What is the Climate Impact of AI?

Talk at AI Opener for Destinations 2025
Feb. 2025

Raghavendra Selvan

Assistant Professor
Machine Learning Section
Dept. of Computer Science
University of Copenhagen
Member of Pioneer Center for AI (DK) & ELLIS

@raghavian
raghav@di.ku.dk
https://raghavian.github.io/

enRichMyData

What is the Climate Impact of AI?

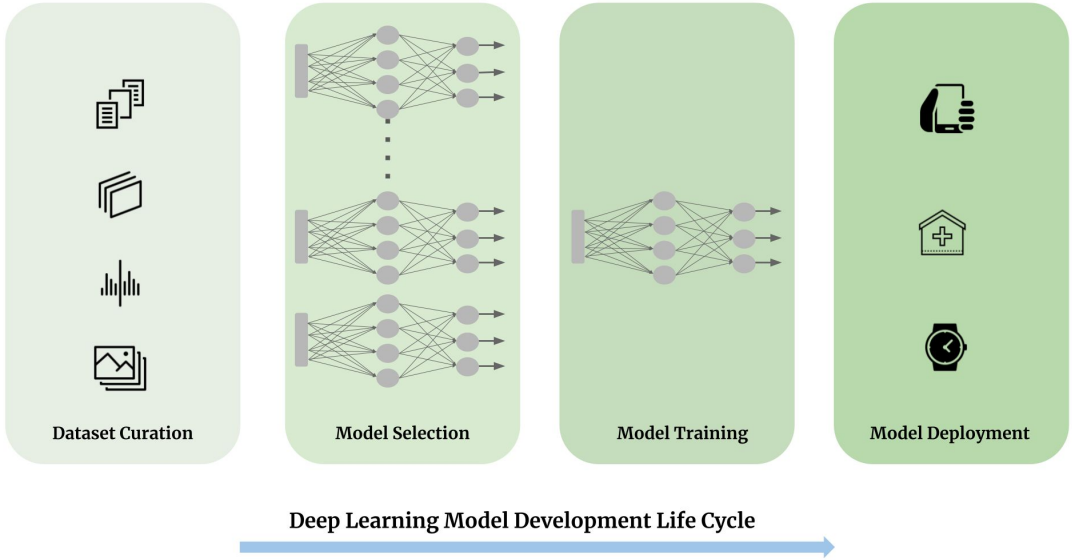
What is the Carbon Footprint of AI?

What is the Carbon Footprint of AI?

Focus has primarily been on the carbon footprint due to energy consumption when using AI.

What is the Carbon Footprint of AI?

Focus has primarily been on the carbon footprint due to energy consumption when **using** AI.



What is the Carbon Footprint of AI?

Currently, by AI many are only thinking about Generative AI

Compute Needs are Growing Exponentially!

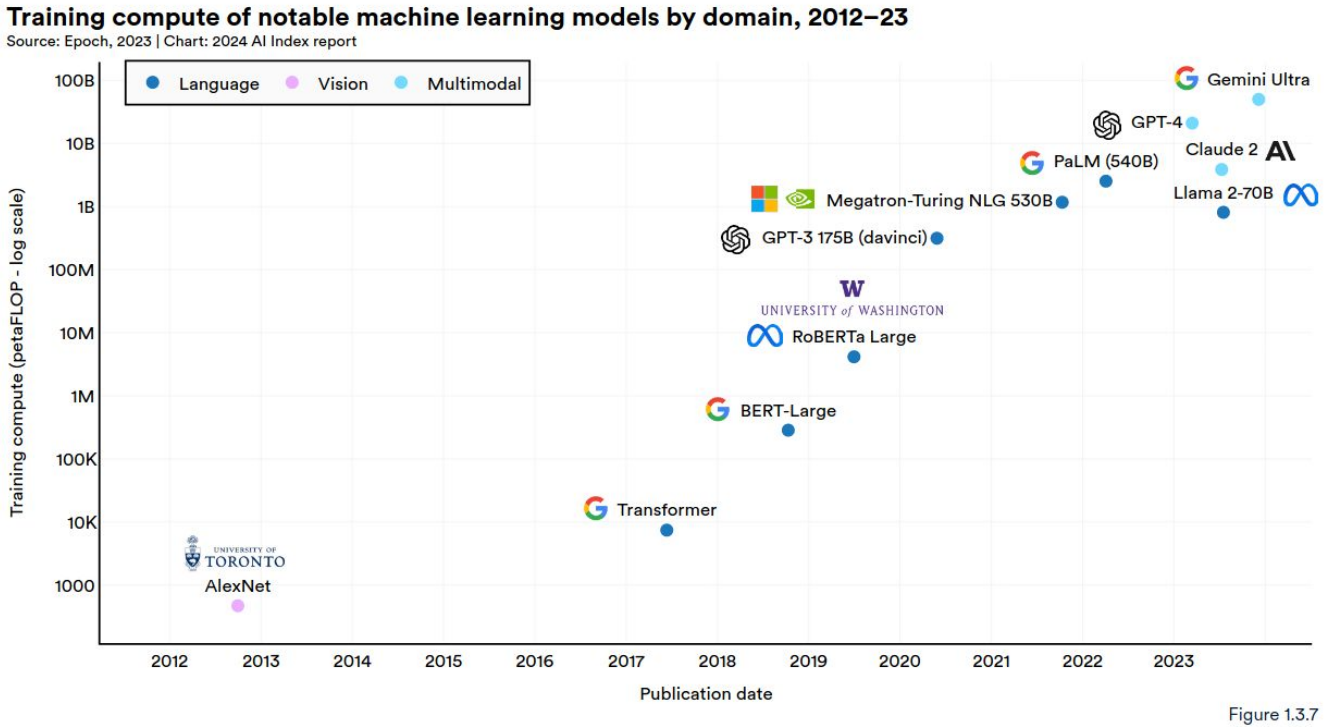


Figure 1.3.7

Artificial Intelligence Index Report 2024 by Stanford University

ML Research Community has some estimations

[2] https://github.com/meta-llama/llama-models/blob/main/models/llama3_2/MODEL_CARD.md
[3] Table from Luccioni et al. 2022. Estimating the carbon footprint of BLOOM
[4] https://github.com/meta-llama/llama-models/blob/main/models/llama3_1/MODEL_CARD.md
[5] V. Avelar et al. “The AI disruption: Challenges and guidance for data center design,” Schneider Electric, 2023.

ML Research Community has some estimations

Model name	Number of parameters	Power consumption	CO_2eq emissions	CO_2eq emissions × PUE
GPT-3	175B	1,287 MWh	*502 tonnes*	552 tonnes
Gopher	280B	*1,066 MWh*	*352 tonnes*	380 tonnes
OPT	175B	*324 MWh*	70 tonnes	*76.3 tonnes* [3]
BLOOM	176B	433 MWh	25 tonnes	30 tonnes

[2] https://github.com/meta-llama/llama-models/blob/main/models/llama3_2/MODEL_CARD.md
[3] Table from Luccioni et al. 2022. Estimating the carbon footprint of BLOOM
[4] https://github.com/meta-llama/llama-models/blob/main/models/llama3_1/MODEL_CARD.md
[5] V. Avelar et al. "The AI disruption: Challenges and guidance for data center design," Schneider Electric, 2023.

ML Research Community has some estimations

Model name	Number of parameters	Power consumption	CO_2eq emissions	CO_2eq emissions × PUE
GPT-3	175B	1,287 MWh	*502 tonnes*	552 tonnes
Gopher	280B	*1,066 MWh*	*352 tonnes*	380 tonnes
OPT	175B	*324 MWh*	70 tonnes	*76.3 tonnes* [3]
BLOOM	176B	433 MWh	25 tonnes	30 tonnes

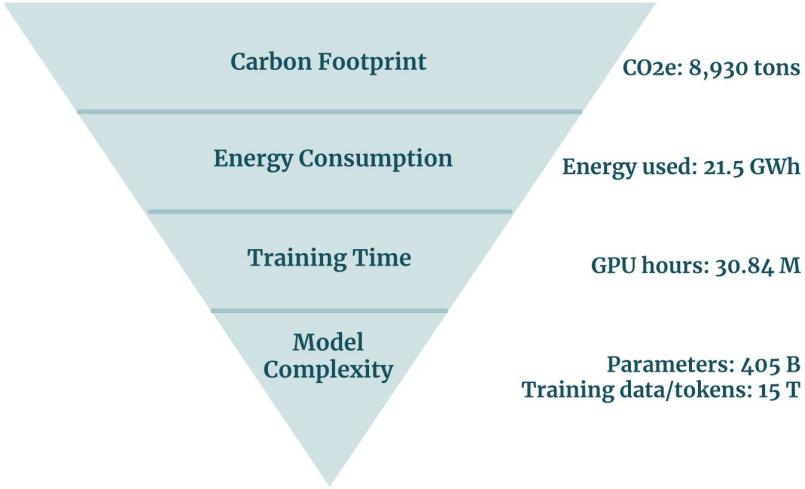
Carbon Footprint of Selecting and Training Deep Learning Models for Medical Image Analysis

Raghavendra Selvan[1,2], Nikhil Bhagwat[3], Lasse F. Wolff Anthony[1], Benjamin Kanding[1], and Erik B. Dam[1]

[1] Department of Computer Science, University of Copenhagen, Denmark
[2] Department of Neuroscience, University of Copenhagen, Denmark
[3] McGill University, Canada
raghav@di.ku.dk

Llama 3: 39.3M GPU hours

	Training Time (GPU hours)	Training Power Consumption (W)	Training Location-Based Greenhouse Gas Emissions (tons CO2eq)	Training Market-Based Greenhouse Gas Emissions (tons CO2eq)
Llama 3.1 8B	1.46M	700	420	0
Llama 3.1 70B	7.0M	700	2,040	0
Llama 3.1 405B	30.84M	700	8,930	0
Total	39.3M		11,390	0



(Annual energy consumption of ~6k people)

[2] https://github.com/meta-llama/llama-models/blob/main/models/llama3_2/MODEL_CARD.md
[3] Table from Luccioni et al. 2022. Estimating the carbon footprint of BLOOM
[4] https://github.com/meta-llama/llama-models/blob/main/models/llama3_1/MODEL_CARD.md
[5] V. Avelar et al. "The AI disruption: Challenges and guidance for data center design," Schneider Electric, 2023.
[6] Carbon Footprint of Selecting and Training Deep Learning Models for Medical Image Analysis. R Selvan, N Bhagwat, LFW Anthony, B Kanding, EB Dam. 2022
[7] Ten recommendations for reducing the carbon footprint of research computing in human neuroimaging. NE Souter, L Lannelongue, G Samuel, C Racey, LJ Colling, N Bhagwat, R Selvan, C Rae. 2023

But, what exactly is the electricity consumption of AI?

https://futurism.com/sam-altman-energy-breakthrough
https://x.com/dwarkesh_sp/status/1781328614270947492
https://www.theverge.com/2024/9/20/24249770/microsoft-three-mile-island-nuclear-power-plant-deal-ai-data-centers

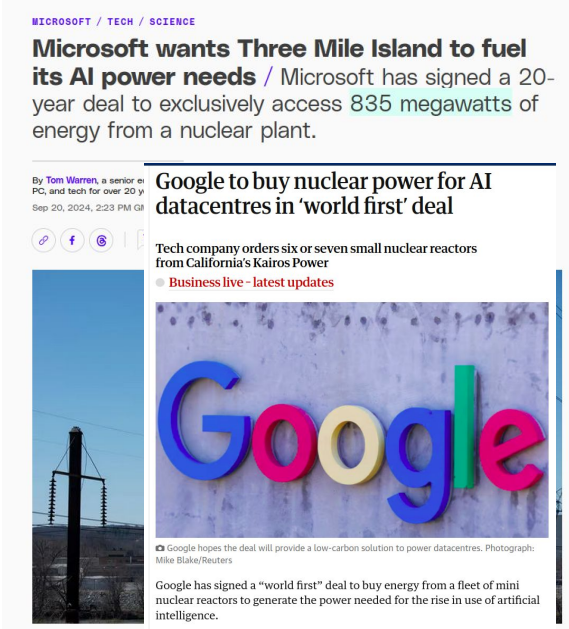
But, what exactly is the electricity consumption of AI?

We don’t know!

https://futurism.com/sam-altman-energy-breakthrough
https://x.com/dwarkesh_sp/status/1781328614270947492
https://www.theverge.com/2024/9/20/24249770/microsoft-three-mile-island-nuclear-power-plant-deal-ai-data-centers

But, what exactly is electricity consumption of AI?

We don't know!

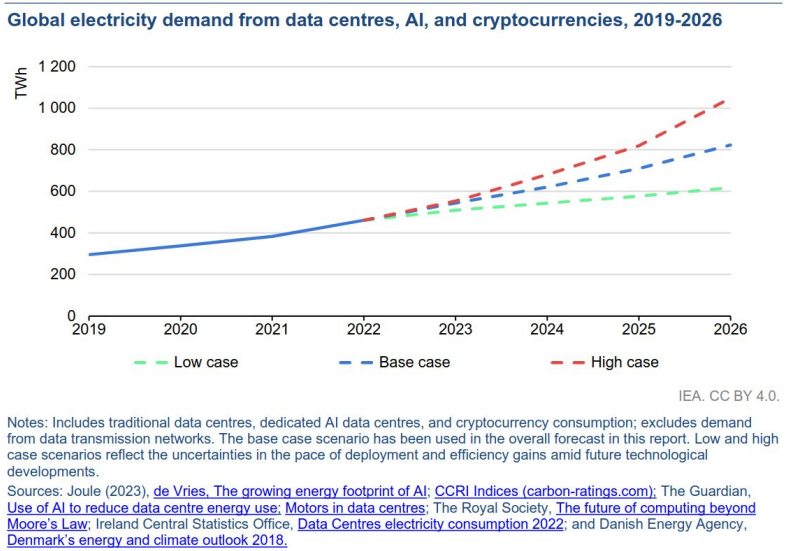


https://futurism.com/sam-altman-energy-breakthrough
https://x.com/dwarkesh_sp/status/1781328614270947492
https://www.theverge.com/2024/9/20/24249770/microsoft-three-mile-island-nuclear-power-plant-deal-ai-data-centers
https://www.theguardian.com/technology/2024/oct/15/google-buy-nuclear-power-ai-datacentres-kairos-power

Estimations from International Energy Agency

Source: Electricity 2024: Analysis and Forecast to 2026. IEA. International Energy Agency

Estimations from International Energy Agency

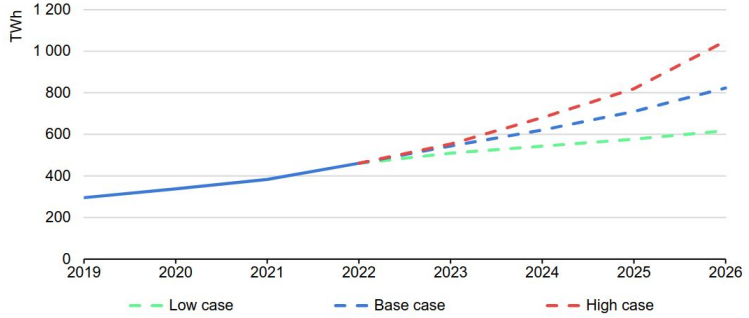


"...global electricity consumption of data centers to range between 620-1050 TWh in 2026, with our base case for demand at just over 800 TWh – up from 460 TWh in 2022. This corresponds to an additional 160 TWh up to 590 TWh of electricity demand in 2026 compared to 2022, roughly equivalent to adding at least one Sweden or at most one Germany."

Source: Electricity 2024: Analysis and Forecast to 2026. IEA. International Energy Agency

Estimations from International Energy Agency

Global electricity demand from data centres, AI, and cryptocurrencies, 2019-2026

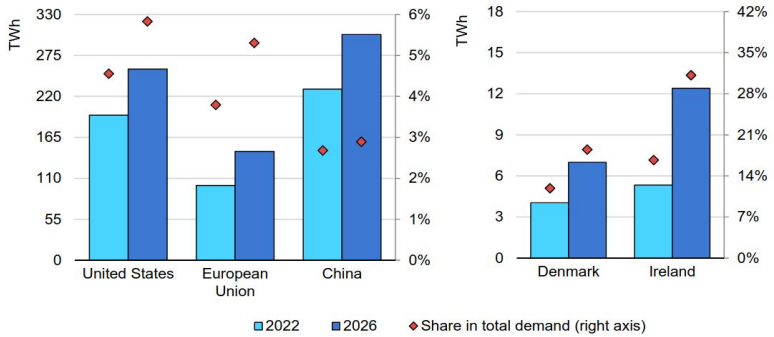


IEA. CC BY 4.0.

Notes: Includes traditional data centres, dedicated AI data centres, and cryptocurrency consumption; excludes demand from data transmission networks. The base case scenario has been used in the overall forecast in this report. Low and high case scenarios reflect the uncertainties in the pace of deployment and efficiency gains amid future technological developments.

Sources: Joule (2023), de Vries, The growing energy footprint of AI; CCRI Indices (carbon-ratings.com); The Guardian, Use of AI to reduce data centre energy use; Motors in data centres; The Royal Society, The future of computing beyond Moore's Law; Ireland Central Statistics Office, Data Centres electricity consumption 2022; and Danish Energy Agency, Denmark's energy and climate outlook 2018.

Estimated data centre electricity consumption and its share in total electricity demand in selected regions in 2022 and 2026



IEA. CC BY 4.0.

Sources: IEA, Data Centres and Data Transmission Networks; Lawrence Berkeley National Laboratory, United Stated Data Center Energy Usage Report; Ireland Central Statistics Office, Data Centres Metered Electricity Consumption 2022; Danish Energy Agency, Denmark's Energy and Climate Outlook 2018; China's State Council, Green data centres in focus; European Commission, Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market; Joule (2023), Alex de Vries, The growing energy footprint of artificial intelligence; and Crypto Carbon Ratings Institute, Indices.

"...global electricity consumption of data centers to range between 620-1050 TWh in 2026, with our base case for demand at just over 800 TWh – up from 460 TWh in 2022. This corresponds to an additional 160 TWh up to 590 TWh of electricity demand in 2026 compared to 2022, roughly equivalent to adding at least one Sweden or at most one Germany."

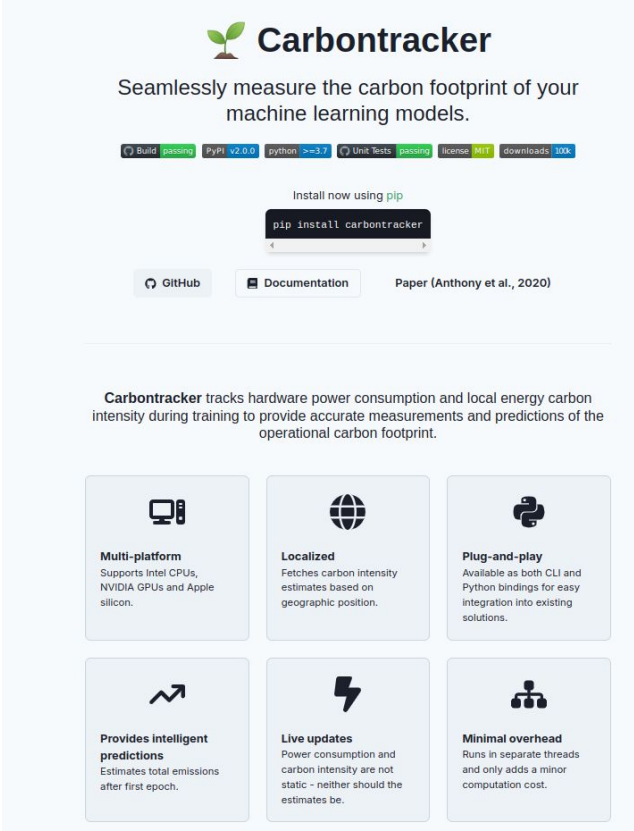
Source: Electricity 2024: Analysis and Forecast to 2026. IEA. International Energy Agency

Can we estimate the Carbon Footprint of AI?

Can we estimate the Carbon Footprint of AI?

Yes/Maybe. Either way, we first need some tools.

Carbontracker: Python Tool for tracking Carbon Footprint



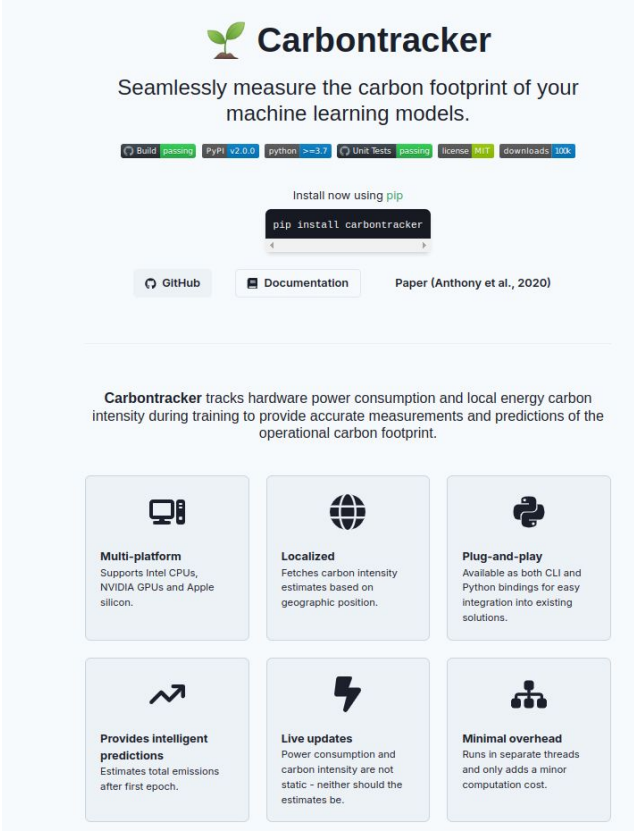
https://carbontracker.info/

Anthony, L. F. W., Kanding, B., & Selvan, R. (2020). Carbontracker: Tracking and predicting the carbon footprint of training deep learning models.

Carbontracker: Python Tool for tracking Carbon Footprint

- Developed at UCPH
- May 2020
- Open Source (MIT license)
- About 116k downloads

```
~: pip install carbontracker
~: carbontracker your_script <args>
```



https://carbontracker.info/

Anthony, L. F. W., Kanding, B., & Selvan, R. (2020). Carbontracker: Tracking and predicting the carbon footprint of training deep learning models.

Carbon Footprint of End Point Devices

Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

Carbon Footprint of End Point Devices

- Use tools like Carbontracker
- Run on phones, laptops, workstations, browsers
- Measure the energy consumption and carbon footprint locally
- Users have access (mostly)
- Easy to measure and report

Carbon Footprint of End Point Devices

- Use tools like Carbontracker
- Run on phones, laptops, workstations, browsers
- Measure the energy consumption and carbon footprint locally
- Users have access (mostly)
- Easy to measure and report

Let us measure it!

Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

Carbon Footprint of End Point Devices

- Use tools like Carbontracker
- Run on phones, laptops, workstations, browsers
- Measure the energy consumption and carbon footprint locally
- Users have access (mostly)
- Easy to measure and report

Are we done?

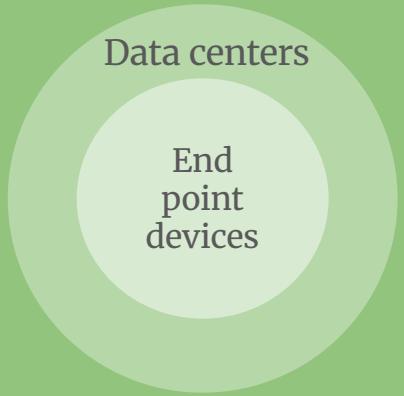
Most Generative AI algorithms live in the Cloud

End Point Devices

Most Generative AI algorithms live in the Cloud

- Data centers with compute clusters
- Energy consumption can still be measured
- Users do not have as much control
- However, ***data centers can measure and report***

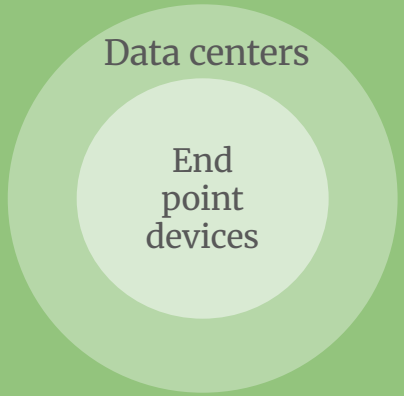
What about the “non-computational” emissions?



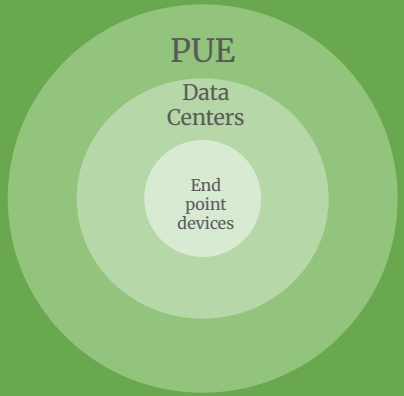
Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

What about the “non-computational” emissions?

- IEA reports only 40% electricity used for processing
- Another 40% is used for cooling
- Remaining 20% from other IT equipment, transmission
- Not always easy to measure
- Varies between infrastructure
- Power usage effectiveness (PUE)



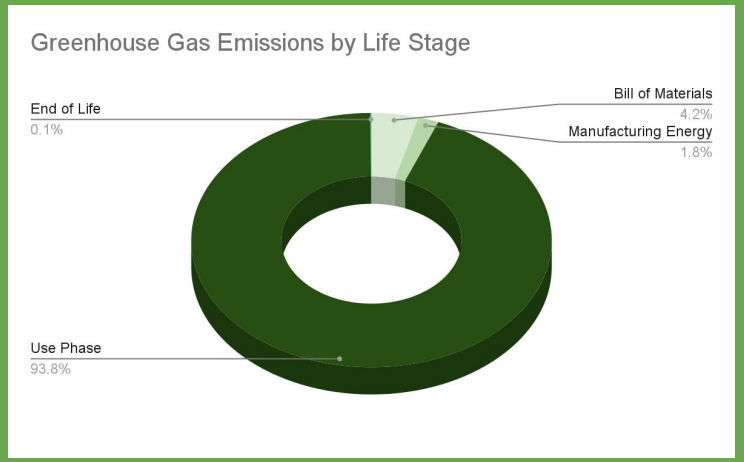
What about the Life Cycle Emissions?

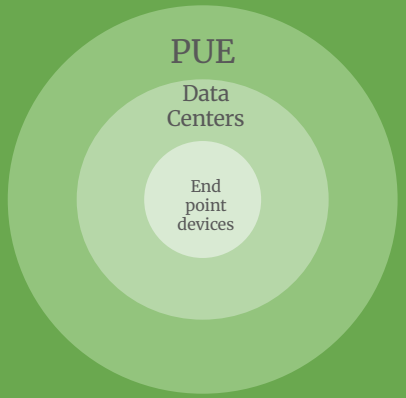


Source: Seagate Sustainability Report. 2023

Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

What about the Life Cycle Emissions?

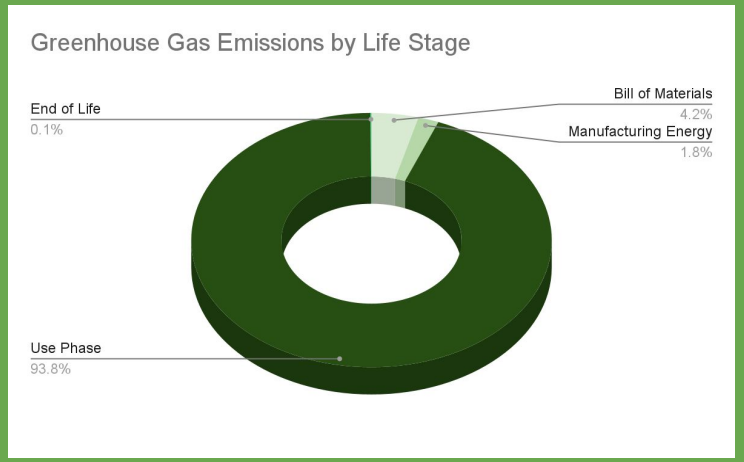




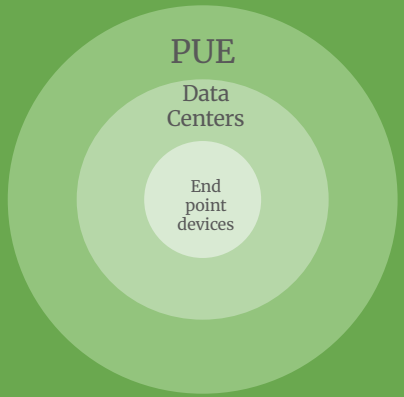
Source: Seagate Sustainability Report. 2023

Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

What about the Life Cycle Emissions?



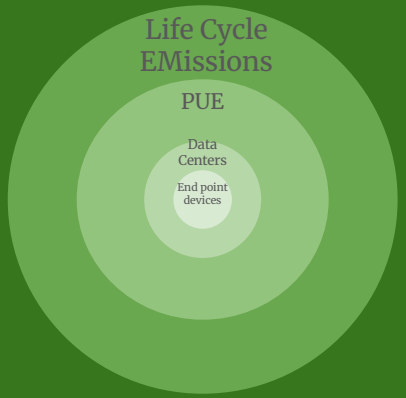
- Life cycle analysis is difficult
- Not all vendors publish this
- Amortizing these costs over AI model use is not straightforward



Source: Seagate Sustainability Report. 2023

Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

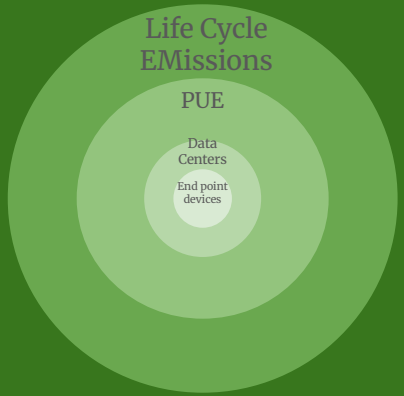
Other Environmental Impacts?



Wright et al. Efficiency is not Enough: A Critical Perspective on Environmentally Sustainable AI. (2024)

Other Environmental Impacts?

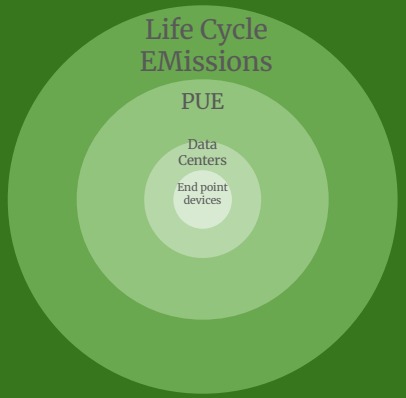
- Extractive mining for rare Earth minerals
- Fresh water uptake for cooling
- Building infrastructure
- Disposal of e-waste



Wright et al. Efficiency is not Enough: A Critical Perspective on Environmentally Sustainable AI. (2024)

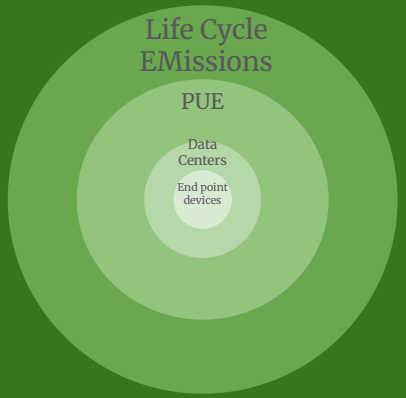
Other Environmental Impacts?

- Extractive mining for rare Earth minerals
- Fresh water uptake for cooling
- Building infrastructure
- Disposal of e-waste



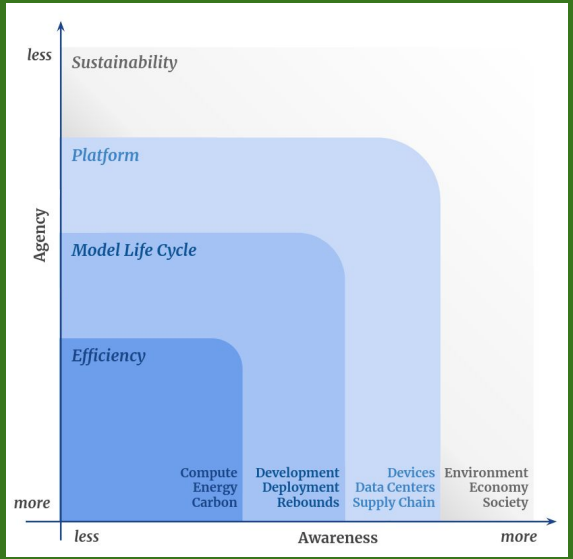
Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

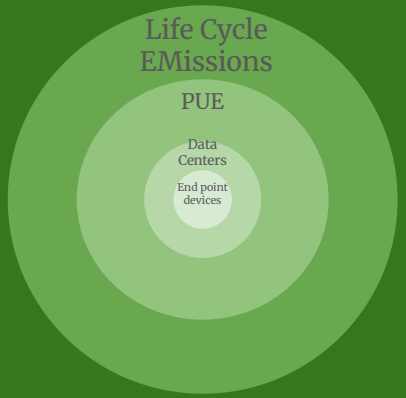
So, what can we do?



Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

So, what can we do?

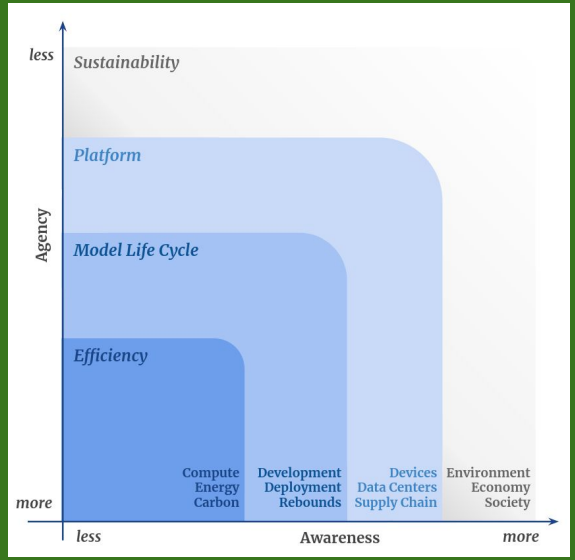


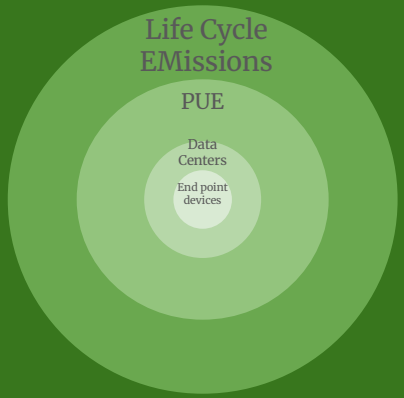


Wright et al. Efficiency is not Enough: A Critical Perspective on Environmentally Sustainable AI. (2024)

So, what can we do?

- Multi-stakeholder efforts
- Work towards standardised reportings
  - Energy labels
  - Model cards
- Seek transparency; publishing of data at each level
- Policies and recommendations on adoption at organisational levels
- Democratically designed regulations





Wright et al. Efficiency is not Enough: A Critical Perspective on Environmentally Sustainable AI. (2024)

Raghavendra Selvan, UCPH. raghav@di.ku.dk. 2025

What is the Climate Impact of AI?

Raghavendra Selvan

Assistant Professor
Machine Learning Section
Dept. of Computer Science
University of Copenhagen
Member of Pioneer Center for AI (DK) & ELLIS

@raghavian
raghav@di.ku.dk
https://raghavian.github.io/

Upcoming book on ...

Sustainable AI

by Raghavendra Selvan
Released October 2025
Publisher(s): O'Reilly Media, Inc.
ISBN: 9781098155513

https://www.oreilly.com/library/view/sustainable-ai/9781098155506/

Funding

European Union's HorizonEurope research and innovation programme undergrant agreements No. 101070284 and No. 101070408