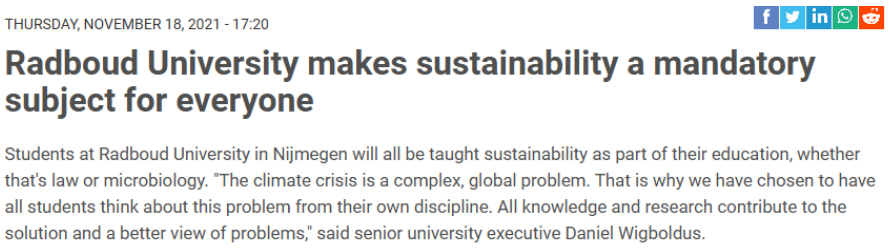


THURSDAY, NOVEMBER 18, 2021 - 17:20

Radboud University makes sustainability a mandatory subject for everyone

Students at Radboud University in Nijmegen will all be taught sustainability as part of their education, whether that's law or microbiology. "The climate crisis is a complex, global problem. That is why we have chosen to have all students think about this problem from their own discipline. All knowledge and research contribute to the solution and a better view of problems," said senior university executive Daniel Wigboldus.

Djoerd Hiemstra (Radboud University)

Wessel Kraaij (Leiden University)

ENVIRONMENTAL IMPACT OF ‘SEARCH’ (AI AND DATA CENTERS)

The success of search

- Faster
- More diverse (search is everywhere, in most apps)
- Larger
- Market of almost $100 billion
  - Google pays Apple $15 billion alone to remain default search engine on Apple devices
  - 63,000 searches per second, 5.4 billion per day, 2 trillion per year

Search is ‘my cup of tea’

- Sunday Times, 11 January 2009*:
  - “Revealed: The environmental impact of Google searches”
  - One search releases 7 g of CO
  - Alex Wissner-Gross (Harvard): “performing two Google searches uses up as much energy as boiling the kettle for a cup of tea”
  - “Google are very efficient but their primary concern is to make searches fast and that means they have a lot of extra capacity that burns energy,”
  - A separate estimate from John Buckley, managing director of carbonfootprint.com, a British environmental consultancy, puts the CO2 emissions of a Google search at **between 1g and 10g**, depending on whether you have to start your PC or not**. Simply running a PC generates between 40g and 80g per hour,** he says. of CO2 Chris Goodall, author of Ten Technologies to Save the Planet, estimates the carbon emissions of a Google search **at 7g to 10g (assuming 15 minutes’ computer use).**
  - https://business.directenergy.com/blog/2017/november/powering-a-google-search :
  - https://www.technologyreview.com/2011/09/09/257912/what-it-takes-to-power-google/

*http://web.archive.org/web/20090115112144/http://technology.timesonline.co.uk/tol/news/tech_and_web/article5489134.ece

Google PR: “Not true”

- Google Blog, 11 January 2009*:
  - “Powering a Google search”
  - One search releases 0.2 g of CO

*https://googleblog.blogspot.com/2009/01/powering-google-search.html

What happened next?

- Wissner-Gross' paper was never accepted/published
- Google publishes yearly sustainability updates
  - https://sustainability.google/progress/energy/
  - https://blog.google/outreach-initiatives/sustainability/

Environmental impact of ‘search’

- A ‘macro’ point of view
  - Search as key functionality for apps
  - Web search
  - Life Cycle Analysis
  - Energy use
  - **Today: Preliminary analysis**

- A ‘micro’ point of view
  - Energy requirements of search functionality elements (e.g. deep learning)
  - **Today: Preliminary analysis**

Macro
Succes of large scale cloud computing

- CPUs becoming faster
- Standard memory size increasing even more rapidly
- Sharp development of mobile networks
  - 2G-3G-4G-5G
- Mobile computing in combination with cloud services is dominant

Bang for your $

- A.I. thrives due to more data/CPU and strong GPUs!!
  - We get used to all these services… (Iphone was introduced in 2007)

Data is the new oil

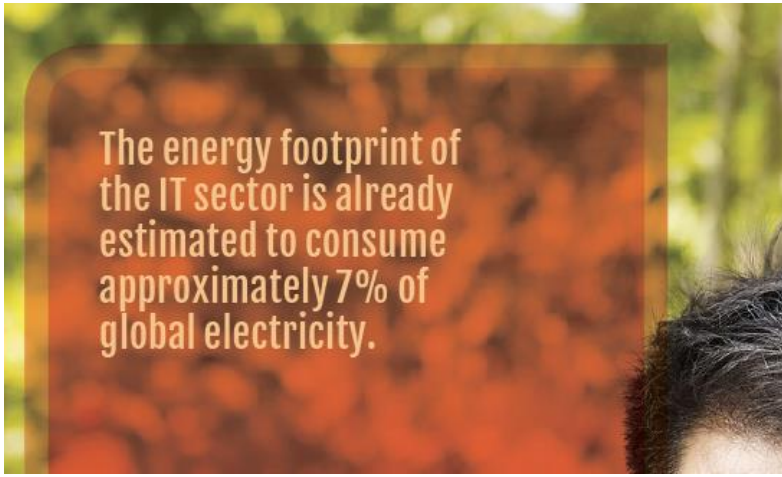
- Big tech: Amazon, Meta(FB), Google, Microsoft , Apple
- Business model: advertizing, cloud platform services (Amazon, Microsoft, Apple, Alibaba)
- The cycle of an annual new model, or new software updates that make old hardware obsolete
- Big tech wants us to make many photos and videos and store them online, share them
- This is big money, supported by investors (including our pension funds) all around the world
- Cloud computing and search rely on data centers (example hyperscalers)

Cloud services enable a new way of working

- Economy could continue and even grow during pandemic
- Was able to reduce commuting
- Perhaps will reduce (intercontinental) business travel

But there are downsides

- Energy use (mobile computing) hyperscalers
  - the amount of land surface necessary for the center and for the energy generation, is kind of offshoring the problem, while the money is going elsewhere
- Use of (rare) resources (cobalt, etc)
  - Google: reducing e-waste from land-fills
- Emission of greenhouse gases during production, transport, operation and disposal



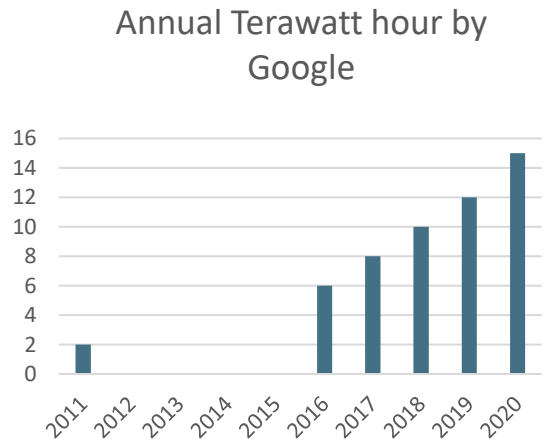
Energy use of data centers

- Difficult to find data on energy use of data centers (and their growth)
  - MIT: Google uses 260MW continuously (2011), 80-90% data centers (running and cooling)
  - This means : 2.2 Tera watt hour annually
- Platform companies' strategy:
  - Buy energy offset certificates
  - Compensate with renewable energy on a global scale (variant of 'salderingsregeling' for PV)
  - Do not use any fossil fuel based energy anymore
- However, energy demands outgrow carbon-free energy growth!

Recent Google energy use data

Key performance indicator	Assured for 2020	Unit	Fiscal year 2016	2017	2018	2019	2020
ENERGY							
Energy use							
Energy consumption[38]	●	MWh	6,513,719	8,029,409	10,572,485	12,749,458	15,439,538
Total electricity consumption	●	MWh	6,209,191	7,609,089	10,104,295	12,237,198	15,138,543

Google environmental report 2021



Google 1998

Micro
what does this mean for (IT) research

- How do we measure environmental impact of cloud technology?
- Can algorithms be used for LifeCycleAnalysis? (Blockchain)?
- Are there specific architectures /regimens that would help to cut down on energy consumption?

What does it mean for (web) search?

- Can we quantify the footprint of one search query, or supporting search for 8 billion users?
  - Very difficult
- Models
- architecture (decentral)?
- How would a ‘green’ search infrastructure look like?

Energy impact of search algorithms

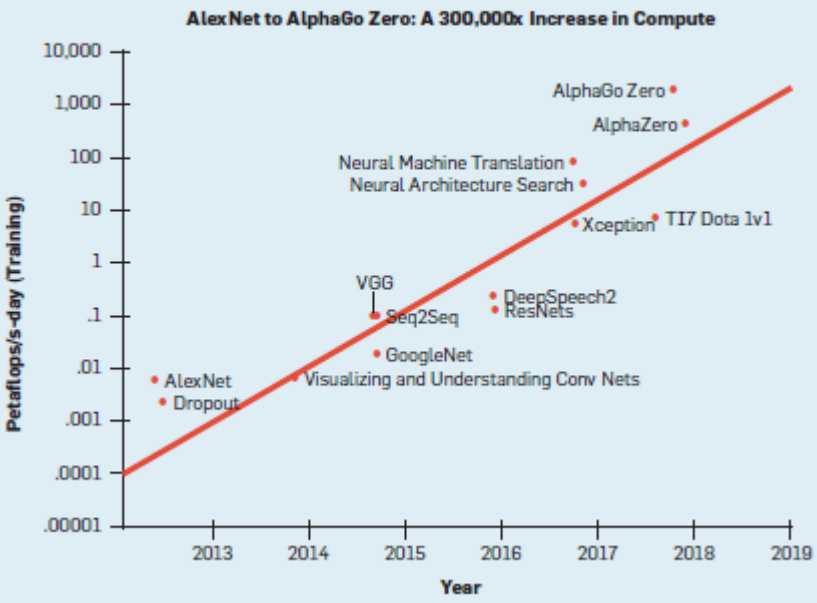
- Crawlers (freshness)
- Selection of content for indexing
- Every page is personalized (with ads) so caching is difficult
- One global vs multiple local search engines?
  - Meta search engine relaying
- Neural approaches are energy intensive
- Energy use is not charged (services are ‘free’)

Green AI vs Red AI (Schwartz et al 2020)

- Red AI: Object detection and NLP research strictly focused on accuracy
- Law of diminishing returns (~80/20 rule)
  - Relatively easy and efficient to build a (very) good system
  - Exponential effort needed to move to #1 on the leaderboard
  - Teams “buy” stronger results
- Green AI:
  - Focus on efficiency

Non linear increase of computing for DL

Figure 1. The amount of compute used to train deep learning models has increased 300,000x in six years. Figure taken from Amodei et al.[2]



Consumption	CO_2e (lbs)
Air travel, 1 person, NY↔SF	1984
Human life, avg, 1 year	11,023
American life, avg, 1 year	36,156
Car, avg incl. fuel, 1 lifetime	126,000
Training one model (GPU)	
NLP pipeline (parsing, SRL)	39
w/ tuning & experiments	78,468
Transformer (big)	192
w/ neural arch. search	626,155

Table 1: Estimated CO_2 emissions from training common NLP models, compared to familiar consumption.[1]

OpenGPT-3 : 175 billion parameters (2020)

Model	Hardware	Power (W)	Hours	kWh·PUE	CO_2e	Cloud compute cost
$T2T_{base}$	P100x8	1415.78	12	27	26	$41–$140
$T2T_{big}$	P100x8	1515.43	84	201	192	$289–$981
ELMo	P100x3	517.66	336	275	262	$433–$1472
$BERT_{base}$	V100x64	12,041.51	79	1507	1438	$3751–$12,571
$BERT_{base}$	TPUv2x16	—	96	—	—	$2074–$6912
NAS	P100x8	1515.43	274,120	656,347	626,155	$942,973–$3,201,722
NAS	TPUv2x1	—	32,623	—	—	$44,055–$146,848
GPT-2	TPUv3x32	—	168	—	—	$12,902–$43,008

Strubell et al

What should we do?

- Governments: tax / cap emissions, do not allow companies to monopolize renewable energy
- Make environmental impact of cloud services/ AI transparent
  - E.g. energy use (Strubell at al)
  - Or # Floating Point Operations for training (Schwartz et al)

- Adapt lifestyle: consume less technology or invest in upgradeable technology
- Creating awareness of the link between behaviour on micro level and macro level effects

Conclusions

- Difficult to estimate the environmental impact of ‘one search’
- However, design choices (e.g. search quality, speed and freshness / exhaustivity) have substantial impact
- Law of diminishing returns (“good enough?”)
- Platform companies just focus on growth
- Will use a large part of the available renewable resources that are needed for e.g. home energy conversion or green hydrogen production.

Conclusions 2:

- We need to prioritize quality over quantity
- New business models are needed
- Regulation is needed for prioritizing services that should use renewable energy (4K Netflix or heating homes?)

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