Environmental Impacts of Digital Technology

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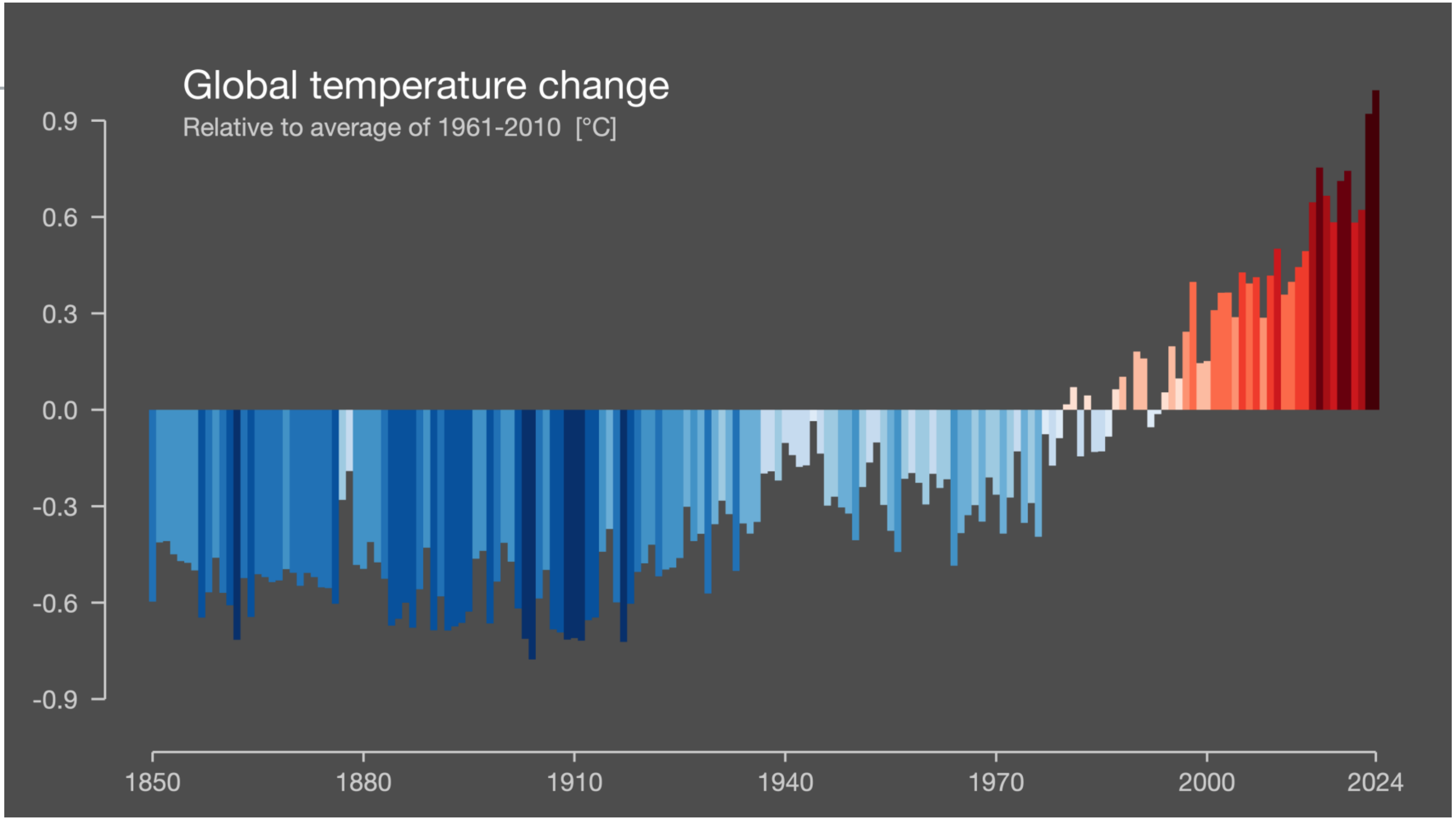
(Based on Bran Knowles material from 23/24)

Contents:

- Environmental impacts
- Environmental impacts of digital technologies
- Case study: NLP, LLM, AI
- Other ethical and social considerations
- Positive impacts
- What can those working with digital technologies do to reduce their negative impacts?
- Questions

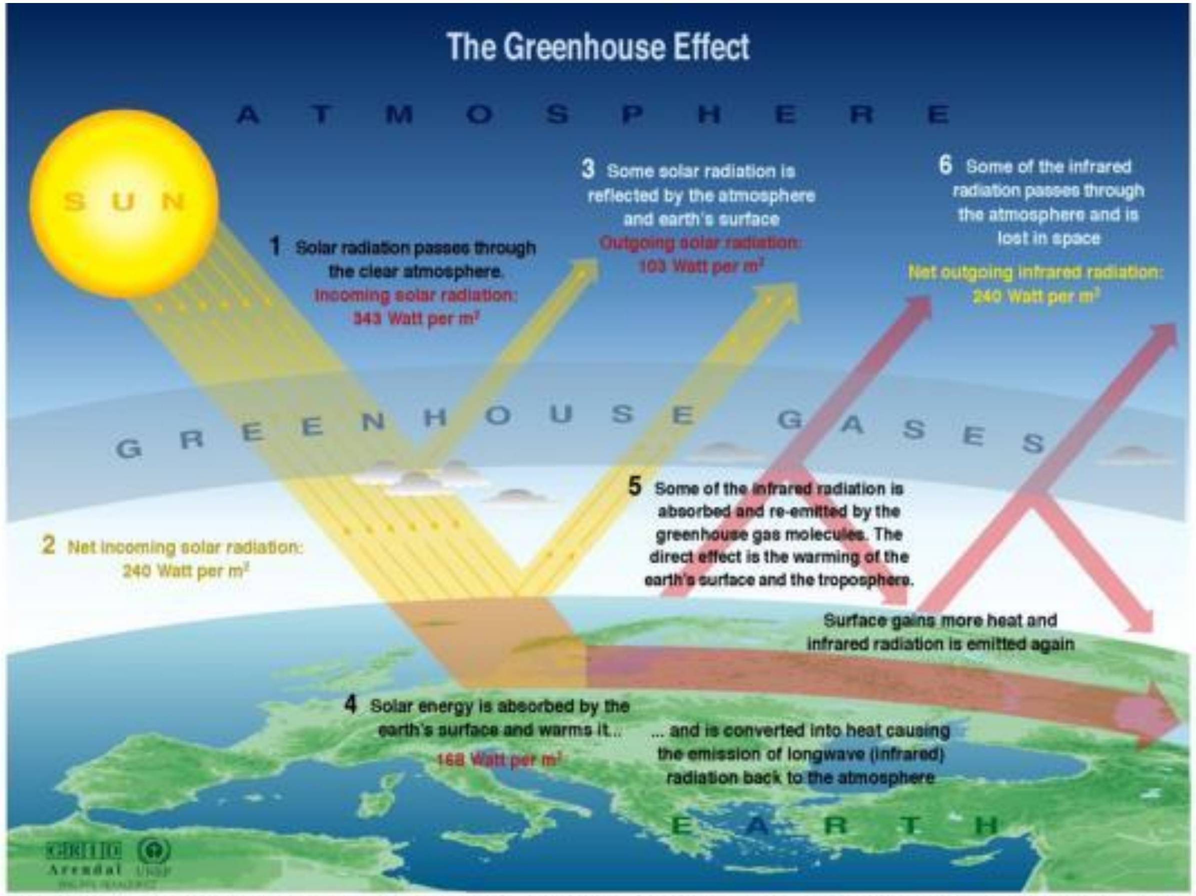
Why is it important to think about Environmental Impacts?

Rising average global temperature



Graphics and lead scientist: Ed Hawkins, National Centre for Atmospheric Science, University of Reading., National Centre for Atmospheric Science, UoR.
Data: Berkeley Earth & ERA5-Land, NOAA, UK Met Office, MeteoSwiss, DWD, SMHI, UoR & ZAMG

Greenhouse effect



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

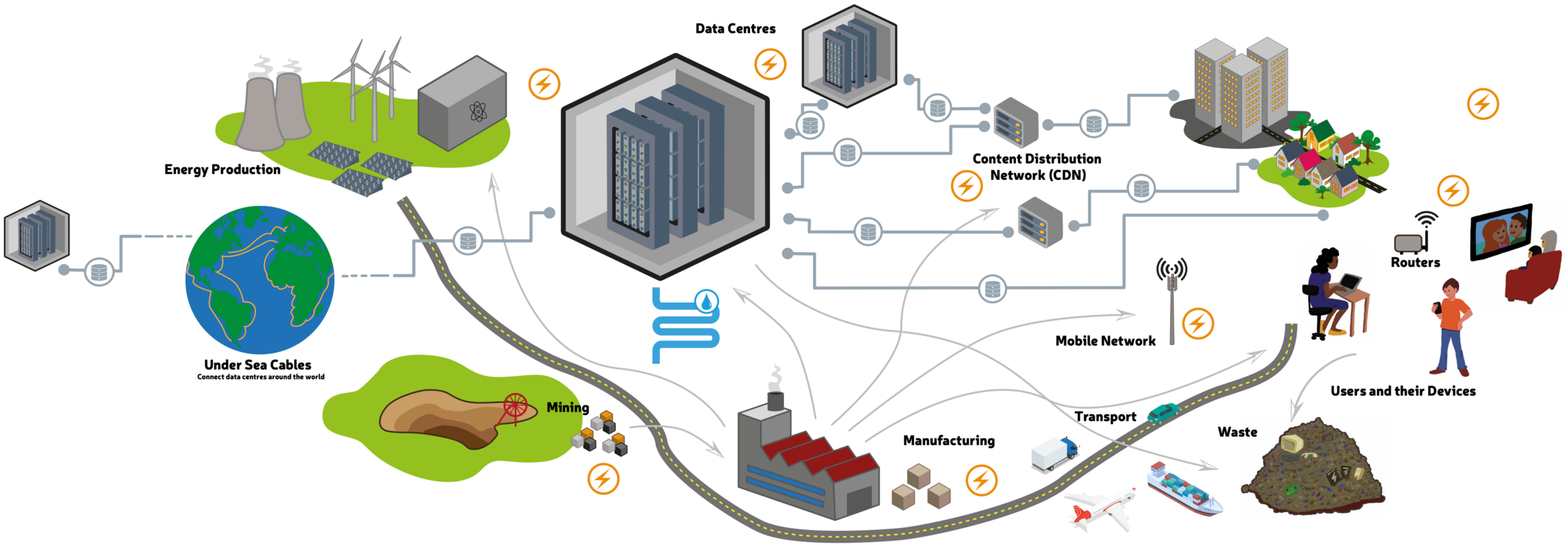
https://www.grida.no/resources/6888

Contributors include:

- **Burning of fossil fuels** (for energy)
- **Deforestation** (reduction of trees that remove carbon from the atmosphere)
- **Farming** (methane produced by animals)
- **Waste** (gasses released in landfill)

What are the Environmental Impacts of Digital Technology?

Physical Infrastructure behind the 'Cloud'



Energy Usage and GHG emissions

- The carbon emissions of the Information and Communication Technology (ICT) sector is estimated to be between 2.1% to 3.9% of global carbon emissions[1].
- This estimate did not include blockchain, IoT or AI.
- Carbon emissions of ICT come from energy used in computation (devices and network infrastructure), embodied carbon emissions from manufacturing and construction, transport of equipment and the end-of-life of devices.

1. Freitag, C., Berners-Lee, M., Widdicks, K., Knowles, B., Blair, G. S., & Friday, A. (2021). The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. Patterns, 2(9).

Carbon Emissions Accounting

- Carbon emissions generated by energy production vary geographically and is dependent on the proportion of fossil fuel and renewable energy sources that are employed in energy production of a certain location, season and time of day.
- Calculating carbon emission of ICT is not a simple task. The supply chains of services and products in ICT are very complex and it can be difficult to have data from all stages of manufacturing and usage.
- Emissions are classified as scope 1 (direct emissions), scope 2 (indirect purchased electricity, steam, heating, or cooling) or scope 3 (all the rest of the supply chain)[1]

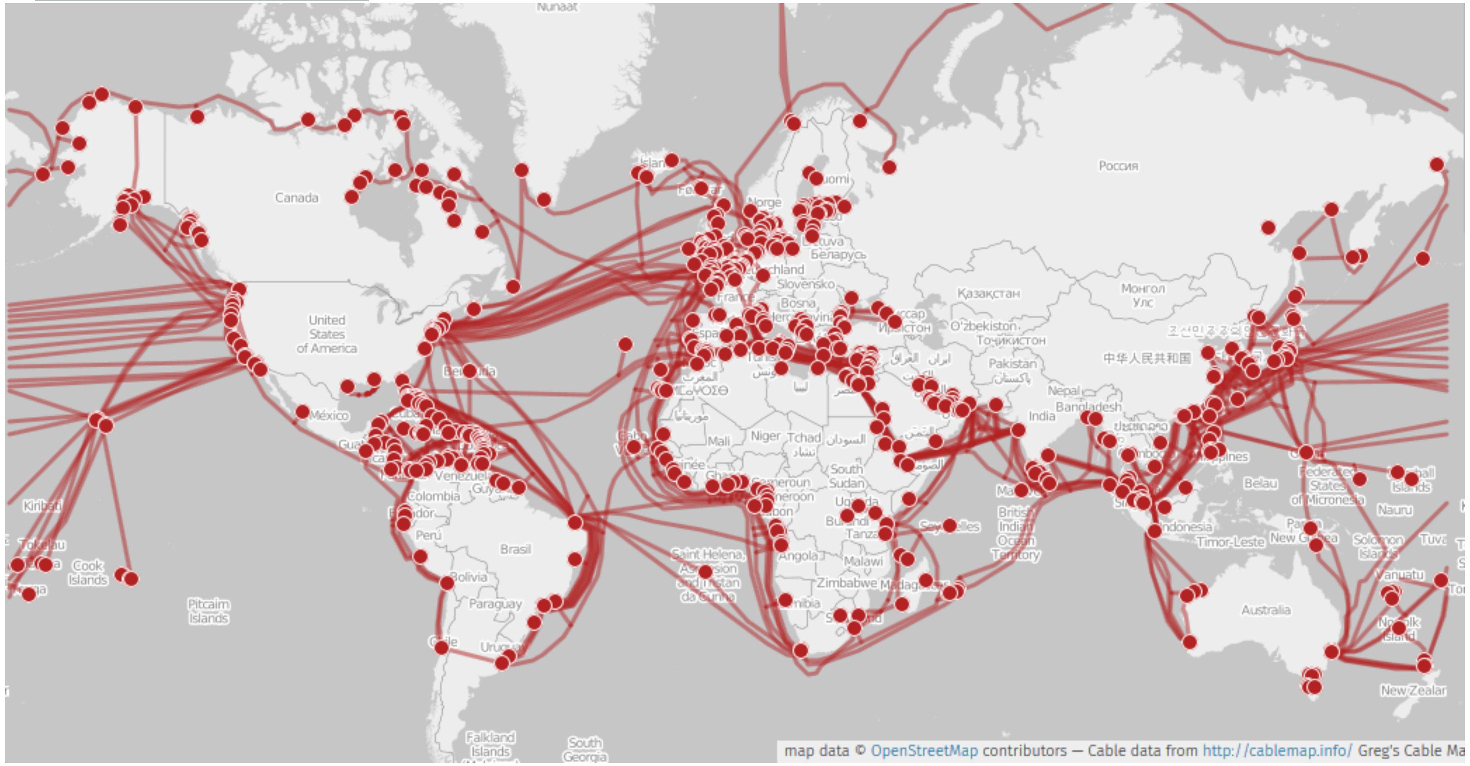
1. Greenhouse Gas Protocol - https://ghgprotocol.org/sites/default/files/2022-12/FAQ.pdf

Water usage

- Water usage to cool down data centres.
- Water usage for energy generation.
- Water usage in manufacturing and mining.
- Google reported that in 2023 their data centres and offices consumed 24 billion litres. In their estimations this is the equivalent to irrigate 43 golf courses for one year. This was a 14% increase from 2022.[1]

1. Google environmental report 2024. https://www.gstatic.com/gumdrop/sustainability/google-2024-environmental-report.pdf

Infrastructure and facilities



- Cables, networks, mobile masts
- Data centres: there are more than 7,000 data centres built or under development in 2024[2]

1. cable data by Greg Mahlknecht , map by Openstreetmap contributorsOpenStreetMap contributors, CC BY-SA 2.0 <https://creativecommons.org/licenses/by-sa/2.0>

2. Bloomberg (June 21, 2024) AI is already wreaking havoc on global power systems. https://www.bloomberg.com/graphics/2024-ai-data-centers-power-grids/

Manufacturing, mining and transport

- Manufacturing of devices
  - Energy use in the industrial processes
  - Consumption of materials
- Mining for minerals to make electronic components
  - Soil disruption and contamination
  - Water contamination
- Transporting goods around the world
  - Burning fossil fuels
  - Means of transportation production

Waste

- Devices that are disposed when they become obsolete or undesirable.
- For example, it is estimated that Bitcoin produces 30.7 metric kilotons annually[1]
- In competitive industries devices may become outdated fast.
- When they are highly specialised, they may not be reused in other functions.
- Recycling is not simple and uses energy, causing emissions.
- e-waste can contaminate soil and water.

1. de Vries, A., & Stoll, C. (2021). Bitcoin's growing e-waste problem. *Resources, Conservation and Recycling*, *175*, 105901.https://doi.org/https://doi.org/10.1016/j.resconrec.2021.105901

Change of land use

- For example, from forest to industrial, rural to city.
- Deforestation (reduction of trees that remove carbon from the atmosphere) leading to desertification.
- Loss of biodiversity (animals, plants)
- Pollution

Impact on communities

- Scarcity of resources – energy and water
- Dislocation or relocation
- Disease from pollution
- Jobs?

Systems thinking to understand the impacts of digital technologies

- **Rebound effects**
- Jevon’s Paradox[1] – coal and efficiency
- The more efficient a technology becomes, the more likely it is to become more affordable, accessible or faster. So, instead of the expected savings on resources, efficiency leads to increase demand and consequently more consumption of resources and therefore, more carbon emissions.

1. Jevons, W.S. (1865). The Coal Question—Can Britain Survive?. First published in 1865, reprinted by Macmillan in 1906.

Computing's responsibility

https://www.youtube.com/watch?v=lef7yvVObbU

What does it look like in practice?

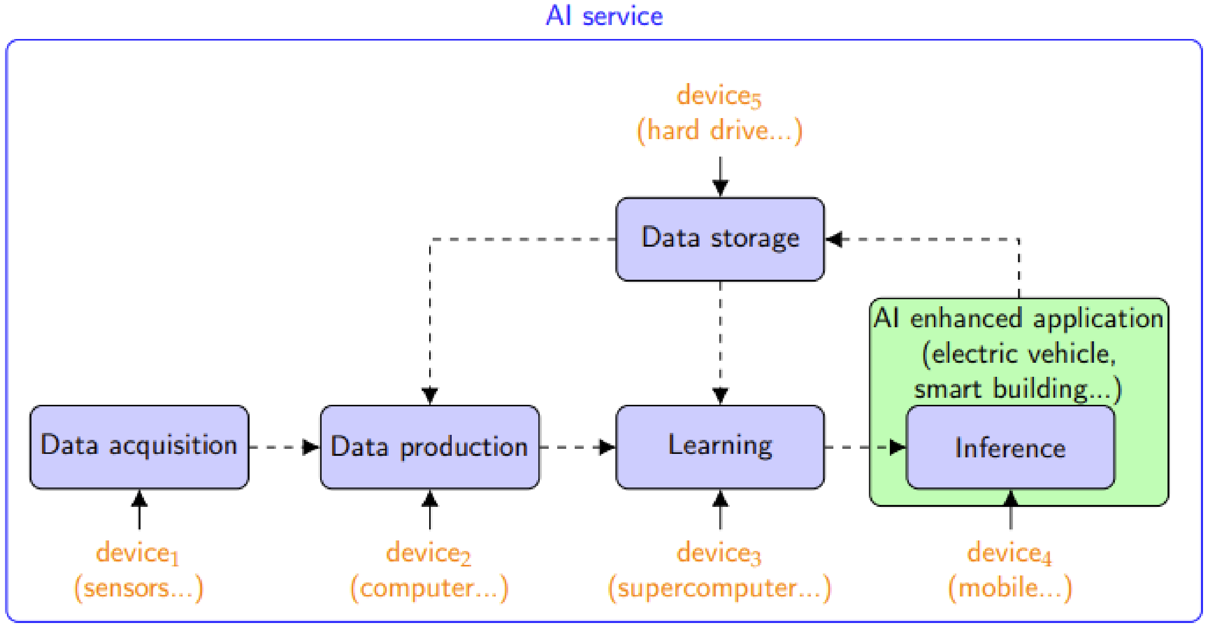
Case study: NLP, LLM, AI

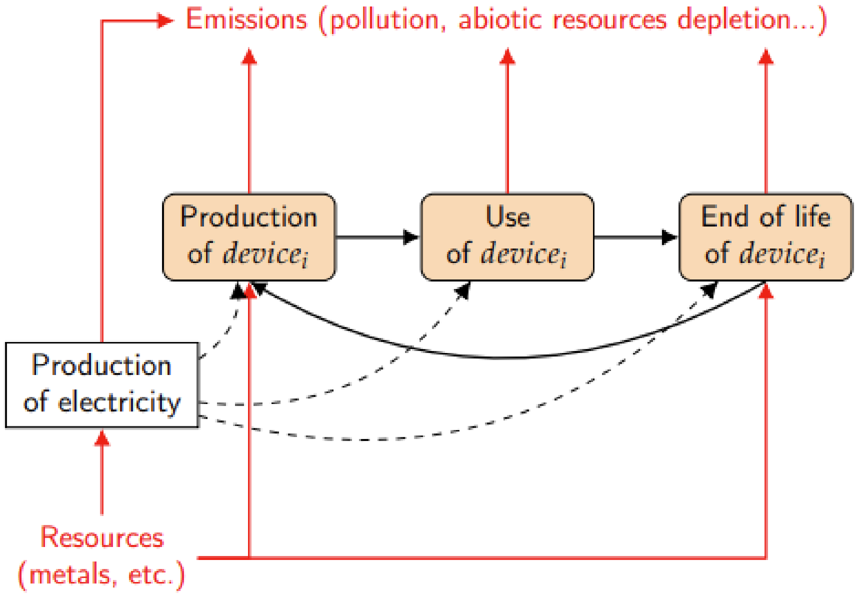
- In 2020, training an LLM (transformer) emits 284 tonnes CO_2e
  - About 300 flights between New York and San Francisco
  - Then, most the carbon emissions happened during training
- Now, with generative AI applications, because it is widely used most emissions come from inference. ChatGPT emissions are estimated as 25 times bigger than training the GPT-3[2].

- NLP – Natural Language Processing
- LLM – Large Language Model
- AI – Artificial Intelligence generative AI

1. Strubell, E., Ganesh, A., & McCallum, A. (2020). Energy and Policy Considerations for Modern Deep Learning Research. Proceedings of the AAAI Conference on Artificial Intelligence, 34(09), 13693-13696. https://doi.org/10.1609/aaai.v34i09.7123.
2. Chien, A. A., et al. (2023). Reducing the Carbon Impact of Generative AI Inference (today and in 2035). In Proceedings of the 2nd Workshop on Sustainable Computer Systems (HotCarbon '23). Association for Computing Machinery, New York, NY, USA, Article 11, 1–7. https://doi.org/10.1145/3604930.3605705

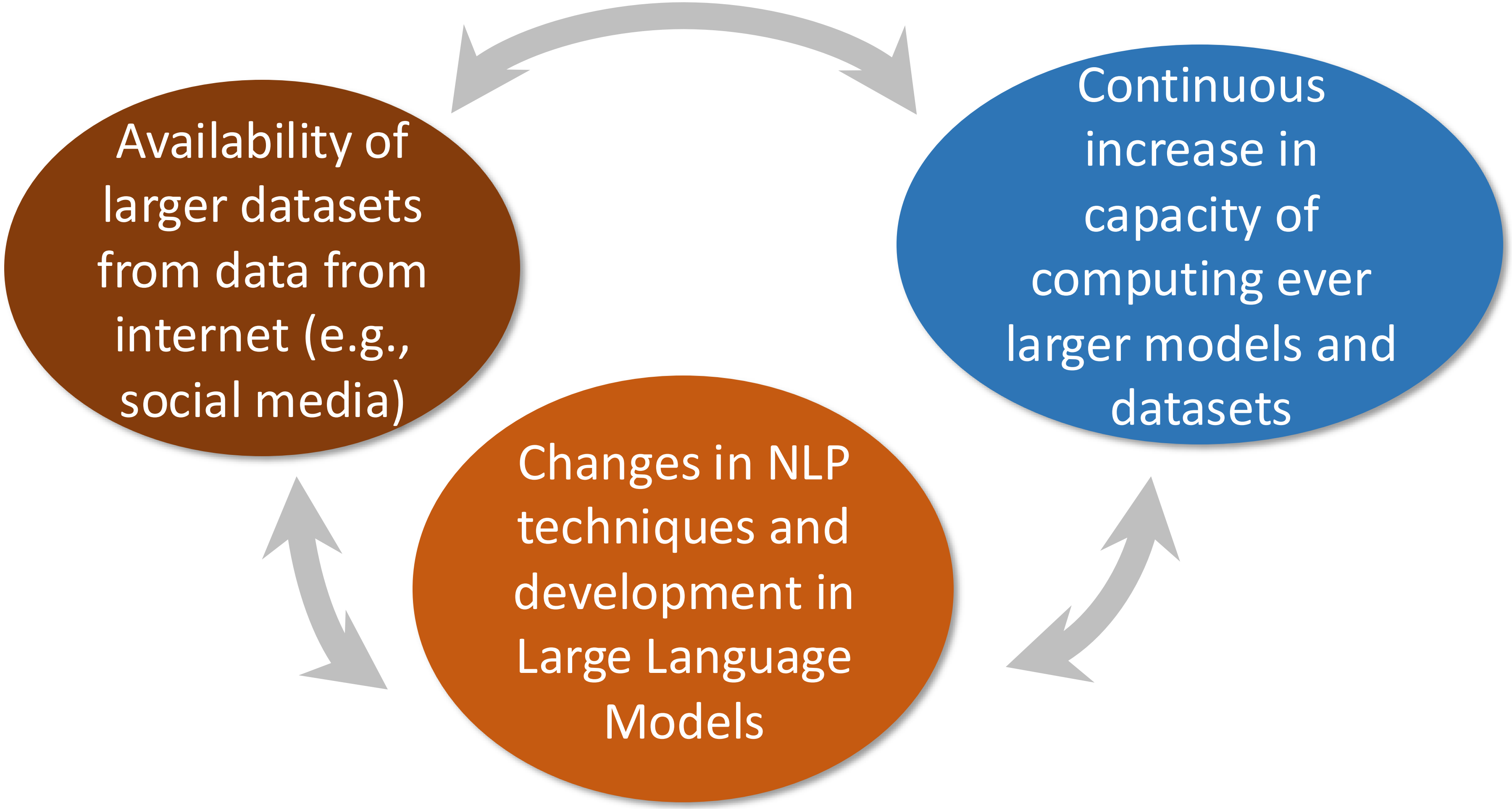
Carbon emissions of AI





Images from Ligozat, A. L., Lefèvre, J., Bugeau, A., & Combaz, J. (2022). Unraveling the hidden environmental impacts of AI solutions for environment. *arXiv preprint arXiv:2110.11822*.

System Dynamic – Feedback loop



Some ethical and social impacts

- **Language and culture**
- LLM development has been focused on English and a few other dominant languages.
- Low resources languages (fewer people speak them or less economic power to invest) don't get the same level of attention.
- Data comes from documents, literature and internet that has been published in those languages, resulting in greater input from those cultures.
- **Bias**
- Data from the internet can carry a bias based on who is posting online and what they have to say. Not everybody uses technologies the same way.

Some ethical and social impacts (cont.)

- **Accessibility and inequality**
- Costs developing LLM are very high. Development of LLM require investment in resources like equipment, staff, skills.
- Innovation is the sector is concentrated on a small group of organisations. They hold a lot of power on the way the technology is developed. Who is benefited by that?
- Not everyone in the planet has the same level of access to digital technologies.

It is not all bad: the positive impacts

- Help to work more efficiently and faster
- Ability to deal with complex tasks
- Applications in health, climate change, security
  - AI is already partly enabling a transition to low-carbon energy, as well as improving energy efficiency and transport

What can we do to reduce the impacts of Digital technologies?

Insert date, month, year here

Insert presenter name here

What can those working in tech do?

- **Raise awareness**
  - Be aware of environmental impacts that could be caused by your actions or by the products and services you develop.
  - Share what you know about the environmental impacts of digital technologies with others working in this area.
  - Build environmental sustainability into work practices.

What can those working in tech do?

- **Reflect and ask questions:**
  - Is this needed?
  - Can this be achieved with using fewer resources (e.g., energy) and less computation?
  - What is sufficient to achieve the results needed?
  - What are the likely consequences of people using the digital products and services you are creating?

What can those working in tech do?

- **Improve transparency of the impacts of ICT**
  - Through improved communication and reporting the environmental impacts of the products, services and organisations.
- **But avoid green washing**
  - Not cherry-picking benchmarks (only showing positive results or metrics and hiding negatives)

What can those working in tech do?

- **Don’t be paralysed by uncertainty**
  - You don’t need to know the exact amount of carbon emissions of every activity to take action.
  - We know that we have to reduce energy consumption and carbon emissions.

What can those working in tech do?

- **Green Computing: Reducing the use of resources in computation**
  - Using techniques like hyperparameter tunning, distilling (using only part of the model), optimising code.
  - Checking that the size of model is right for the type of the project
  - Using renewable energy when available (workload migration)
  - Running routine tasks not at peak time

- **But efficiency alone is not enough because of rebound effects**

What can those working in tech do?

- **Be aware of thinking that renewable energy will solve it all**
  - Is preferable to fossil fuel but it is not the solution. Renewable energy is not unlimited and there are emissions from building the infrastructure.
  - It is not replacing but adding to fossil fuel consumption

What can those working in tech do?

- **This is a systemic problem**
  - Individual action alone will only have limited impact. However, individuals can change and influence the mindset and culture of organisations and the sector.
  - Work together with others to find more sustainable alternatives.
  - Don’t put all the blame on consumers and individual choices.
  - Regulations are needed

What can those working in tech do?

- **And once more, remember the rebound effects**
  - If you increase efficiency, what will you do with the resources that are freed? Could you use it in a way that doesn't increase emissions?
  - What could be the consequences of the products, services and systems you are working on to other sectors and the public?
  - What changes it contributes to and are those changes desirable to all society and planet?

Questions?

Thank you for attending

References and further reading

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