# Energy Consumption of AI

Thomas Fricke

December 7, 2023

# Wer sind wir?

## Innovationsverbund Öffentliche Gesundheit

- Entstanden aus dem *WirVsVirus* Hackathon
- Private Spenden Holistic Foundation
- Projekte
  - Open Source
  - Schutz der User
  - Open Social Innovation
- Iris Connect
  Kontaktnachverfolgung Gesundheitsämter
  Björn Steiger Stiftung

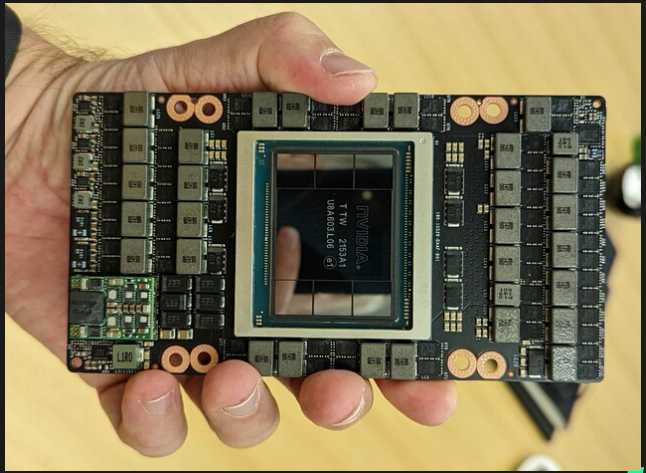
Thomas Fricke

- Kubernetes Cloud Security
- Statistische Physik
- Disclaimer
  - Ehrenamtlich: OpenCode, Beratung IT Planungsrat
  - Für Geld: OpenDesk, Fitko

# Hardware NVIDIA Hopper H100

Energy Consumption

- Single Graphics Card
- 700 Watts = 0.7kW
- ~30 kW / rack
- instead of 3 to 6 KW / rack

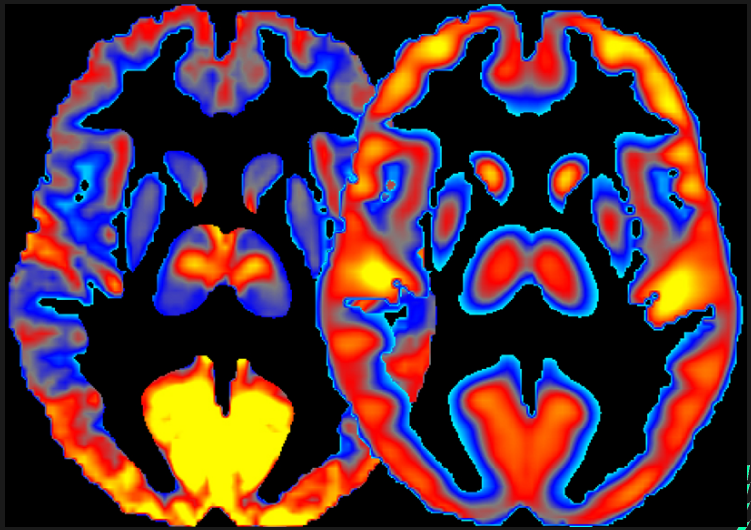



NVDIA Hopper H100 in a Hand

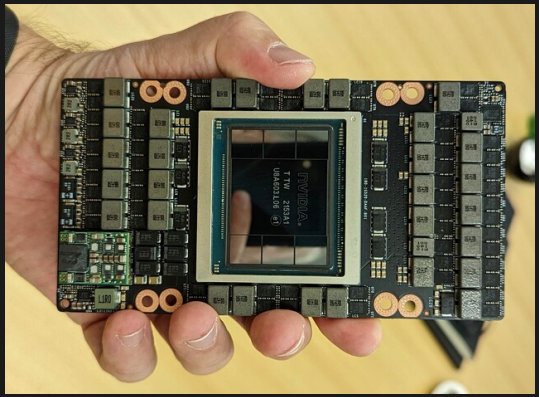
# Legacy Model – Homo Sapiens Sapiens

NIH scientists present a new method for combining measures of brain activity (left) and glucose consumption (right) to study regional specialization and to better understand the effects of alcohol on the human brain.

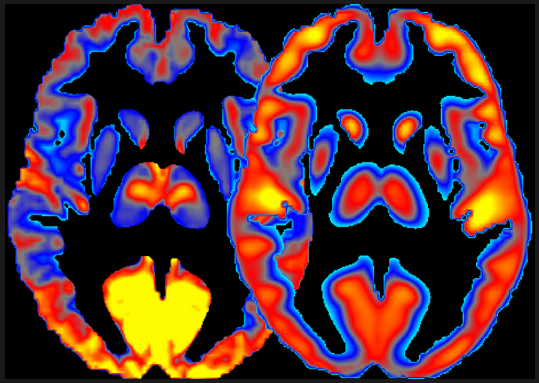
Dr. Ehsan Shokri Kojori, NIAAA



# Comparison

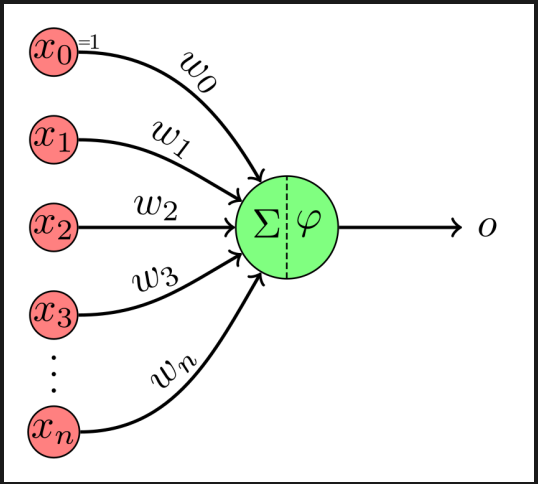



700 Watt

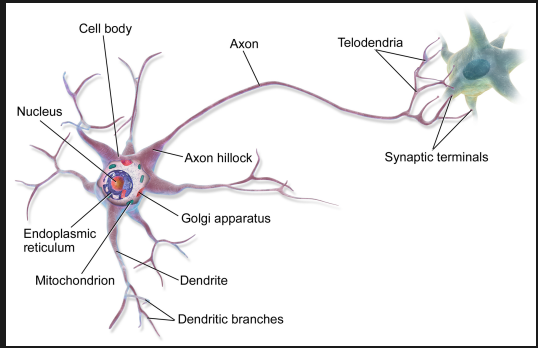


20 Watt

# Some Inconvenient Truth




Perceptron




Neuron

- The AI neuron is not even a biological synapse
- The synapse computes an has the complexity of some handfull of perceptrons

# Numbers

NVIDIA Tensor Core Datasheel

*Built with 80 billion transistors using a cutting-edge TSMC 4N process custom tailored for NVIDIA's accelerated compute needs, H100 is the world's most advanced chip ever built*

Basic Neural Units of the Brain: Neurons, Synapses and Action Potential by Jiawei Zhang

*we will introduce the basic compositional units of the human brain, which will further illustrate the cell-level bio-structure of the brain. On average, the human brain contains about 100 billion neurons and many more neuroglia which serve to support and protect the neurons. Each neuron may be connected to up to 10,000 other neurons, passing signals to each other via as many as 1,000 trillion synapses.*

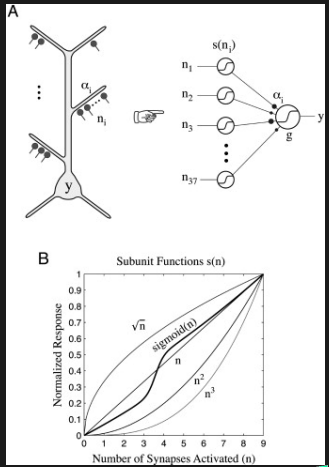
- German Milliarde: American Billion $= 10^9$
- German Billion: American Trillion $= 10^{12}$

# Pyramidal Neuron as Two-Layer ~~Neural~~ Perceptron Network

*We found the cell's firing rate could be predicted by a simple formula that maps the physical components of the cell onto those of an abstract two-layer "neural network." In the first layer, synaptic inputs drive independent sigmoidal subunits corresponding to the cell's several dozen long, thin terminal dendrites.*

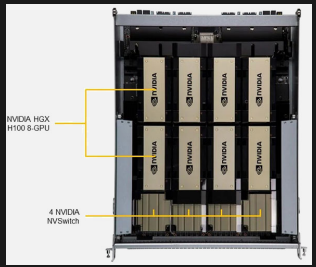
Pyramidal Neuron as Two-Layer Neural Network
by Panayiota Poirazi, Terrence Brannon, Bartlett W. Mel, 2003

- article is old
- simulation of real firing synapses
- consistent result
- hundreds of different types of synapses
  - chemical
  - electrical




Neuronal Network Tree

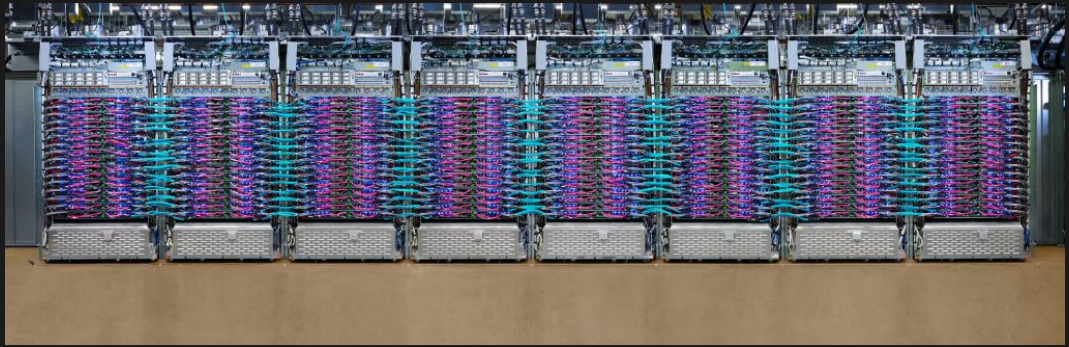
# Racks




Nvidia Rack

- Key Applications : High Performance Computing, AI, Deep Learning and Industrial - Automation.
- Dual AMD EPYC 9004 Series Processors (Socket SP5)
- 8x NIC for GPU direct RDMA (1:1 GPU Ratio)
- High density 8U system with NVIDIA® HGX™ H100 8-GPU
- Highest GPU communication using NVIDIA® NVLINK™ + NVIDIA® NVSwitch™
- 24x DIMM Slots, Up to 6TB DRAM, 4800 ECC DDR5 LRDIMM;RDIMM;
- 8x PCIe Gen 5.0 X16 LP, and up to 4 PCIe Gen 5.0 X16 FHFL Slots
- Flexible networking options
- 1x M.2 NVMe for boot drive only
- 2x 2.5" hot-swap NVMe/SATA drive bays (12x 2.5" NVMe dedicated)
- 2x 2.5" Hot-swap SATA drive bays
- 10x heavy duty fans with optimal fan speed control
- 6x 3000W redundant Titanium level power supplies

# Datacenters

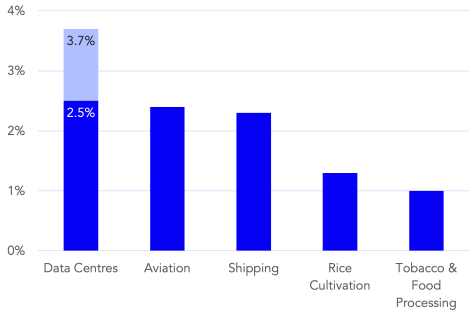


Liquid Cooling Google

# Compared to other businesses

## Global cloud computing emissions exceed those from commercial aviation

Share of global $CO_2$ emission generated by sector/category




Source: Climatiq Analysis, The Shift Project, OurWorldinData

climatiq

## Hyperscale data centres are significantly more efficient than internal data centres

| Category | Energy use (Million MWh) | Computing workloads (million) | Water intensity ($M_3$ $MWh_{-1}$) | Carbon intensity (ton $CO_2$-eq $MWh_{-1}$) | Water intensity ($m_3$/workload) | Carbon intensity (Ton $CO_2$-eq /workload) |
|---|---|---|---|---|---|---|
| Internal | 26.90 | 16 | 7.20 | 0.45 | 12.15 | 0.75 |
| Colocation | 22.4 | 41 | 7.00 | 0.42 | 3.85 | 0.25 |
| Hyperscale | 22.85 | 76 | 7.00 | 0.44 | 2.10 | 0.15 |

Source: Siddik & Sehab 2021

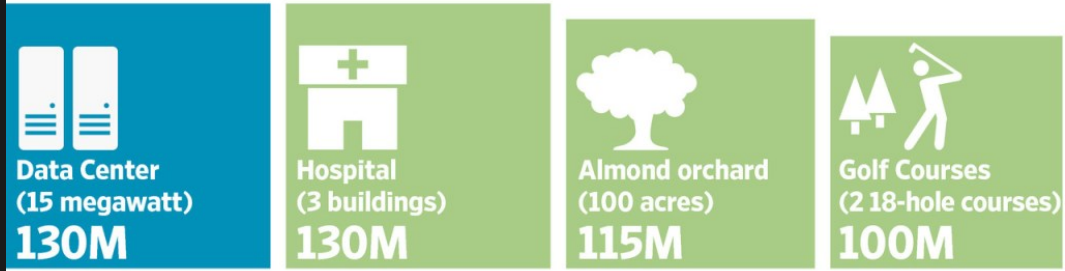
climatiq

# Compared to other usages

## Waterlogged

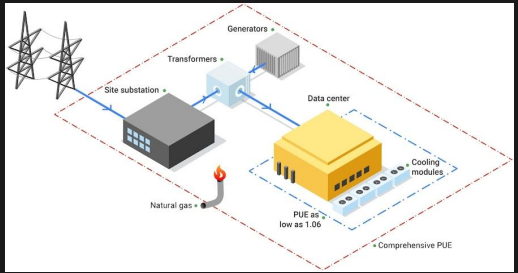
A midsize data center uses roughly as much water as about 100 acres of almond trees or three average hospitals, and more than two 18-hole golf courses.

**Approximate annual water usage, in gallons***

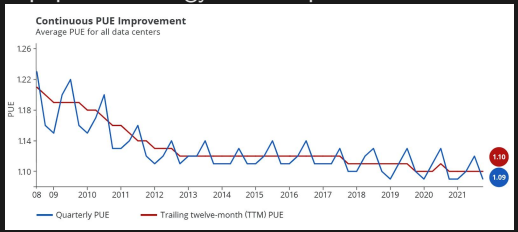


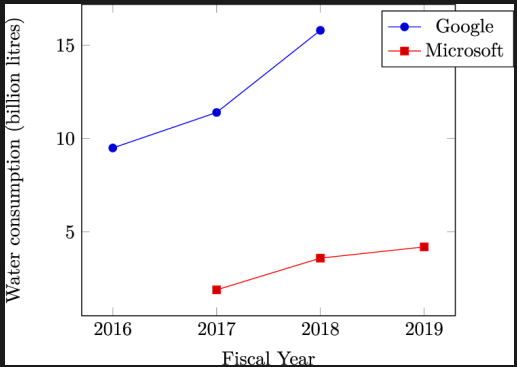

*Use varies depending on climate and other factors
Sources: California Department of Water Resources (orchards); James Hamilton (data centers); U.S. Department of Energy (hospitals); Golf Course

# Google Power Usage Effectiveness – PUE Greenwashing




Centre Total Energy Consumption PUE= ICT Equipment Energy Consumption




$$\text{PUE} = \frac{\text{Data Centre Total Energy Consumption}}{\text{ICT Equipment Energy Consumption}}$$

Source: Google(left), Nature (right)

# Stop Building Data Centers

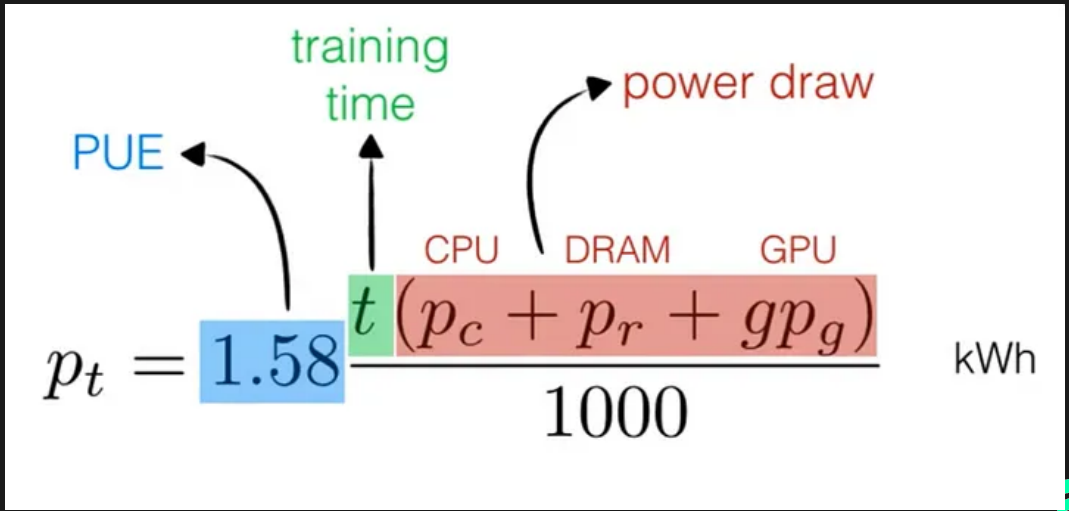
- Ireland: Microsoft and Amazon reportedly halt plans to build data centers ...
- Netherlands: Inside the data centre moratorium movement
- Germany, Brandenburg, Neuenhagen: Alphabet darf kein Rechenzentrum bei Berlin bauen now in Mittenwalde

This was all before the AI Boom took of

Heating up: how much energy does AI use?

*What we do know is that training ChatGPT used 1.287 gigawatt hours, roughly equivalent to the consumption of 120 US homes for a year.*

# Machine learning



# Typical numbers

| Model | Hardware | Hours | $CO_2e$ (lbs) | Cloud compute (USD) |
|---|---|---|---|---|
| $\text{Transformer}_{\text{base}}$ | P100x8 | 12 | 26 | $41-$140 |
| $\text{Transformer}_{\text{big}}$ | P100x8 | 84 | 192 | $289-$981 |
| ELMo | P100x3 | 336 | 262 | $433-$1472 |
| $\text{BERT}_{\text{base}}$ | V100x64 | 79 | 1438 | $3751-$12,571 |
| $\text{BERT}_{\text{base}}$ | TPUv2x16 | 96 | --- | $2074-$6912 |
| NAS | P100x8 | 274,120 | 626,155 | $942,973-$3,201,722 |
| NAS | TPUv2x1 | 32,623 | --- | $44,055-$146,848 |
| GPT-2 | TPUv3x32 | 168 | --- | $12,902-$43,008 |

TPU
GPU

| 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]

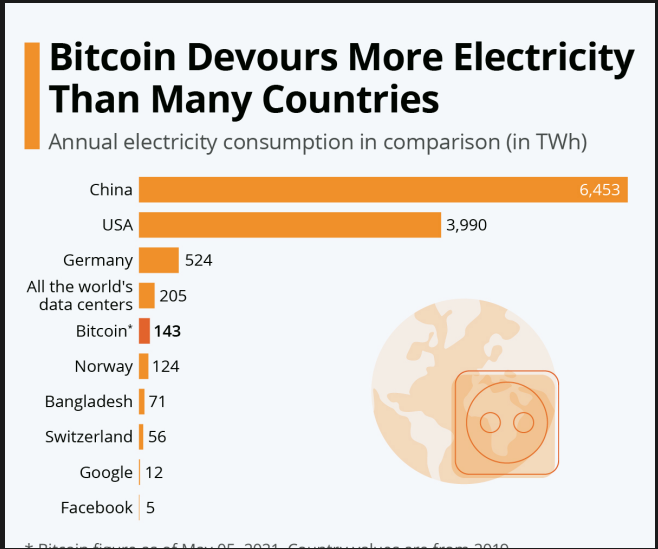
# Moore's Law for Training Neural Networks
# How AI will really kill us


Moore's Law

- H100
  - 10.6 TFlops single precision
  - 5.3 TFlops double presicion
- 10000 TFlops
  - 1000 H100 single precision
    - 700 kW
  - 2000 H100 double precision
    - 1400 kW
  - cooling
    - PUE=1.6

**some 67 MW hours**

# Bitcoin is the worst



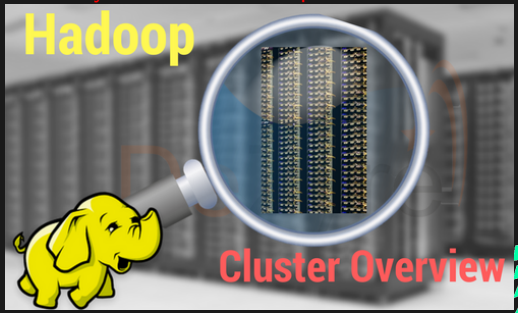
# Applications

## From the trenches

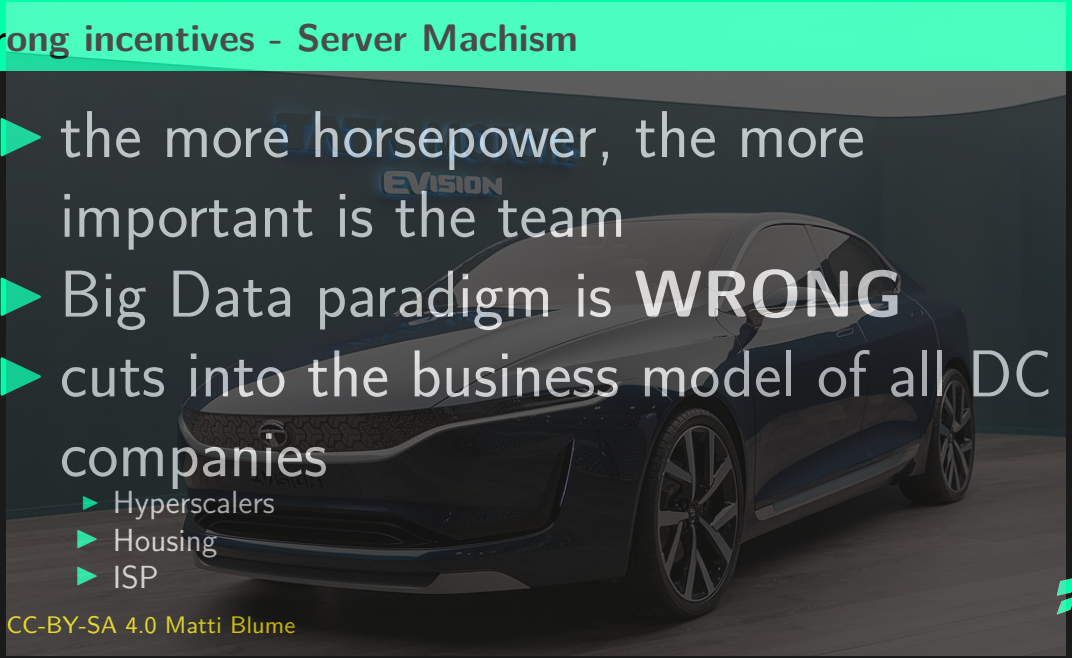
- going life in critical infrastructure
- trading software
- Open Shift
- vendor came up with 10 nodes of HBase
- tried to measure the load neglectable
- calculated the needs
  - MySQL would be oversized
  - SQLite on a Raspi would have done it

## Shrink your app

- Most of the apps are hopelessly overdimensioned
- Factor of 10 is typical
- dissolved the Oracle team at a customer 10 years ago
- they moved to Hadoop

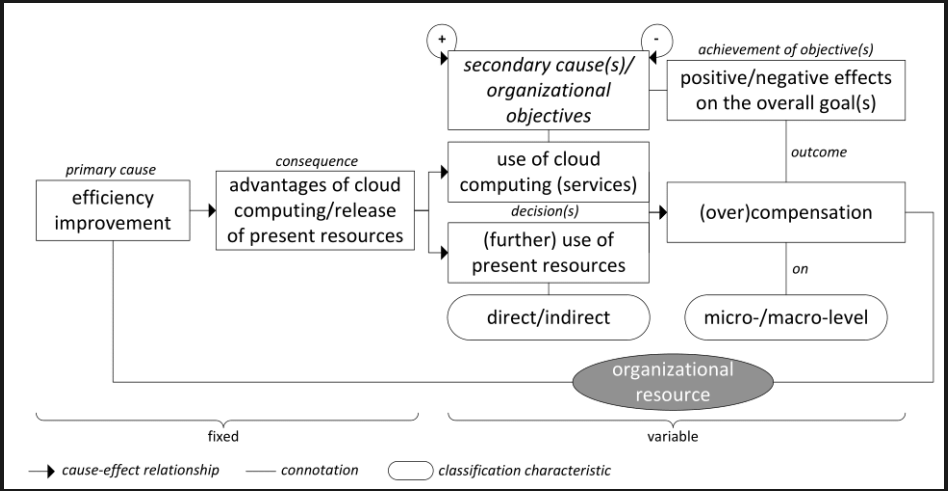


# Wrong incentives - Server Machism



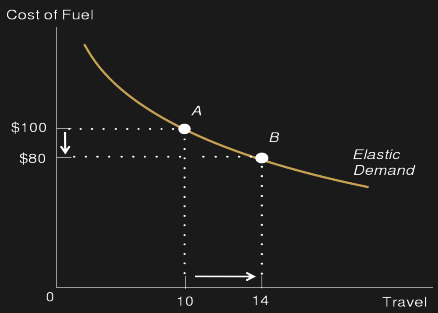

- the more horsepower, the more important is the team
- Big Data paradigm is **WRONG**
- cuts into the business model of all DC companies
  - Hyperscalers
  - Housing
  - ISP

# Rebound Effect




Rebound Effects in Cloud Computing

# Jevons Paradox




Jevons Paradox

Jevons Paradox
- first described for steam engines
- example is for travelling costs
- Rebound Effects in Cloud Computing: Towards a Conceptual Framework

Personal observations
- provisioning times are hidden costs
- self provisioning
- cloud enabling
- virtualisation
- containers
- Kubernetes
- CI/CD pipelines

# Aleph Alpha

Staatsministerium Baden-Württemberg:
Künstliche Intelligenz in der Verwaltung

*Gemeinsam mit dem Heidelberger Start-up Aleph Alpha hat das InnoLab_bw mit der Text-Assistenz „F13“ (Link ist nur aus dem Landesverwaltungsnetz nutzbar) ein Unterstützungssystem entwickelt, das Mitarbeiterinnen und Mitarbeiter der Landesverwaltung bei ihrer täglichen Text-Arbeit entlasten soll.*
*Die vier Funktionen des Prototyps von „F13“ Aktuell beinhaltet der Prototyp, der bis Ende des Sommers laufen soll, vier Funktionen:*

- *Zusammenfassungsfunktion*
- *Kabinettsvorlage-Vermerk*
- *Rechercheassistenz*
- *Fließtextgenerierung / „Vermerkomat“*

Zeit: Bundesrat lehnt Vorschlag zu KI-Einsatz in der Verwaltung ab

*Der Bundesrat hat . . . Einsatz künstlicher Intelligenz (KI) bei Entscheidungen in der öffentlichen Verwaltung abgelehnt. Die Ausschüsse . . . hatten empfohlen, im neuen Onlinezugangsgesetz “die Zulässigkeit des Einsatzes algorithmenbasierter Entscheidungsfindung und -vorbereitung in der öffentlichen Verwaltung zu normieren”, also Regeln für ihren Einsatz festzulegen. Diese Empfehlung verwarf das Parlament in seiner letzten Sitzung vor der parlamentarischen Sommerpause.*

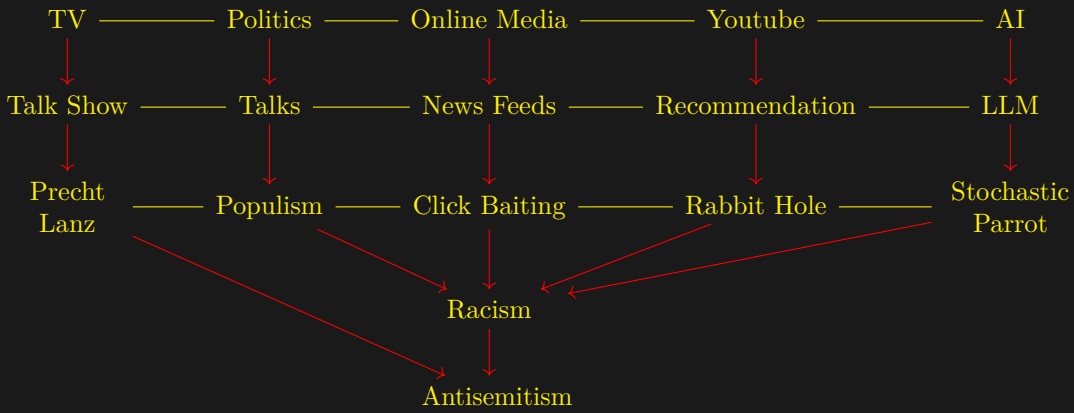
# Adolf Alpha

- Aleph Alpha:
  Sovereignty in the AI era
- Netzpolitik:
  Bundesregierung folgt dem Hype
- Tagesspiegel:
  Sprachmodell von Aleph Alpha liefert Hitler-Lob und Rassismus
- Zeit:
  Braucht die deutsche Vorzeige-KI mehr Erziehung?

Das **K** in **KI** steht für Kenia,
das **A** in **AI** für Afrika

- Tagesschau:
  Wie Klickarbeiter in Kenia ausgebeutet werden
- Zeit:
  Ausgebeutet, um die KI zu zähmen
- SUPERRR LAB:
  WITHOUT US, THERE ARE NO SOCIAL MEDIA PLATFORMS
- Time Magazine:
  150 African Workers for ChatGPT, TikTok and Facebook Vote to Unionize at Landmark Nairobi Meeting

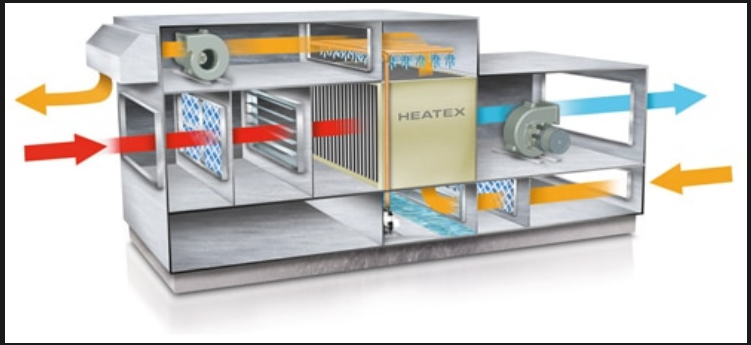
# Diagram of Populism

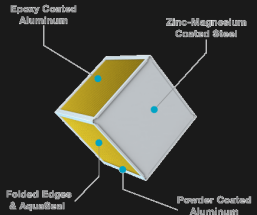


# New Datatacenter Berlin Lichtenberg


- 100MW power usage
  - transformer substation
  - integration of energy management
  - cooperation with local Berlin power network
- integration into district heating
  - 50-60% use of heating energy
  - only 6% of datacenters are integrated
- $\mathrm{PUE} \ll 1.3$
- adiabatic cooling

# Cooling




Quelle: Heatex

# Local Clouds

- Sovereign Cloud Stack
  - Summit
  - Hochschule Osnabrück
    - Campus Netz
    - Datacenter in a Real Container
      Disaster management
      Distributed Usage
- Energy Transition

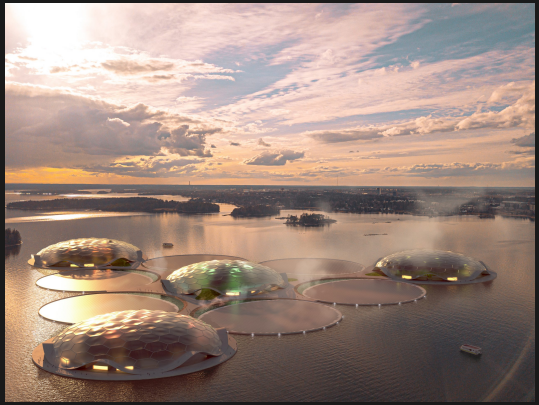
  Datacenter without losses
  - Renewable Energy
  - Cloud Computing
  - local remote heating

  by JH-Computers and OSISM

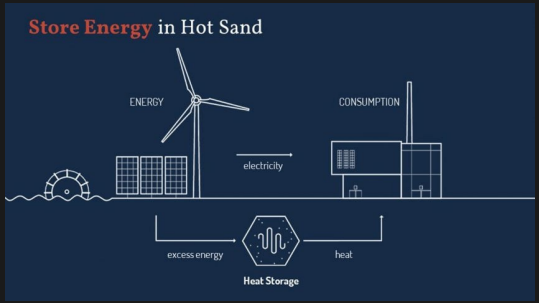
# JH Computers

- upcycling heat to 85C
- scalable between 50kW and 50MW
- makes economic sense $\geq$ 250KW
  - 2GWh/year heat production
  - 400 houses
- customers want at least 5MW datacenters
  - 40 GWh/year
  - 8000 houses
  - industrial usage
- real estate companies are interested

# Energy or Heat Storage in Finnland

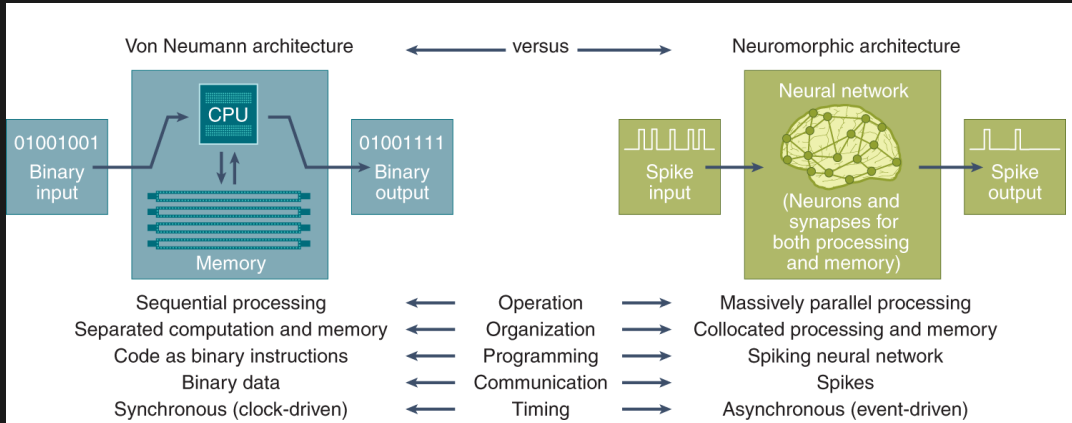


Hot Heart Project




Finnish “sand battery” offers solution for renewable energy storage

# Neuromorphic Computing – Nature



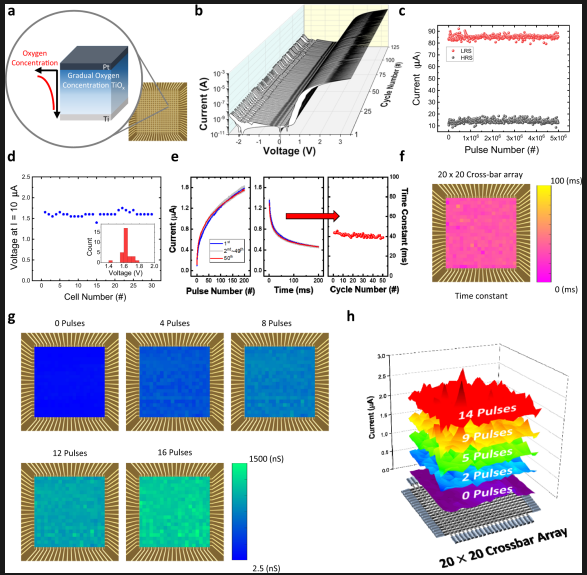
# Neuromorphic Computing – Intel

*Intel Labs' second-generation neuromorphic research chip, codenamed Loihi 2, and Lava, an open-source software framework, will drive innovation and adoption of neuromorphic computing solutions.*

Enhancements include:

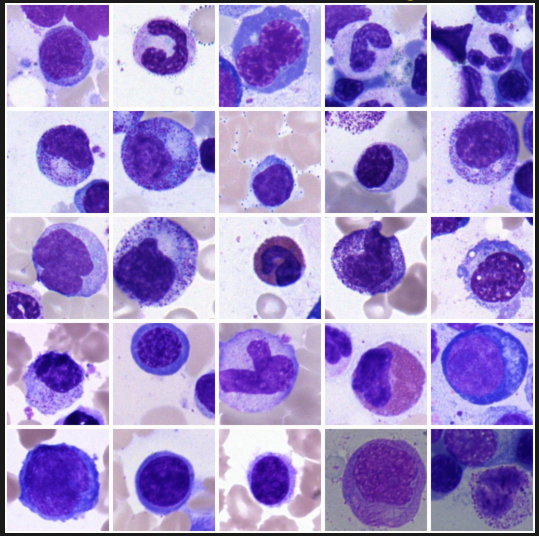
- Up to 10x faster processing capability1
- Up to 60x more inter-chip bandwidth2
- Up to 1 million neurons with 15x greater resource density3
- 3D Scalable with native Ethernet support
- A new, open-source software framework called Lava
- Fully programmable neuron models with graded spikes
- Enhanced learning and adaptation capabilities

# Neuromorphic Computing – Nature about Memristor



# Where is the positive? We want AI!

Helmholtz München Leucemia Recognition



Alpha Fold Protein Folding

# Where is the positive? We want AI!

- Schreib mir eine Digitalstrategie für Deutschland
- Eine Digitalstrategie für Deutschland könnte folgende Schwerpunkte beinhalten:
  - Ausbau der digitalen Infrastruktur: Dazu gehört der Ausbau von schnellen Internetverbindungen und der Schaffung von Hotspots in ländlichen Gebieten, um eine flächendeckende digitale Versorgung zu gewährleisten.
  - Stärkung der digitalen Kompetenzen: Um die Bevölkerung fit für die digitale Zukunft zu machen, sollten Maßnahmen zur Förderung der digitalen Kompetenzen, wie zum Beispiel digitale Bildungsangebote, unterstützt werden.
  - Förderung digitaler Innovationen: Die Digitalisierung bietet viele Möglichkeiten für Innovationen und neue Geschäftsmodelle. Eine Digitalstrategie sollte daher die Gründung von Start-ups und die Entwicklung von digitalen Technologien fördern.
  - Sicherheit und Datenschutz: Eine Digitalstrategie sollte dafür sorgen, dass die Daten der Bürgerinnen und Bürger sicher sind und dass es Regeln gibt, die den Schutz der Privatsphäre gewährleisten.
  - E-Government: Eine Digitalstrategie könnte auch den Ausbau von E-Government-Angeboten vorsehen, um die Verwaltung für die Bürgerinnen und Bürger transparenter und effizienter zu gestalten.
  - Digitalisierung der Wirtschaft: Um die Wettbewerbsfähigkeit Deutschlands zu stärken, sollte die Digitalisierung der Wirtschaft gefördert werden, indem beispielsweise digitale Technologien in der Industrie eingesetzt werden.

Spock gemalt von van Gogh, Picasso, Botticelli und Dix

# Conclusion

- AI will use a lot of resources
  - without care we will see a factor of 5-10 increase in energy consumption
  - this is a danger to the local climate
- energy hunger cannot be satisfied
  - competion with other industries
  - nuclear power plants
    - really?
    - we are running out of Uranium btw.
    - not under democratic control
- GPUS are a naive way of implementing perceptrons
- research on alternatives?
- there is a problem with bias
  - careful selection of sources
  - expensive human control
- charlatanry
- massive financial interest

# Question? Remarks?

**Some Answers**

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