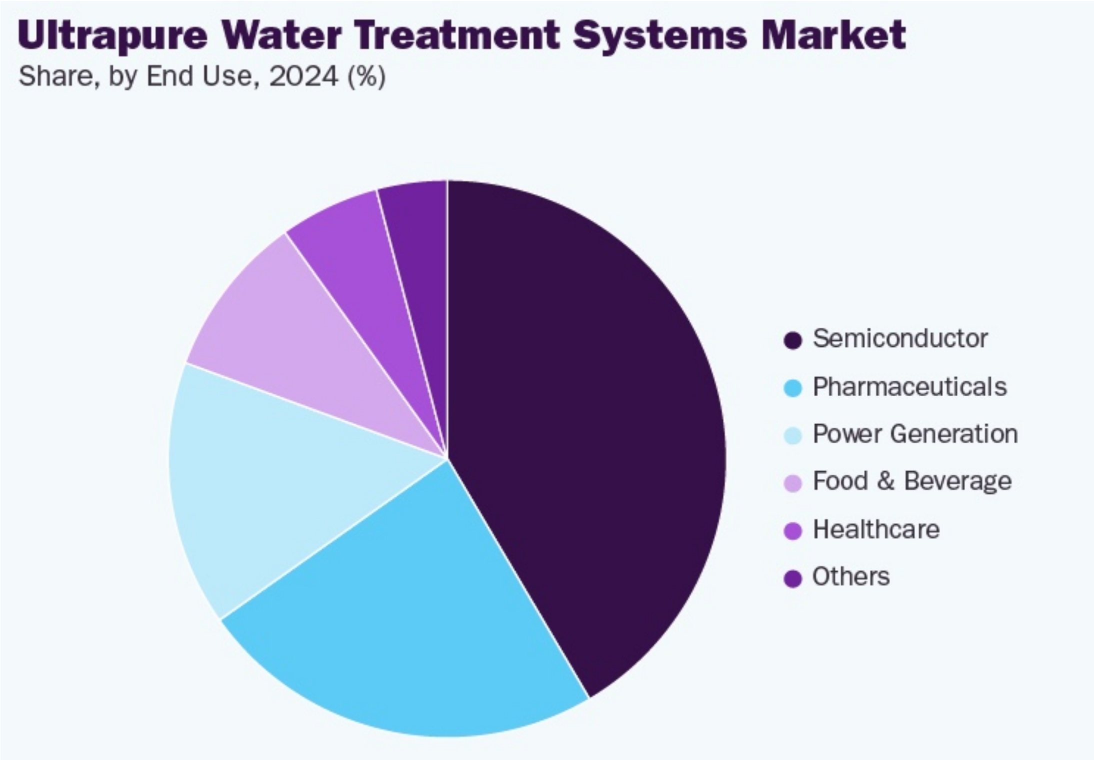


Source: John August 20

The water impact: eutrophication and ecotoxicity

Digital content use is responsible for >10% of the sector's carrying capacity

- Besides withdrawal, ICT has a significant impact on the water bodies through wastewater.
- Eutrophication/ecotoxicity **depend on the location**, i.e., where electricity and cooling water are sourced and treated.
- A study of 3 semiconductor industry sites in China found high levels (**~10-100 times more than normal**) of toxic material (PFAS) in wastewater that is hard to remove (Qiao et al., 2025).

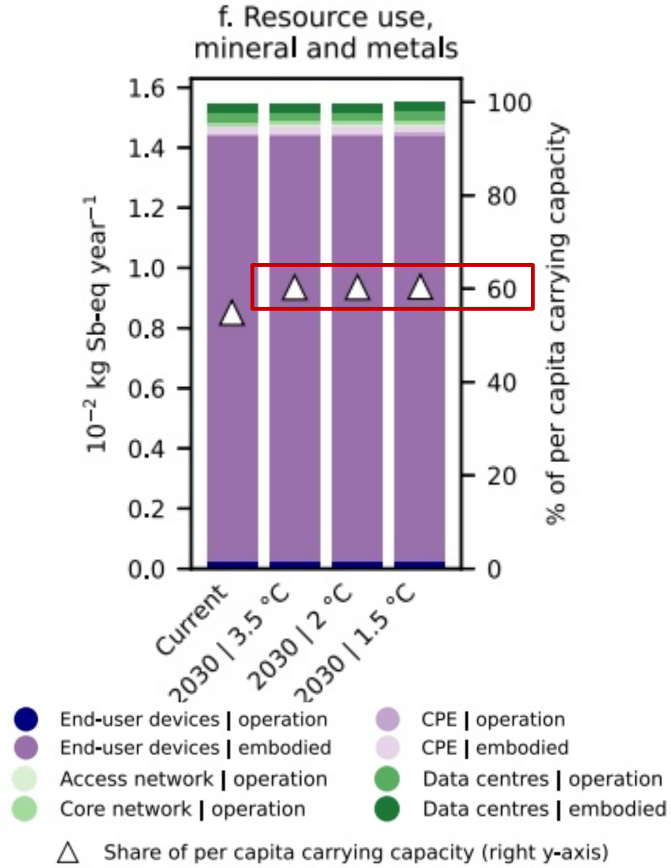


Source: GrandViewResearch

Material use of ICT and AI

Among all, the material use of digital content has the highest risk of exploitation.

- **Copper:** A hyperscale datacentre needs ~50,000 tonnes of copper.
- The copper supply gap of 6 million tonnes by 2035 if demand keeps rising.
- **Rare earth elements (REE)** have a **high supply risk** due to concentration in mining/refining in China.
- **Lithium and cobalt** (devices + backup/storage): The demand conflicts with EVs and batteries.
- Material use will grow irrespective of the **climate scenario.**



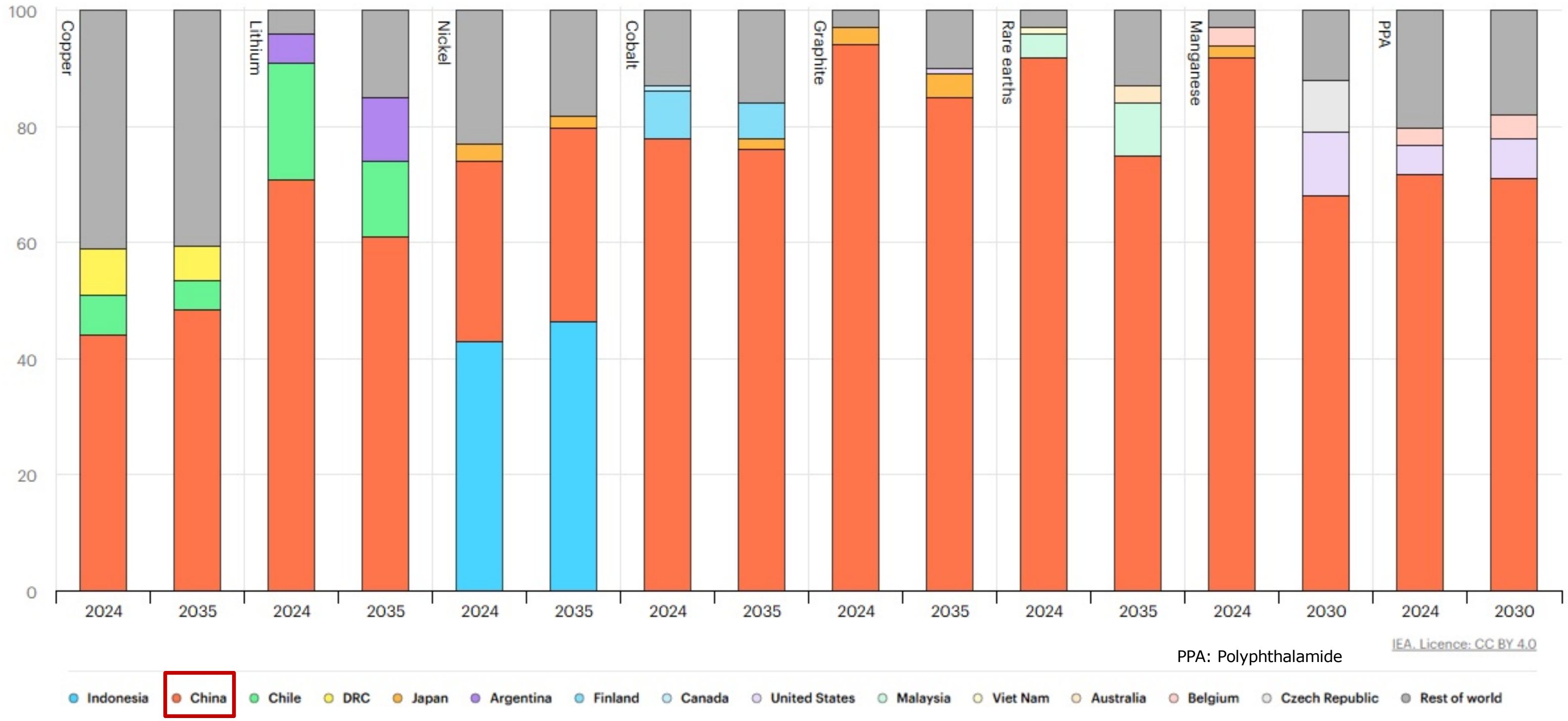
Source: Istrate, et al. (2024) Nature Communications

Supply chain bottlenecks of materials for ICT

Most ICT material needs to pass through China and competes with green technologies

Key ICT materials: Copper, lithium, cobalt, and rare earth elements

Geographical distribution of refined material production for key minerals



PPA: Polyphthalamide

Material impacts: the environment and inequality

Extractive mining has both sustainability and equality issues.

Source: Somo

Source: ArcGIS

Examples of the impact of cobalt mining in the Democratic Republic of Congo (DRC)

Electronic waste

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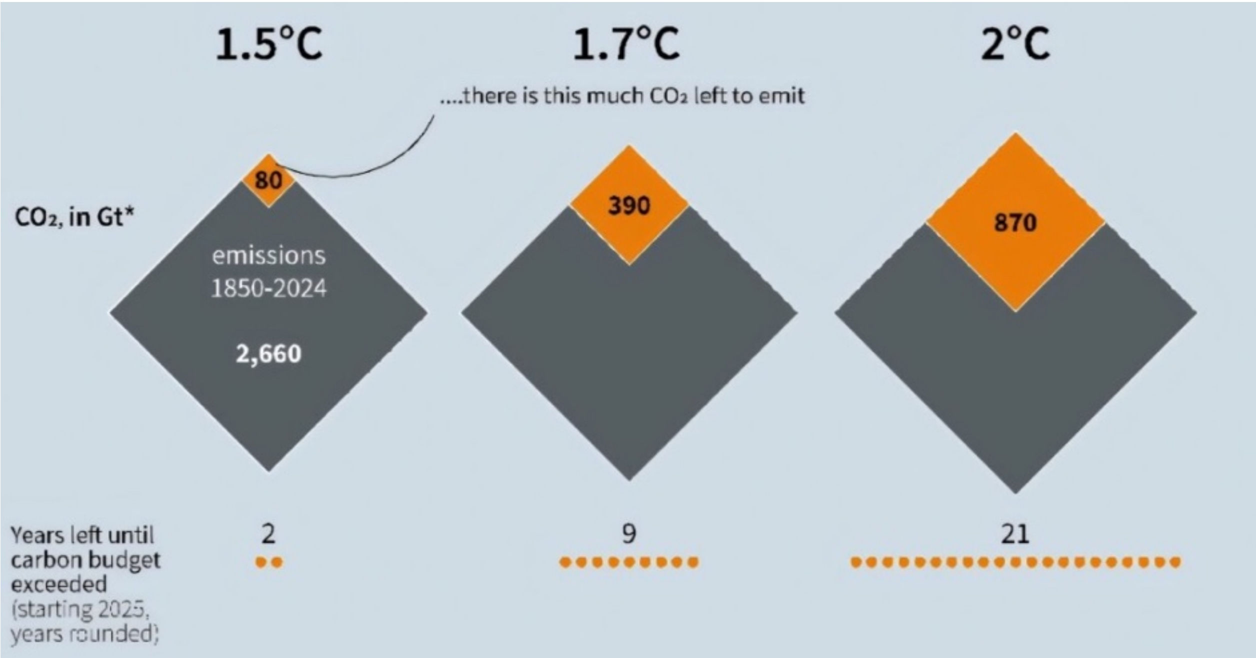
The world's e-waste is rising five times faster than recycling.

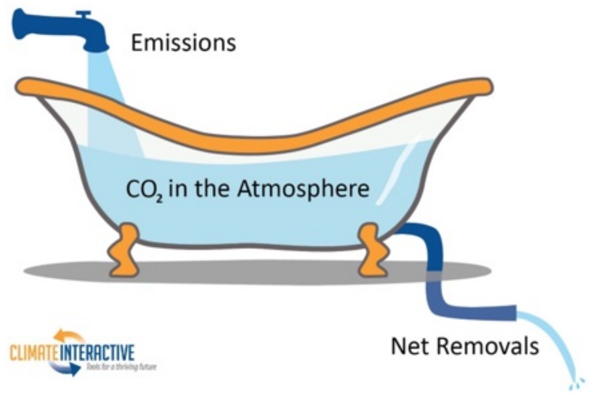
- E-waste is growing by 32% to 82 million tonnes per year by 2030.
- Digital devices (including monitors and TVs) are responsible for ~17% of electronic waste globally (source: the global e-waste monitor)
- Of 10.5 billion kg of digital e-waste, only 24% is recycled.

Image from: scmp

Reminder: Carbon budget

Starting 2025, only ~ 2 years left to limit the warming to 1.5°C (with 67% likelihood)





Source: [Phys.org]

ICT and climate

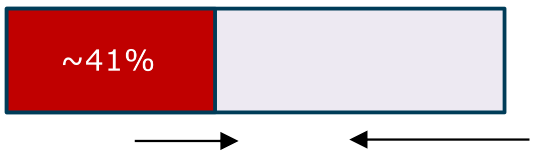
41% of the carbon budget* will be exhausted under the current energy and digital scenarios.

- Carbon footprint of digital content consumption: **~230 kg-CO_2-eq/yr** per person (global average)

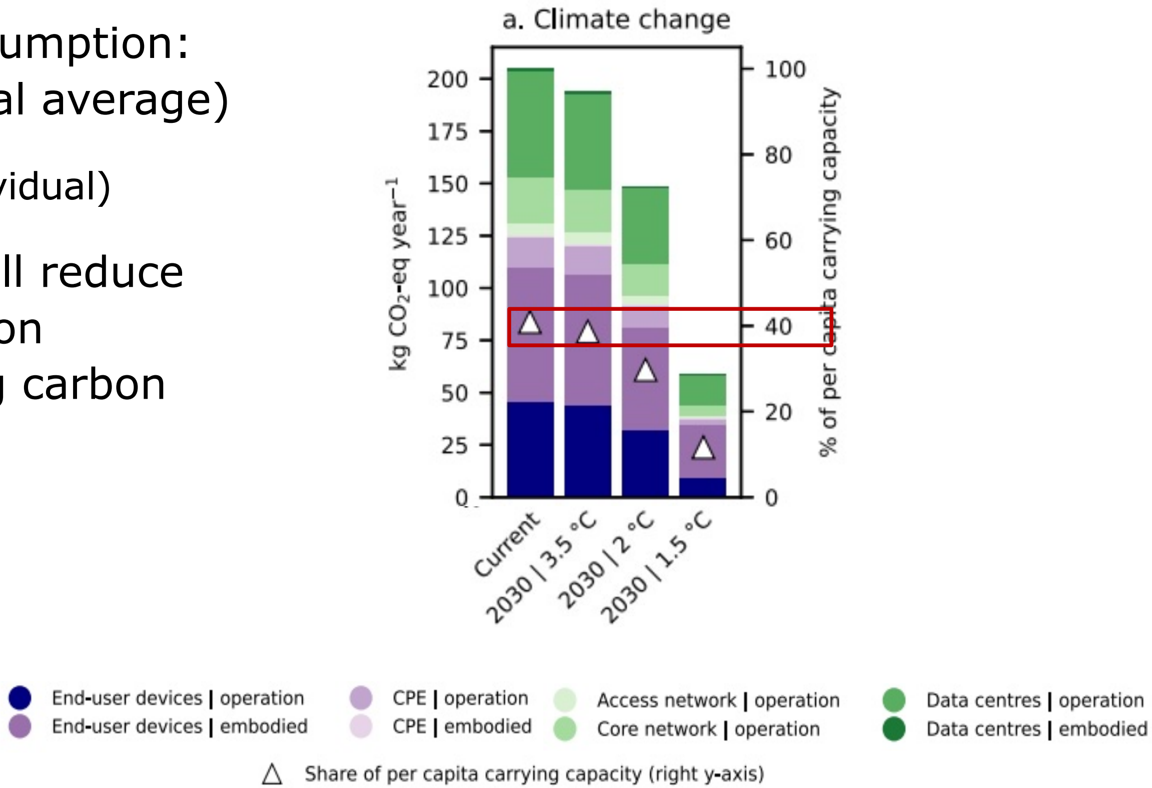
  (~4-6% of the total GHG emissions of an individual)

- A climate-compatible energy system will reduce the climate impact of digital consumption significantly (to ~12% of the remaining carbon budget)

Digital content carbon footprint -> 2030



Global carbon budget*



*Carbon budget for meeting 1.5C with likelihood of 67%

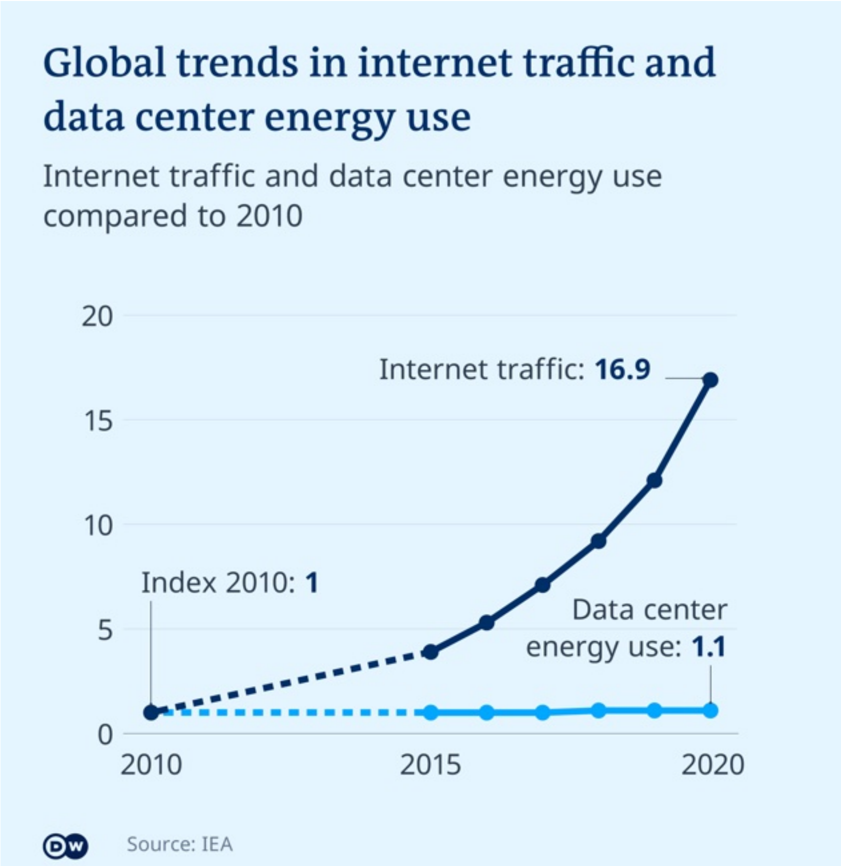
Source: Istrate, et al. (2024) Nature Communications

AI and Data Centres (DCs)

Image from Financial Times

Data centre energy use (Pre-AI)

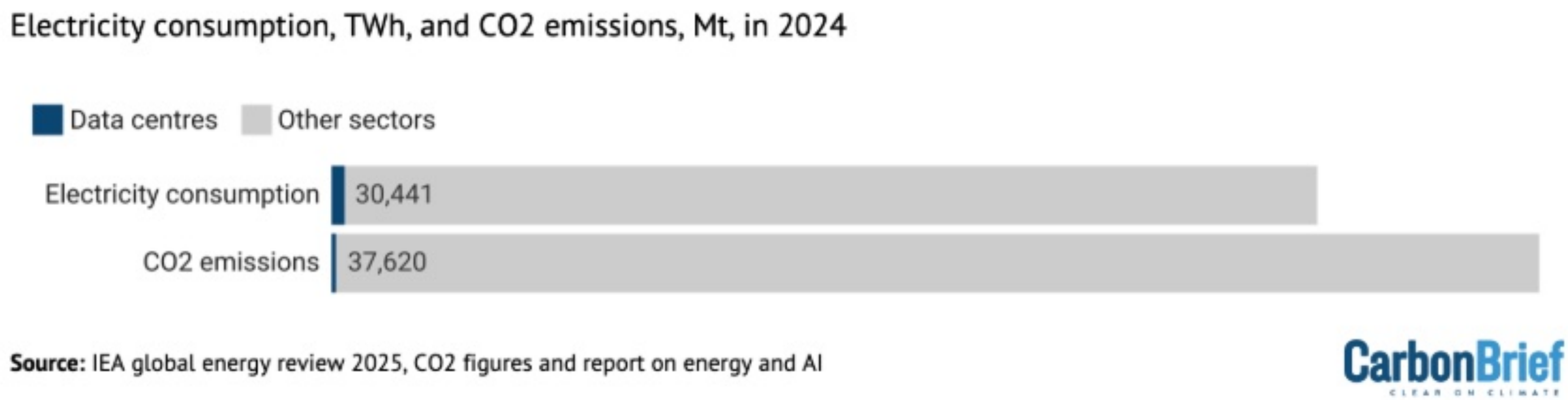
Computational efficiency kept the energy demand stable



Global energy and emission footprint

DCs consume 1-2% of energy and emit less than 1% of CO_2 emissions today*

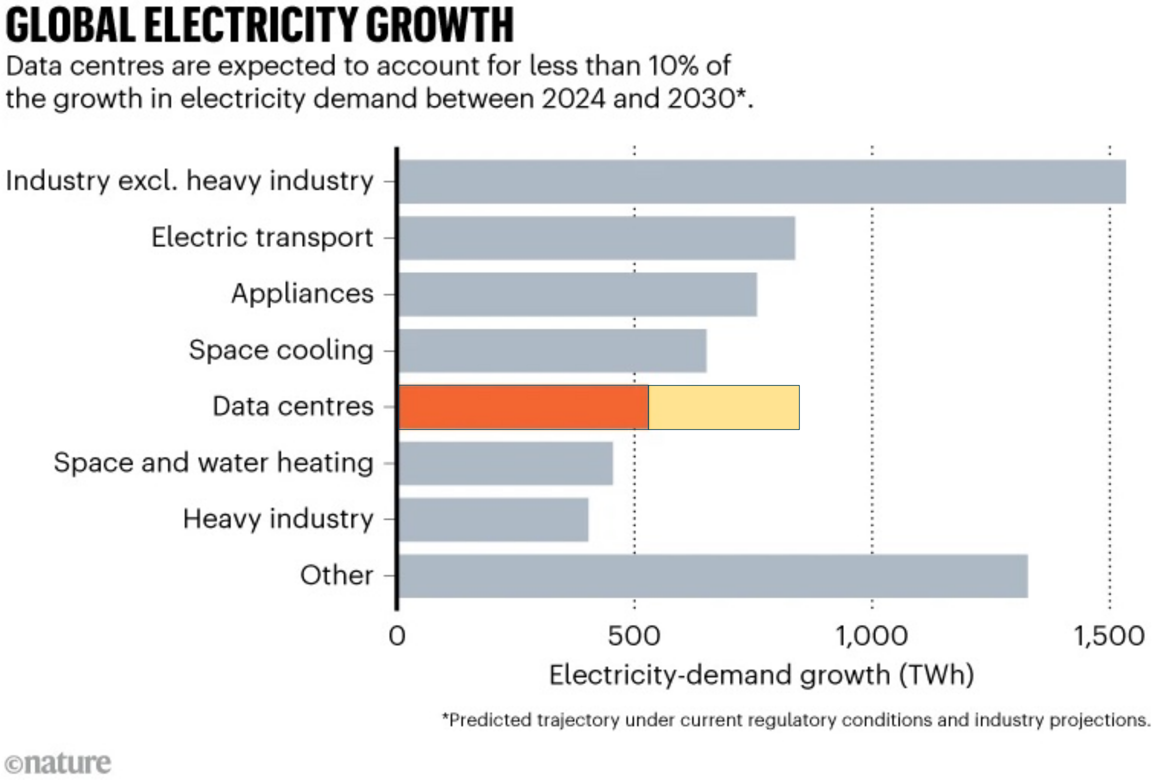
So, why should we be worried about data centres?



* This doesn't include cryptocurrency.

Global growth in electricity use to 2030

Data centre growth is not critical vs. other sectors, if seen at the global scale.



Source: IEA. CC BY 4.0

But,
Other sectors, like cooling, are well distributed globally.
…
Data centres, not!

Uneven distribution of data centres

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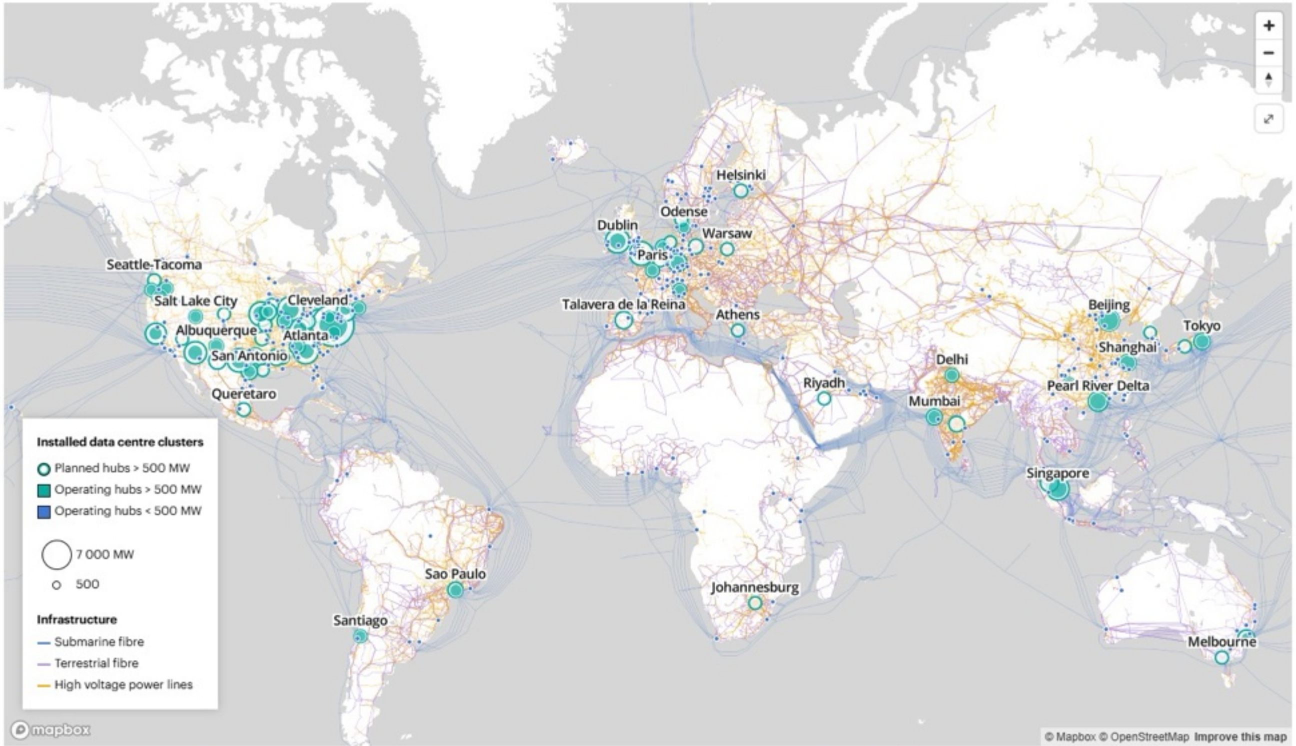
Large data centres are clustered near internet network hubs and large demand centres.

Interactive map of data centre hubs alongside associated power and digital infrastructure



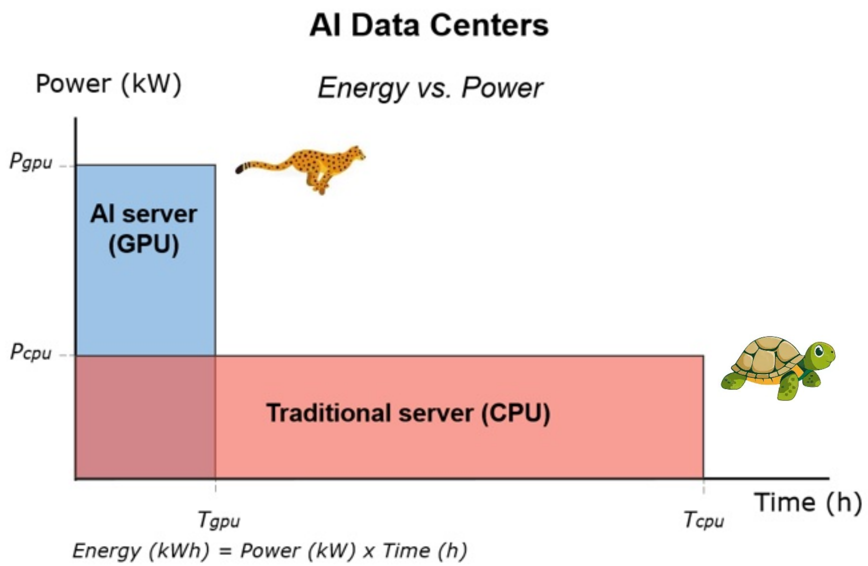
Note: The data centre hubs shown above represent the capacity-weighted centroid of a cluster of data centres within 100 km of each other and totalling over 500 MW of installed capacity. The Pearl River Delta encompasses the combined capacity of Guangzhou, Shenzhen and Hong Kong (China). The high voltage power lines shown reflect the extent of the high voltage powerlines available from the OpenStreetMap server as of the date of export and is provided as is.

Source: IEA analysis of data centre location data from Omdia's Data Center Building Tracker – 2H24 and Data Centre Map (2025), powerline data from OpenStreetMaps (2024), and communications infrastructure data from the ITU Broadband Mapping programme (2025) and submarine fibre optic network from TeleGeography (2021).

The AI energy/power problem

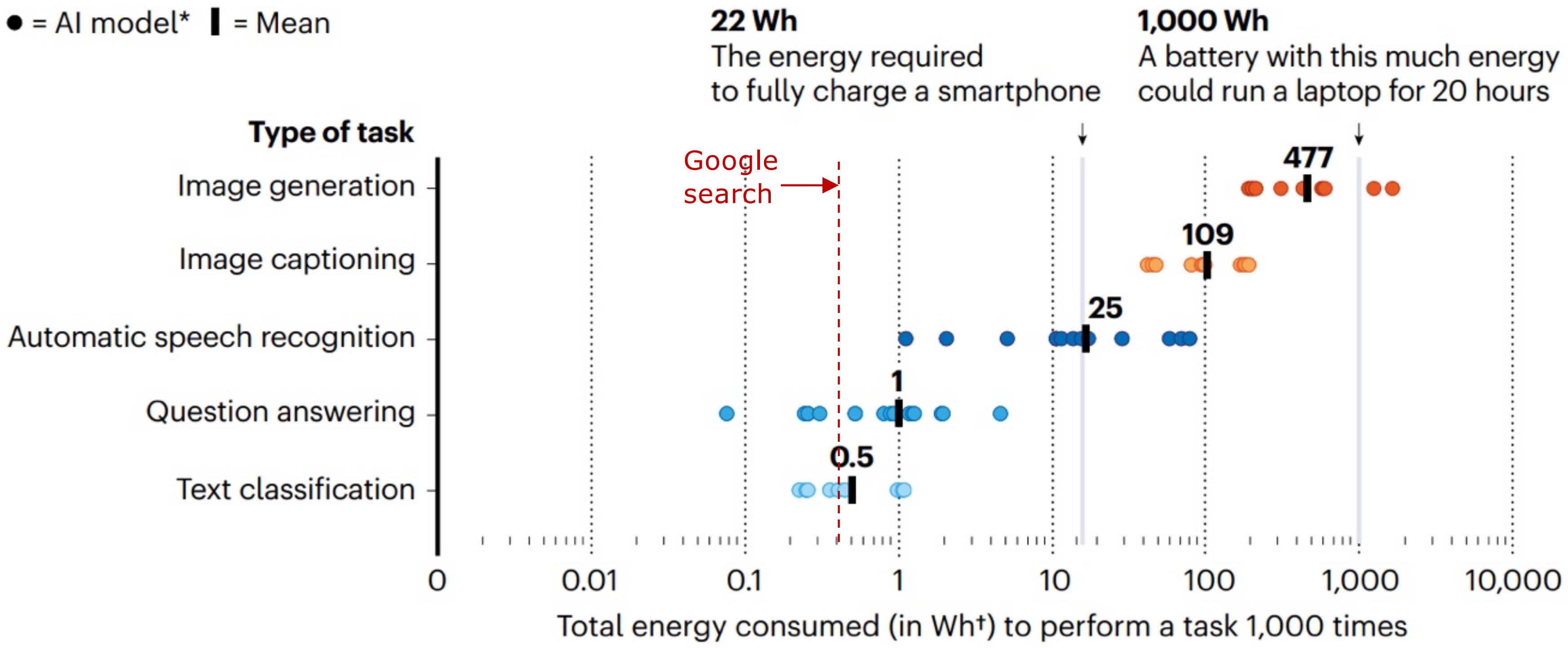
Two main types of servers: Traditional (CPU) vs. AI (GPU/TPU)

- Graphical processing units (GPUs) are well-suited for **parallel computing** and **high-performance tasks** (AI, machine learning, simulations, rendering).
- Central processing units (CPUs) are suitable for **general-purpose tasks** (web hosting, application servers, databases, and transactional workloads).
- GPUs have higher idle power consumption and cooling requirements.
- GPUs are more performant and energy efficient for parallel tasks.
- GPUs demand higher power capacity while using less energy



The more complicated the task, the more energy

The widespread use of AI in many applications is driving demand dramatically.



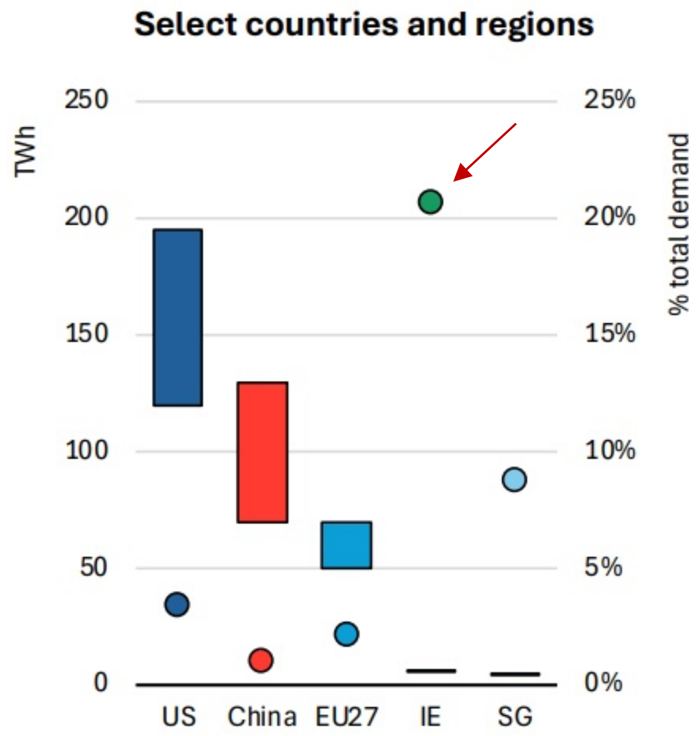
*Tests conducted on 20 popular open-source models. Each dot represents one model; †1 Watt-hour represents power consumption of 1 W extended over 1 hour.

Source: Luccioni, et al. (2024) [Nature]

Problem of the data centre boom

Data centres demand ~22% of Ireland's national electricity.

- Regional hubs: Virginia (USA) hosts 31% of the global hyperscale data centre capacity.
- The power grid is already under stress in data centre hubs.
- The interconnection queues are long (multiple years).
- The growth of data centres is much faster than that of clean electricity in these regions.



Notes: N. Am. = North America. APAC = Asia Pacific, including Oceania. RoW = rest of world, including Latin America, Africa, and the Middle East. EU27 = European Union 27. IE = Ireland. SG = Singapore.

Source: Luccioni, et al. (2024) [IEA/4E]

The data centre–climate dilemma

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Meeting data centres' electricity demand (rapidly) is not aligned with climate goals.

- In Dublin, 50% of electricity demand comes from data centres.
- New data centre connections are banned in Dublin until 2028.
- The new regulation by the Irish authority asks data centres to:
  - Be flexible in reducing their load when the grid wants
  - Match their demand with renewable energy on a 24/7 scale (and not only doing annual accounting)

THE IRISH TIMES

Climate Crisis

Data centre boom under AI growth in Ireland threatening climate targets, report warns

Friends of the Earth calls for 'moratorium on new data centres and expansion of existing ones until robust legislative framework is in place'

The AI boom exacerbating energy problems

Rapid access to reliable electricity is the key challenge.

- Hyperscale data centres seeking rapid build-out anywhere possible.
- Extension or new additions of fossil fuel power (20 GW of new natural gas, only in a few data centre states in the US).
- Data centres are being considered a critical infrastructure to bypass climate targets (e.g., Virginia, US).
- Texas Senate Bill #6 (July 2025) asking for the right to cut data centres from the grid to permit accelerated access.

➔ *The data centre boom is threatening both the climate and grid stability.*

Pollution from Big Tech's data centre boom costs US public health $5.4bn

Research suggests the price of treating illnesses related to building of computing infrastructure in the US is on the rise

Data centres cause pollution through high electricity use © Elijah Nouvelage/Bloomberg

The political side of the data centre problem

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From US to UK and EU: Data centres for national security and tech competitiveness

- The US Secretary of Energy wants to change the regulations for connecting data centres to the grid much faster (in 60 days).

United States Department of Energy
U.S. government department

" … *the nation's ability to remain at the forefront of technological innovation depends on an affordable, reliable, and secure supply of energy* [to data centres]".

techUK
FOR WHAT COMES NEXT

Secure Data Centres and Their Role in The National Security Strategy

cerre Centre on Regulation in Europe

PUBLICATIONS #CROSS-SECTOR, ENERGY & SUSTAINABILITY

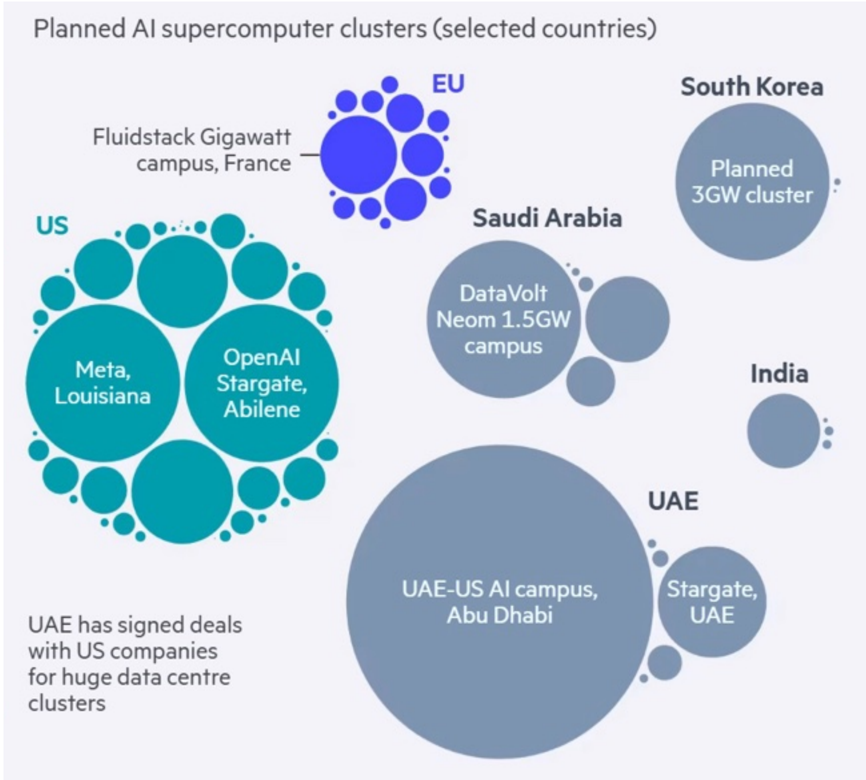
From Gridlock to Grid Asset: Data Centres for Digital Sovereignty, Energy Resilience, and Competitiveness

September 30, 2025

The AI race and energy security

New players and partnerships to win the AI-energy race

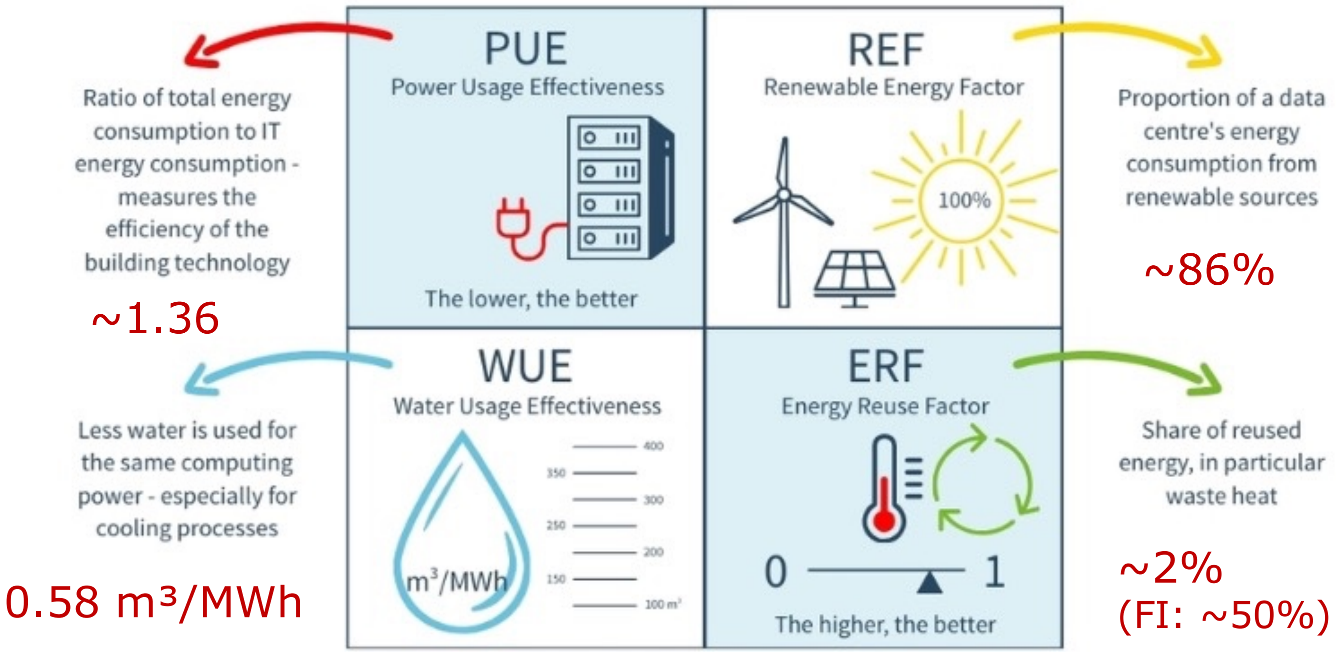
- The US and UAE signed the plan for the world's largest data centre campus in the UAE (May 2025)



Sources: left, Fusion Chat; right, [Financial Times]

Energy and environmental performance of data centres

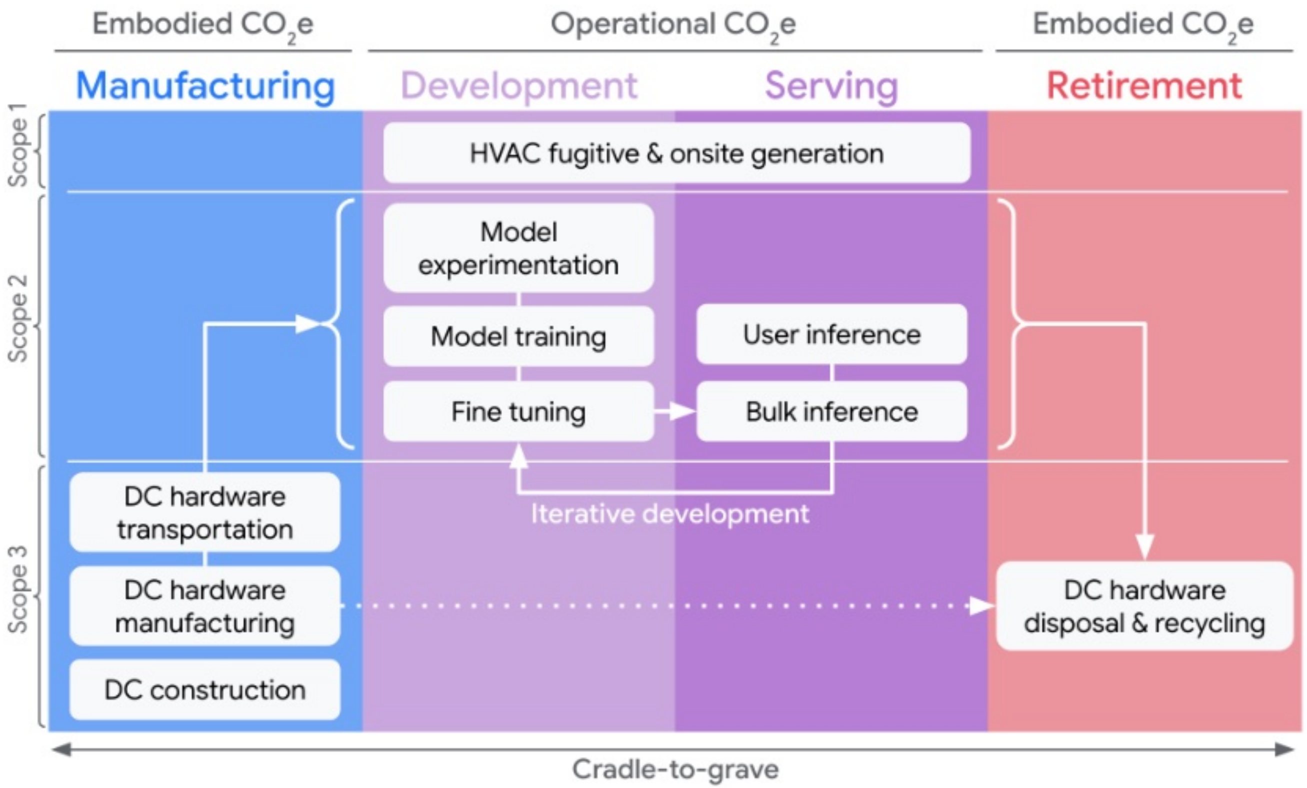
Current metrics focus on input electricity. They don't reflect computation and service.



Source: European Commission's First Technical Report (2025).
Image: Borderstep

Assessing the carbon footprint of LLMs

Making the industry accountable for reporting life cycle GHGs of AI services.



Source: Schneider, et al. (2025) [Google preprint]

Hot chips: AI servers' carbon footprint

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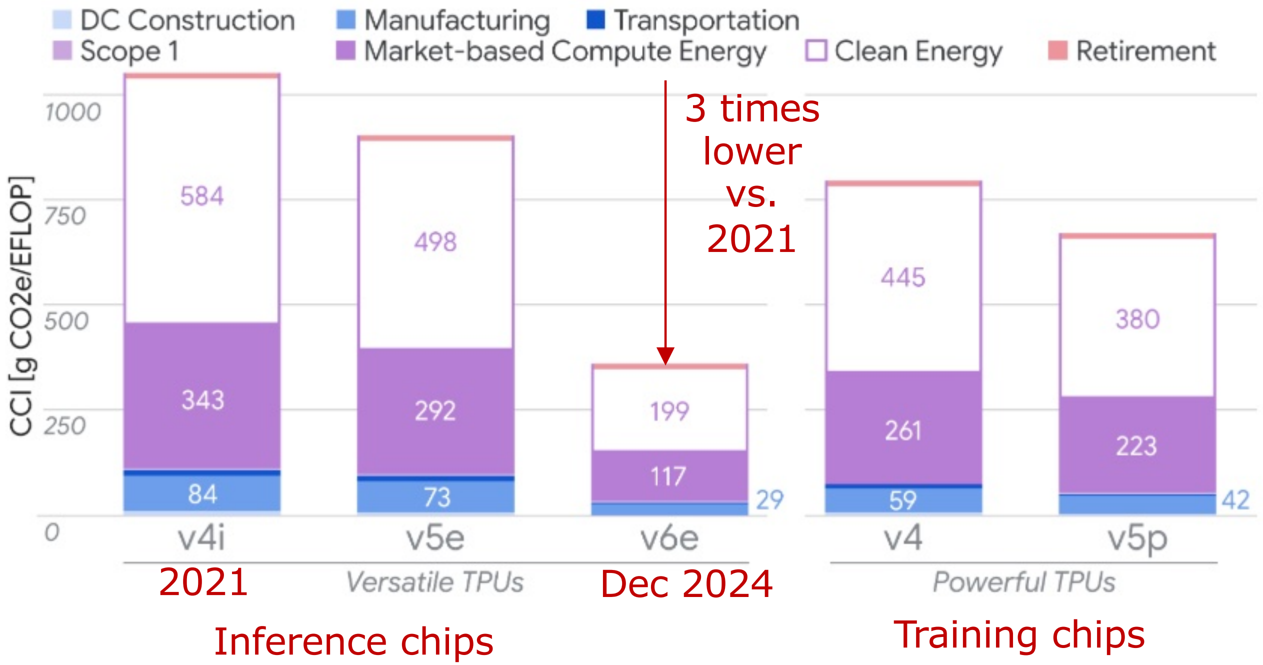
The carbon intensity can be calculated per computational service

- New chips are more material-intensive: higher GHG emissions per unit
- Most GHG emissions come from the energy for the data centre operation

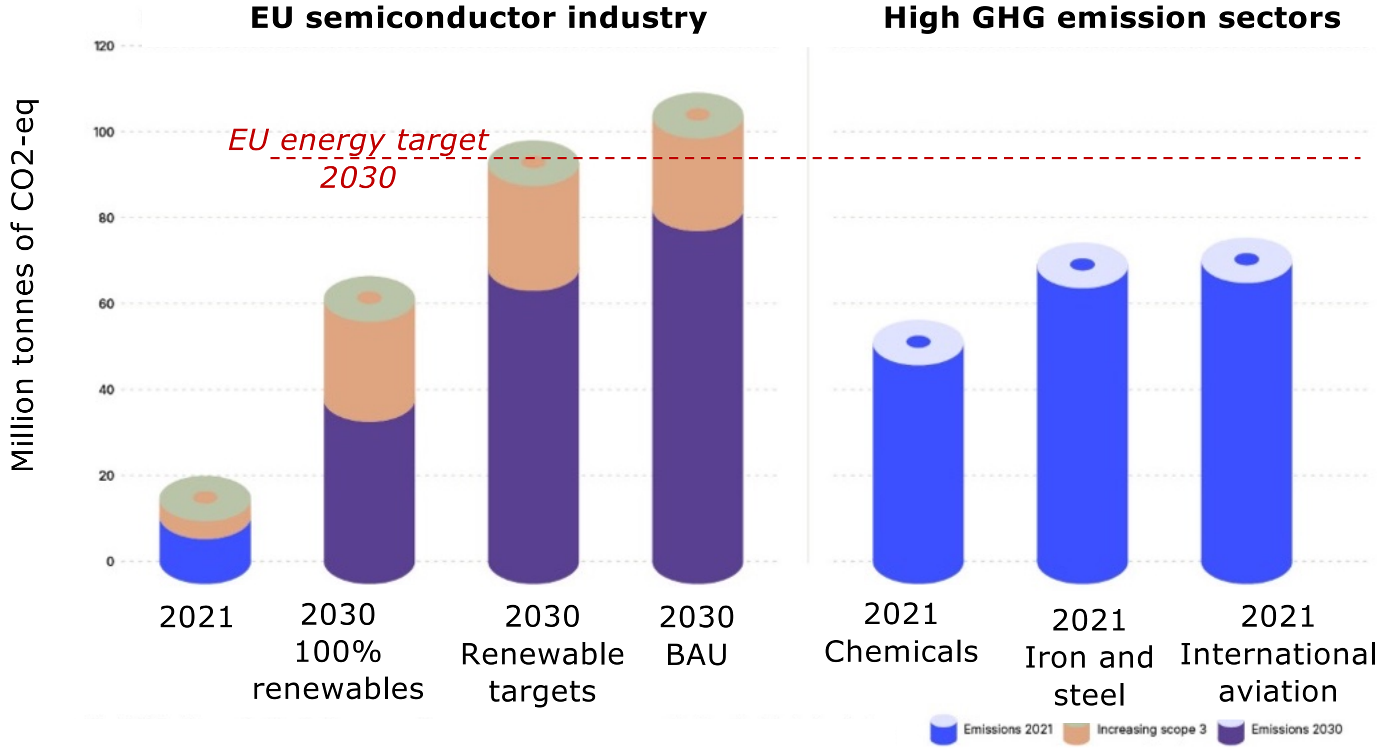
CCI: Compute Carbon Intensity



Source: Schneider, et al. (2025) Google preprint

Carbon footprint of the semiconductor industry

The sector’s GHG emissions will be the highest in the EU by 2030

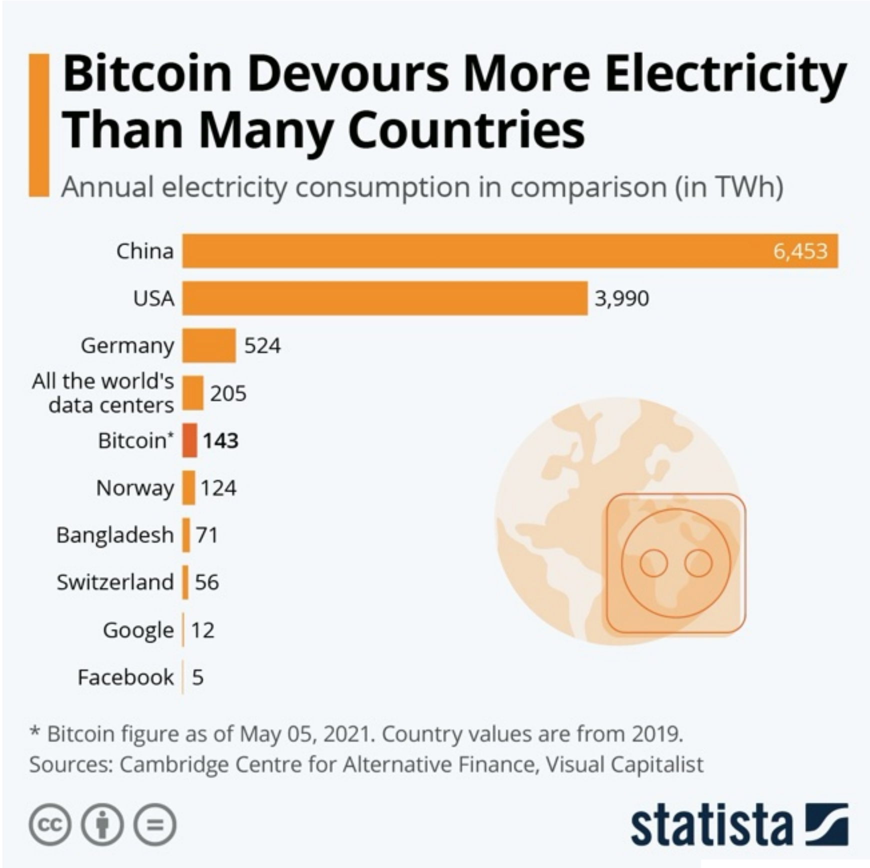


Source: interface-eu

And the cryptocurrency industry?

The ugly part of the ICT environmental footprint.

- Until recently, crypto mining (mainly Bitcoin) electricity consumption was comparable to data centres.
- But crypto mining has higher GHGs as it is mainly happening in countries with dirtier grids.
- No regulation, no control/monitoring, no requirements for efficiency or emissions reporting.



Data centres and renewable energy

Data centre’s energy flexibility could be enhanced to be grid-friendly.

- AI data centres could operate more flexibly, with some tasks like LLM training having high latency.
- Data centre load correlates with solar PV generation in many regions.
- Sources of data centre flexibility:
  - Optimal task scheduling
  - Workload time shifting (e.g., AI tasks)
  - Smart cooling (thermal storage)
  - Geographical load balancing
  - Grid-aware operation (demand response)
  - On-site electricity generation and storage
- User-side flexibility and awareness

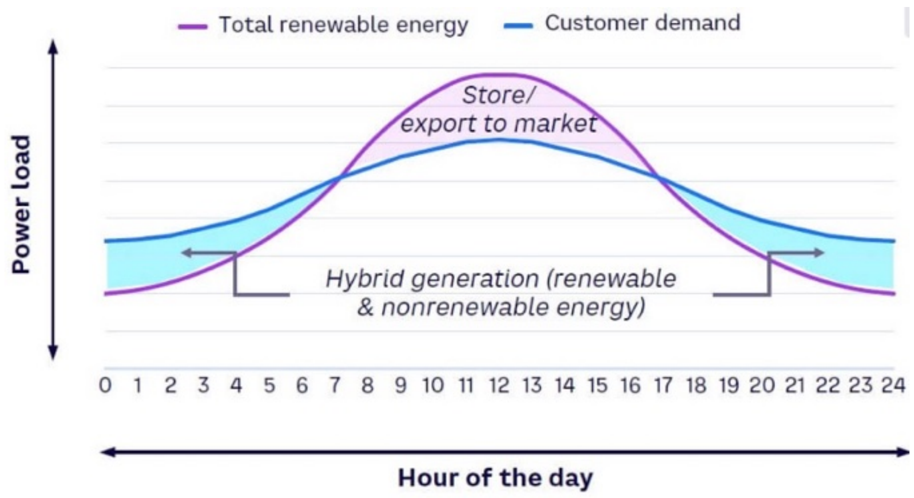
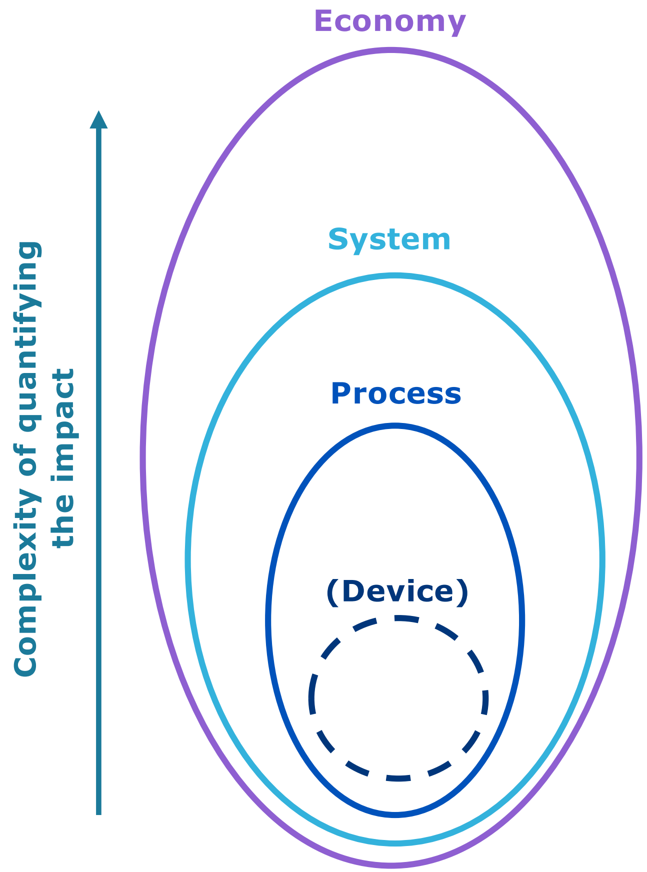


Image: [Arthur D Little]

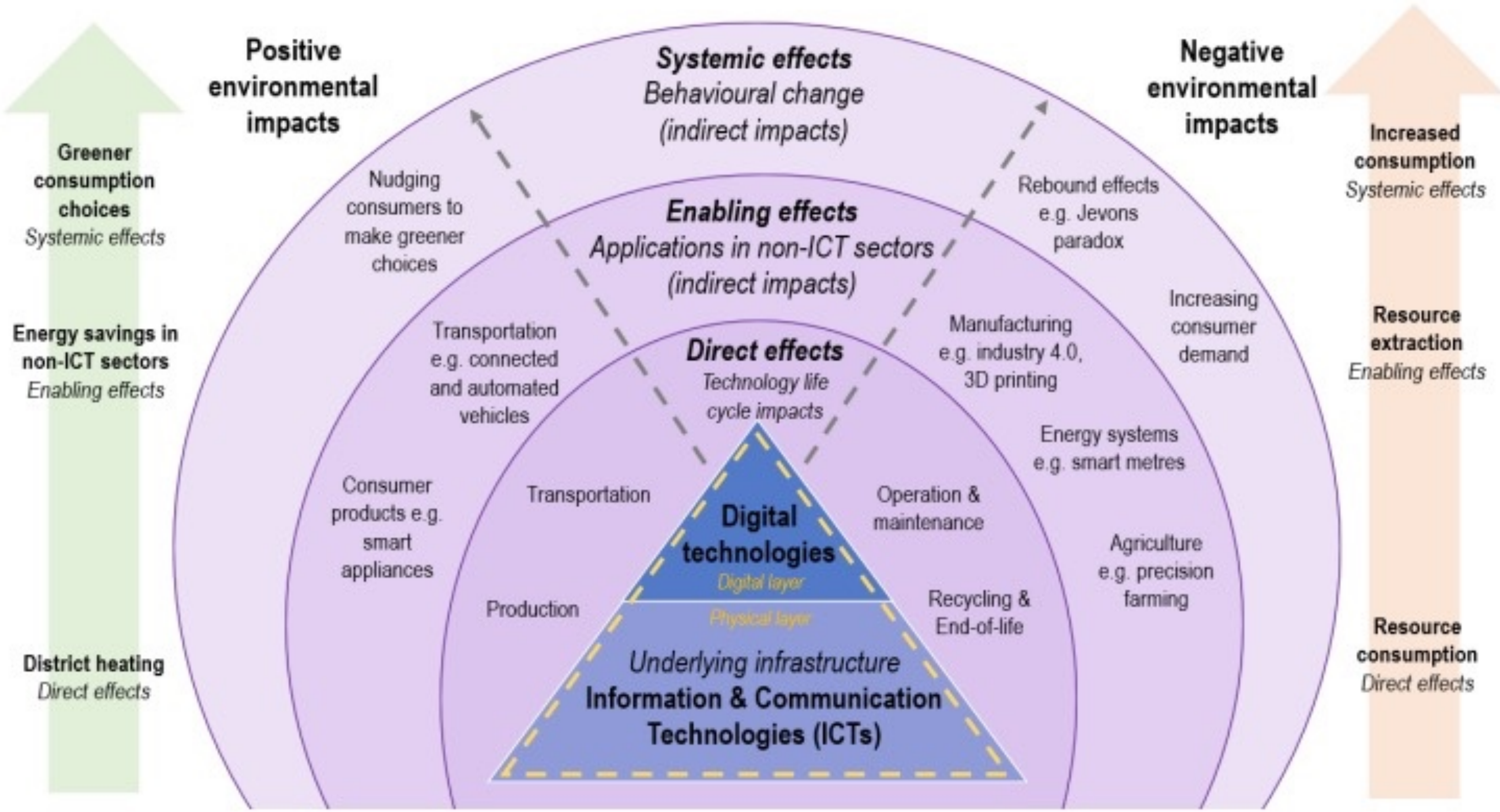

The way forward
gettyimages
Credit: Achim Thomae
1270957243

The environmental impact of digitalisation

- **Direct impact (-)**
  - Attributed to the use of energy, water, material, etc. for digital tools and computations (e.g., material for processing chips, electricity for data centres)
- **Indirect impact (+/-)**
  - Attributed to the way digitalisation can impact a process for which it is being applied (e.g., enhance efficiency of a machine/process vs. increased user activity)
- **System-wide impact (?)**
  - Structural changes in the overarching system due to the "digital transformation" (e.g., new business practices, redesigns of a health system)
- **Economy-wide impact (???)**
  - The wider impact of digitalisation on economies, industries, and lifestyles (beyond the process and overarching system)



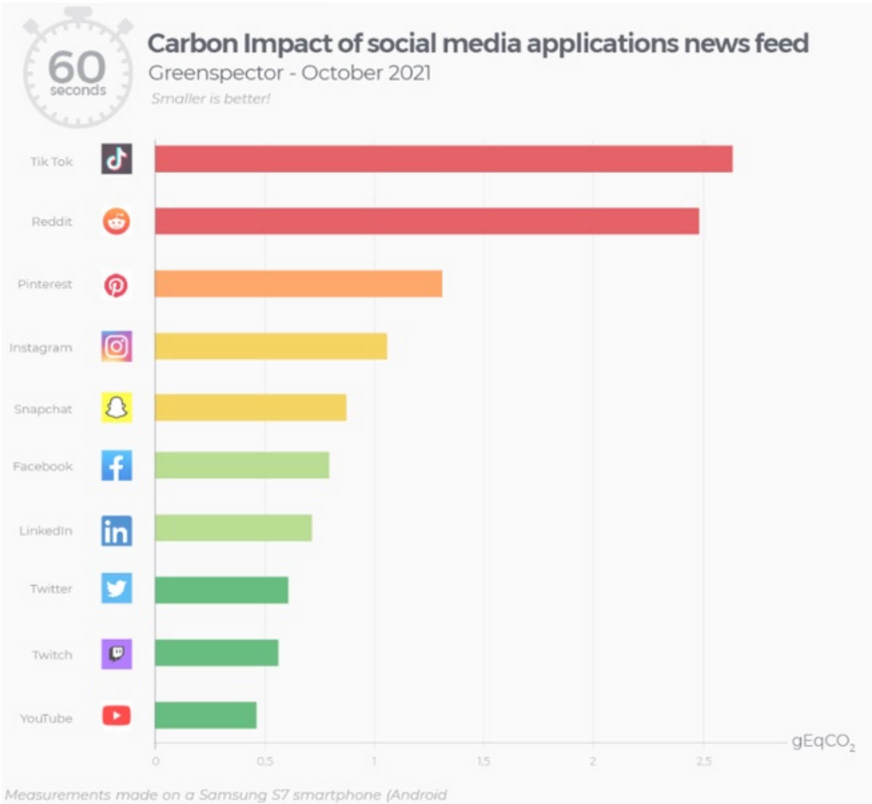
The *real* impact of digitalisation



Source: [OECD Digitalization Papers]

What can we do?

Adding grid- or carbon-aware labels would nudge the user behaviour?



As more data centres crop up in rural communities, local opposition to them has grown.

Light bulbs have energy ratings – so why can't AI chatbots?

Beyond data centres: end-user devices

One less big monitor/TV at home has the biggest environmental contribution

- ~63% related to the user devices/operations
- Using TVs is a major emitter of carbon emissions:
  - 83% of user-side emissions
  - 58% of manufacturing emissions
- Data centres accounted for 25% of the digital carbon footprint.
- Video streaming is responsible for most of the carbon emissions from networks (97%)
- An average German emits ~850 kg CO_2 per year for their digital life.

(cf. 2450 kg for electricity and heat, 2200 kg for transport fuel, 2750 kg for food)

(The numbers are based on an average user in Germany, and before the recent AI hype)

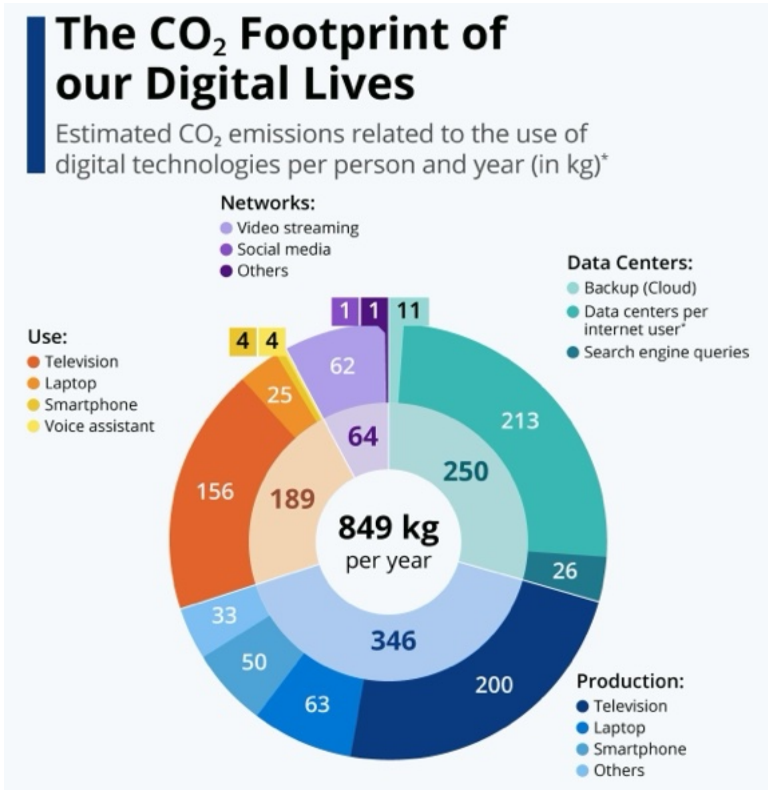


Image from **Statistica** (based on a study by The Öko-Institut)

Challenges

Transparency, accountability, and social responsibility in ICT's impact assessment

- The AI value chain (from chips to data centres) does not reveal/report its environmental footprint, or when they do, the methods are not transparent or expert-reviewed.
- Uneven, distributional effects of the AI race are extreme: typically, high concentration in areas most under stress.
- The data centre water-accounting method must explicitly support time/locational scheduling to lower stress.
- The energy accounting of data centres must move from annual matching to 24/7 carbon-free matching regulation.
- Semiconductor wastewater loads and treatment hurdles underscore the need for point-of-use + centralised abatement and advanced oxidation.

Final notes

The good, the bad, and the ugly

- The AI, like many other technologies, is not good or bad in itself.
- The AI boom has **revealed and exacerbated** the environmental sustainability problems: excessive resource use, distributional effects, inequalities, waste, etc.

- The data centre boom is (re)shaping the narrative around the environmental impact. The AI industry must be held accountable and responsible, not privileged.
- The user’s digital footprint must not be overlooked, especially beyond energy and emissions, including the material footprint (lifetime extension, recycling, etc.).

- The AI hype + national security + industry dominance is creating wasteful races.
- The regulation must be put in place to reduce the environmental impact, including the darker sides of the ICT (e.g., the semiconductor industry and crypto).

Thank you! Any reflection and question is welcome!

The views presented here were those of the presenter, not the position of any institution or group.

Dr. Behnam Zakeri

Assistant Professor, Deputy Head
Institute for Data, Energy, and Sustainability (IDEaS)
Vienna University of Economics and Business

Tel: + 43-1-31336-5677
E-Mail: behnam.zakeri@wu.ac.at
www.wu.ac.at/ideas