

Computer Science Between Energy Savings and Waste: From Videoconferencing to Blockchain



Public Lecture Series „Sustainability in CS”, 2025-11-24 17:00 (UTC+1), Linz/virtual

Univ.-Prof. Dr. René Mayrhofer

Institute of Networks and Security & LIT Secure and Correct Systems Lab, JKU Linz

Christian Doppler Laboratory for Private Digital Authentication in der Physical World (CDL Digidow)

**From lectures and meetings
in the same room...**



To this...



Or this?



ICT: Information and Communication Technology

- Communication is key for Internet services
 - requires communication media
 - requires services on the other side
- Communication media
 - **possible**: dedicated communication infrastructure
 - **likely**: using publicly available infrastructure, possibly with additional security measures

→ All communication tends to converge into **The Internet**
- Communication creates attack surface
 - (unintentional) **Mistakes** (by authorized persons or automated processes)

→ **safety**

 - (intentional) **Attacks** (by unauthorized persons or processes)

→ **security**

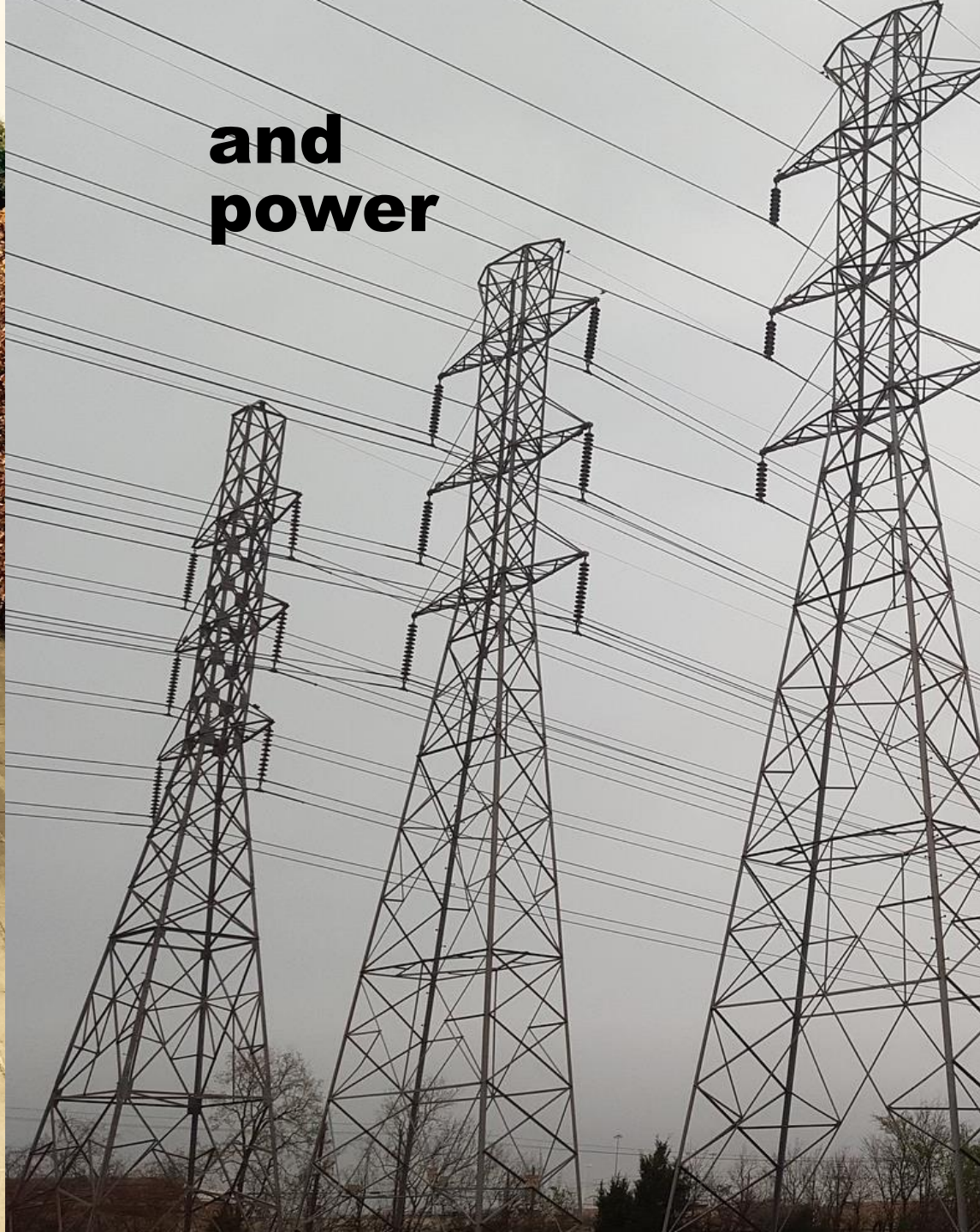
**Digital
communication**



**needs
cables**



**and
power**



But how bad is it in terms of energy consumption?



Some estimates to help quantify

Estimating Zoom video call **network transfer** energy consumption:

- For 1:1 video calling for 1 hour **per participant**:
 - HQ = $0.000075\text{GB/s} = 0.27\text{GB/hr} * 2 \text{ (up/down)} = 0.54\text{GB}$.
 - HD 720p = $0.00015\text{GB/s} = 0.54\text{GB/hr} * 2 \text{ (up/down)} = 1.08\text{GB}$.
 - HD 1080p = $0.000225\text{GB/s} = 0.81\text{GB/hr} * 2 \text{ (up/down)} = 1.62\text{GB}$
 - For group video calling for 1 hour **per participant**:
 - HQ = $0.0001\text{GB/s} + 0.000125\text{GB/s} = 0.36\text{GB/hr} + 0.45\text{GB/hr} = 0.81\text{GB}$.
 - Gallery view and/or HD 720p = $0.0001875\text{GB/s} = 0.675\text{GB/hr} * 2 \text{ (up/down)} = 1.35\text{GB}$.
 - HD 1080p = $0.0003125\text{GB/s} + 0.000375\text{GB/s} = 1.125\text{GB/hr} + 1.35\text{GB/hr} = 2.475\text{GB}$
- 0.0162 – 0.0486 kWh for 1h 1:1, 0.0729 – 0.22275 kWh for 1h with 6 people
- Up to 1000 participants: 12.15 – 37.125 kWh (*if all have sending video enabled – please don't!*)

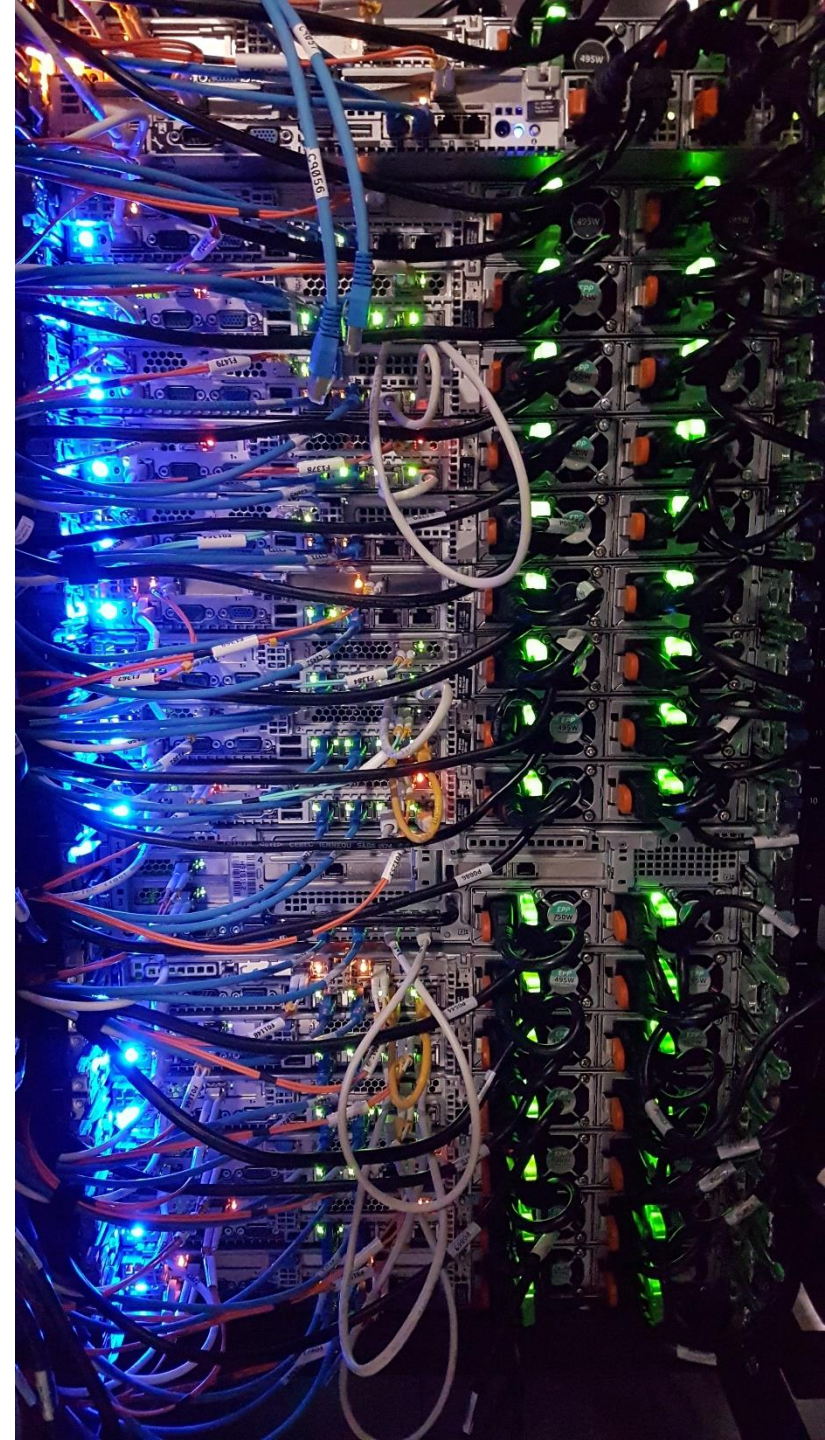
Source: <https://davidmytton.blog/zoom-video-conferencing-energy-and-emissions/>

Some estimates to help quantify

Estimating Zoom video call **additional** energy consumption:

- Mobile networks instead of fixed lines: 0.1kWh/GB instead of 0.015kWh/GB
- Device energy consumption: massive difference between big screen, laptop, or phone
- “Cloud” data centers for central coordination and network traffic relaying
- Speech-to-text transcription services with Large Language Models (LLMs) → unknown energy impact, but potentially large

Sources: <https://davidmytton.blog/zoom-video-conferencing-energy-and-emissions/> [updated 2023], <https://www.mdpi.com/2071-1050/10/7/2494> [2018]



Energy consumption of digital services?

- **Video conferencing**

- Group video call with 5 participants for **1 hour** in HD quality: ca. **0,10kWh**
(comparable to ca. 0,2km with combustion engine car or **1km with battery electric car**)
- Can save transfer efforts significantly (estimates around 90%) with audio-only
(doesn't consider consumption of client devices, maybe best with smartphone on WiFi)
- Textual communication (the old email...) much more efficient
(but not if intermixed with all kinds of media like large video memes, audio messages, ...)

Note: Data collected from different sources in summer 2021; <https://www.utilitybidder.co.uk/business-electricity/zoom-emissions/>

How much can we trust digital communication?



End-to-end encryption (E2EE) for instant messages



- Finally, **true E2EE messengers** exist and are in broad use
→ **Provider cannot decrypt content**
 - + Signal, Wire
 - Threema, Matrix, WhatsApp
 - Telegram, etc.→ Law enforcement can no longer perform mass scanning
- Note: they all **leak** (from less to more) **meta data** – primarily phone number network graphs and usage statistics (*who* do I communicate *with*, *when*, *how often*, *how much*, which *media type*, which *groups* do I belong to, etc.)
- Current discourse (EU Commission, Council and Parliament):
 - #chatcontrol client-side scanning of content inside the E2EE messenger app clients?
 - banning E2EE encryption again, or attacking devices?

Digital Identity on phones – potential improvements for privacy, unclear impact on energy consumption

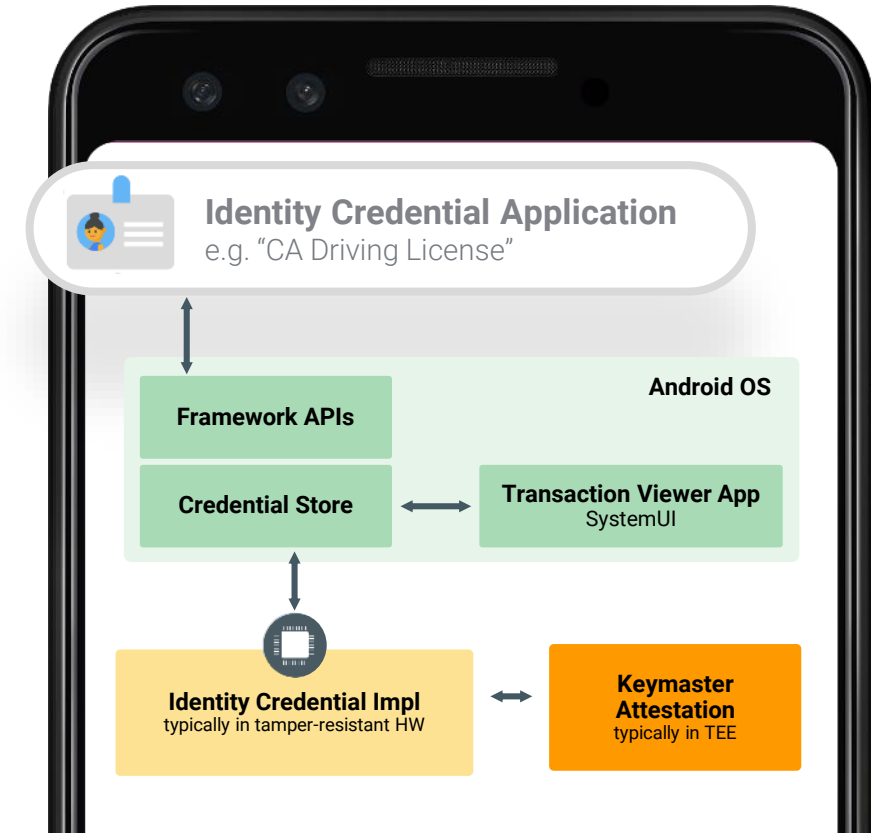
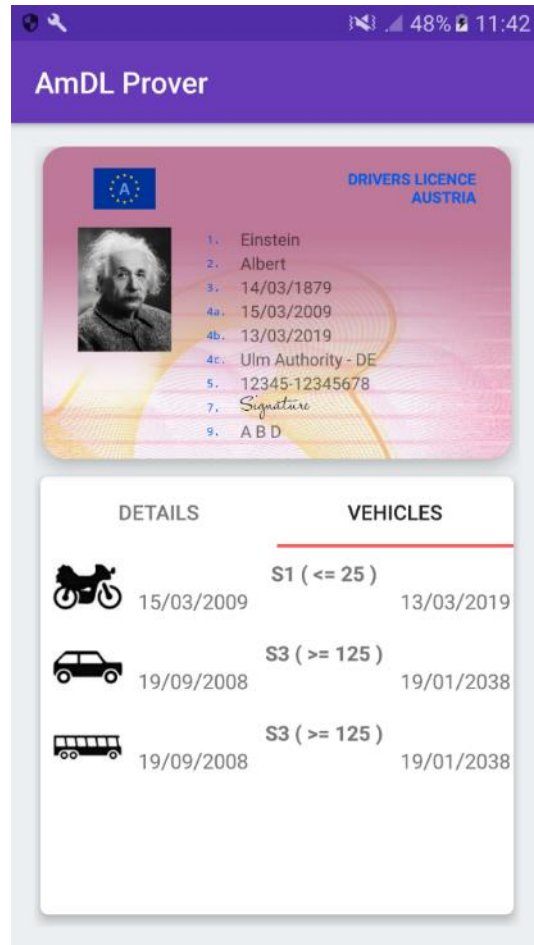
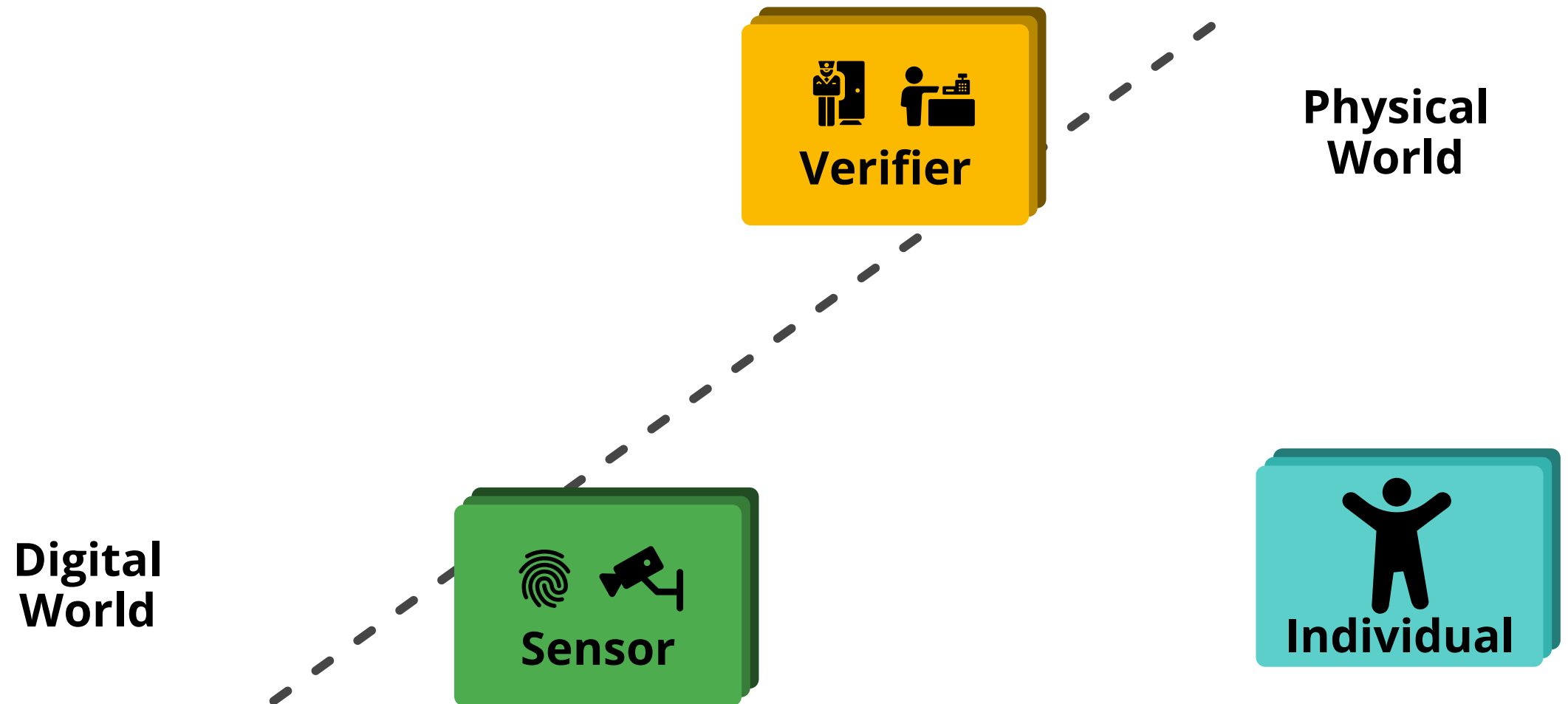
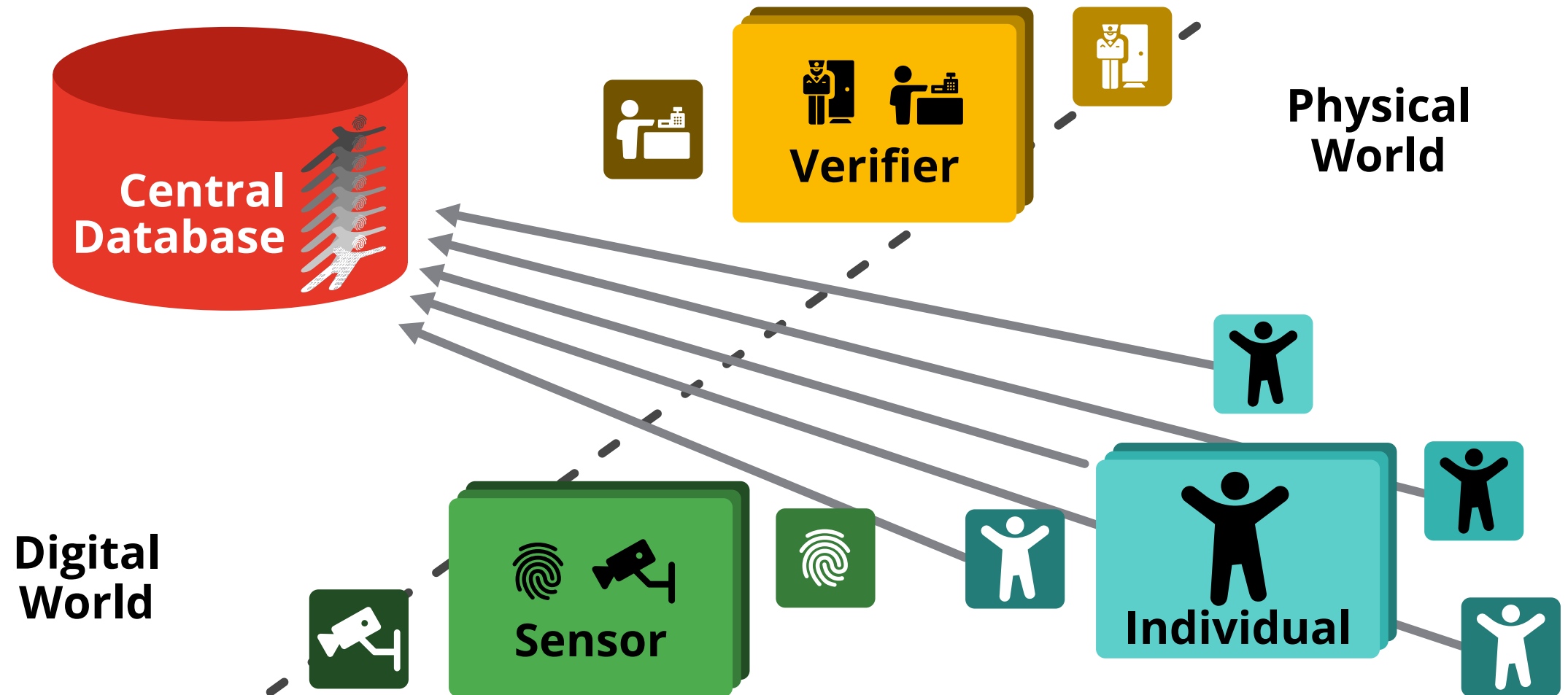


Image credit: Google

Digital Identity in the cloud – Vision



Digital Identity in the cloud – Centralized Approach

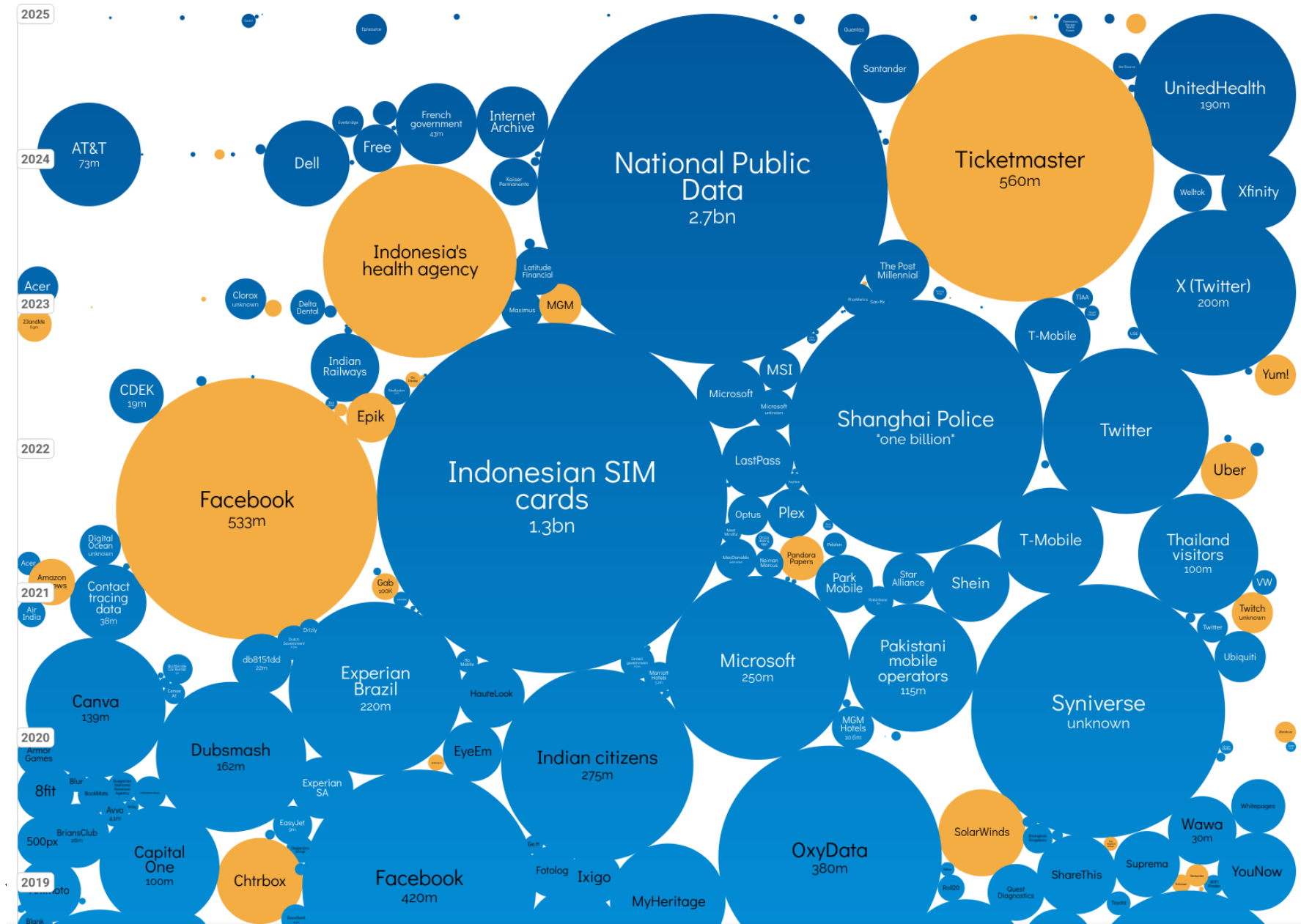


interesting story

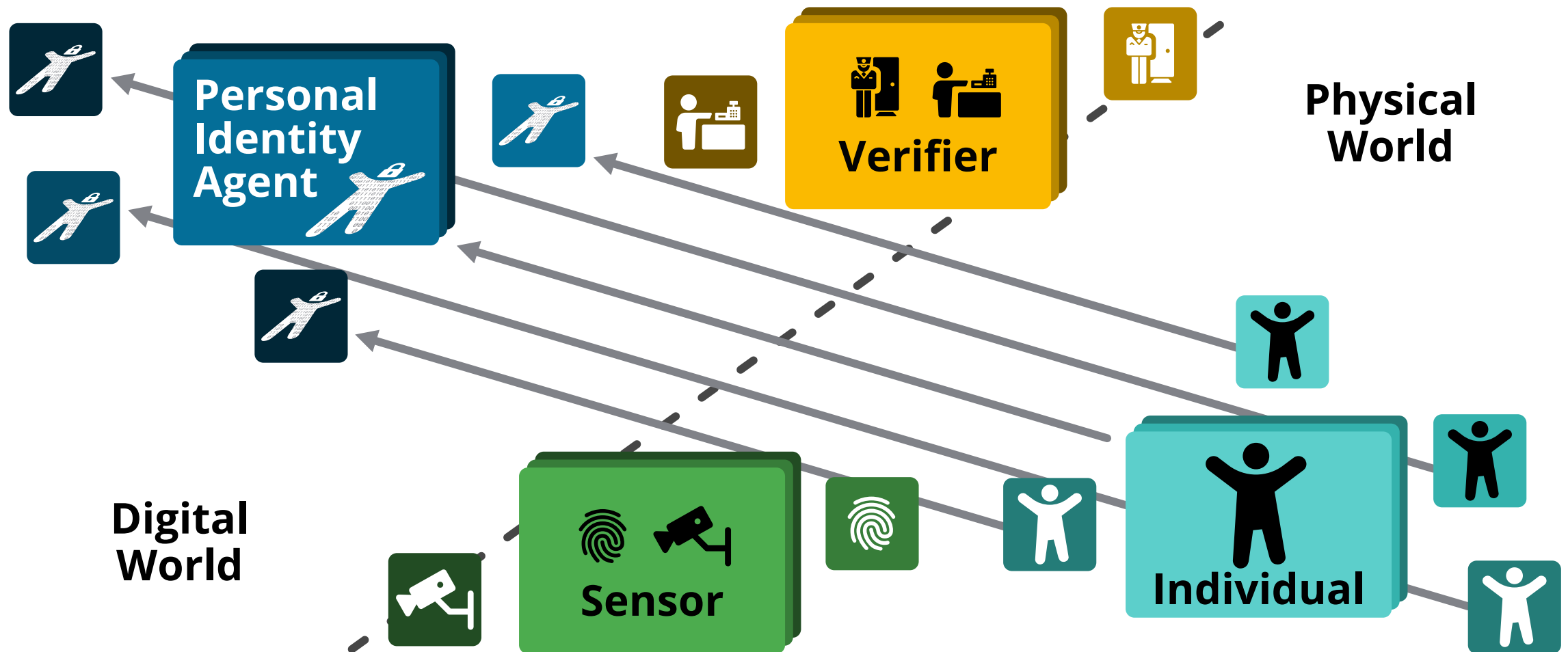
UPDATED: Sep 2025

filter

<https://www.informationisbeautiful.net/visualizations/worlds-biggest-data-breaches-hacks/>



Digital Identity in the cloud – Decentralized Approach



Supply Chain Security



Complex **chain of dependencies**

- Software libraries and *systems of systems*
- Network services
 - local – e.g., car charging stations via Open Charge Point Protocol (OCPP)
 - remote – required Internet services, e.g., time service
- (Availability of secure) hardware

Supply chains are interdisciplinary

- technical
- organizational
- economical (license and service contracts)
- legal / regulatory

Energy consumption of security measures?

- **Digital communication** to save energy consumption (travel, shipping) **needs security**
- **Security needs energy**
 - Run-time checks
 - Encryption, Signatures – will likely increase with the move to Post-Quantum Cryptography (PQC)
 - Public Key Infrastructures (PKIs)
 - Fuzzing and other security testing → significant and regular compute efforts
 - Auto-updates of large software packages → storage and networks transfer costs
 - Public logs of software (libraries) for supply chain verification
 - ...
- How much overhead do we produce with security mitigations?
 - → see talk by Daniel Gruss
 - → write more code in memory safe systems languages likes Rust
(Benchmarks in relation to C: Rust 1.03x, Java 1.98x, C# 3.14x, Go 3.23x, Python 75.88x)

Source: <https://www.sciencedirect.com/science/article/pii/S0167642321000022> with a critique at <https://arxiv.org/pdf/2410.05460>

Some estimates to help quantify other services

Estimating Netflix video streaming energy consumption:

- Wildly different estimates for mobile network transfer: 0.9 kWh/GB or 0.1 – 0.2 kWh/GB?
- Especially for wireless transfers: probably better to calculate per time than per transfer volume
- Estimate for transfer: 0.077kWh per hour of streamed video
- Highly dependent on viewing device:
 - TV: 50 – 200W, typically 100 – 150 W
 - Desktop computer: 50 – 500+ W
 - Laptop: 5 – 150+ W
 - Smartphone: 0,3 – 5 W
- Lower for audio streaming (music), but still significant data transfer consumption because of radio power requirements → much better to have locally cached music / video files!

Sources: <https://www.carbonbrief.org/factcheck-what-is-the-carbon-footprint-of-streaming-video-on-netflix> [2020], <https://www.rtings.com/tv/learn/led-oled-power-consumption-and-electricity-cost> [2021], <https://ieeexplore.ieee.org/document/8930492> [2019]

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- **Video streaming**

- **1 hour** Netflix network streaming: ca. **0,077kWh – 0,8kWh**
- Depends mostly on device: 50" TV screen ca. 100x, laptop ca. 5x compared to smartphone
- For smartphone viewing (**<0,05kWh**), ca. 80% of energy used for data transmission (networks)

- Energy consumption of **devices**: **30%** for TVs, **80%** for smartphones **during production**

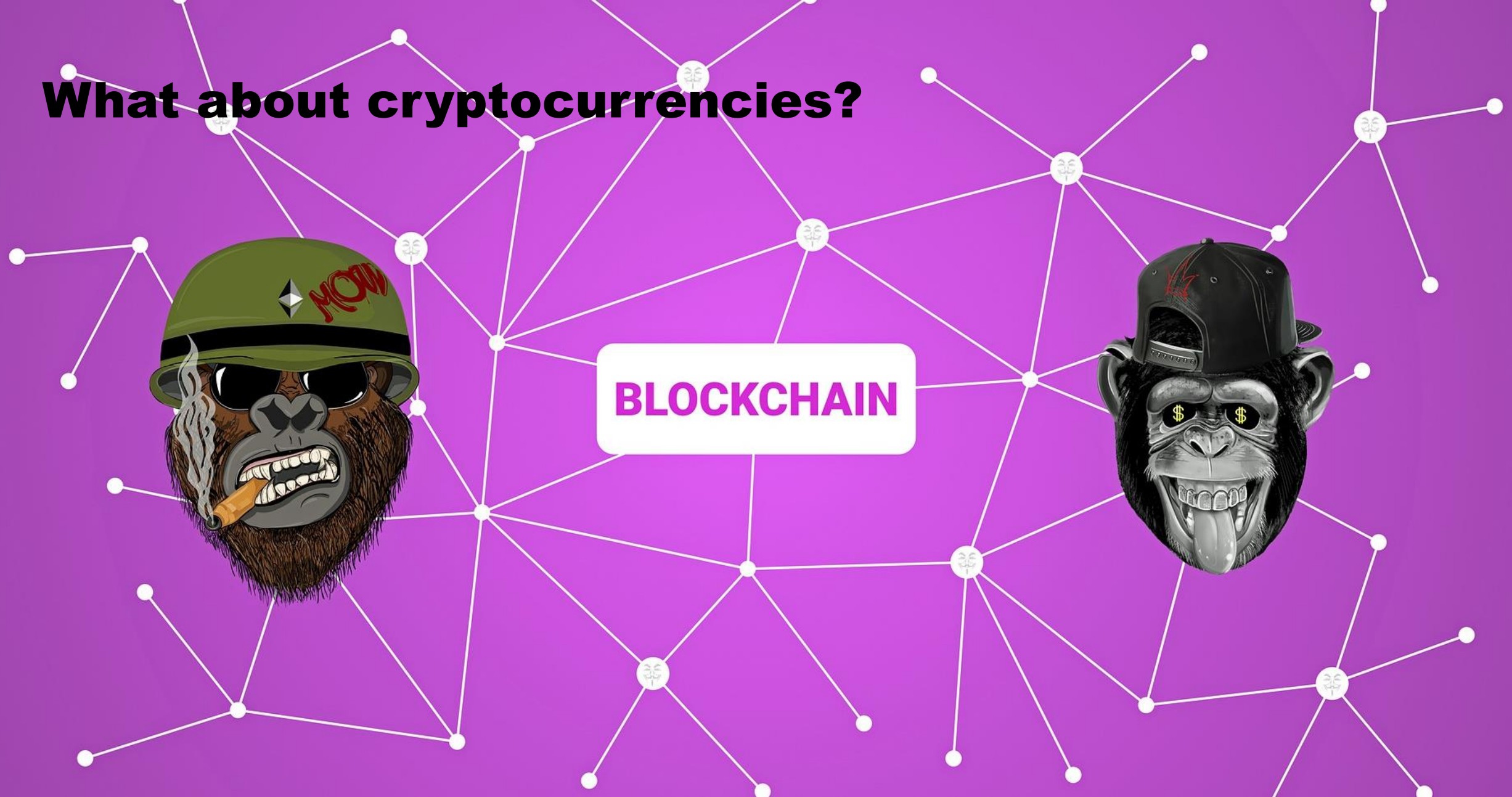
- All **data centers**: annually ca. **200 TWh + 250 TWh** network → ca. 2% of global consumption

Note: Data collected from different sources in summer 2021; <https://www.utilitybidder.co.uk/business-electricity/zoom-emissions/>, <https://www.carbonbrief.org/factcheck-what-is-the-carbon-footprint-of-streaming-video-on-netflix>, <https://www.sciencedaily.com/releases/2021/01/210114134033.htm>, <https://www.iea.org/reports/data-centres-and-data-transmission-networks>, <https://cbeci.org/cbeci/comparisons>

But beware: Vendor Lock-In



What about cryptocurrencies?



Annualised consumption

Power demand

7d

1m

3m

6m

YTD

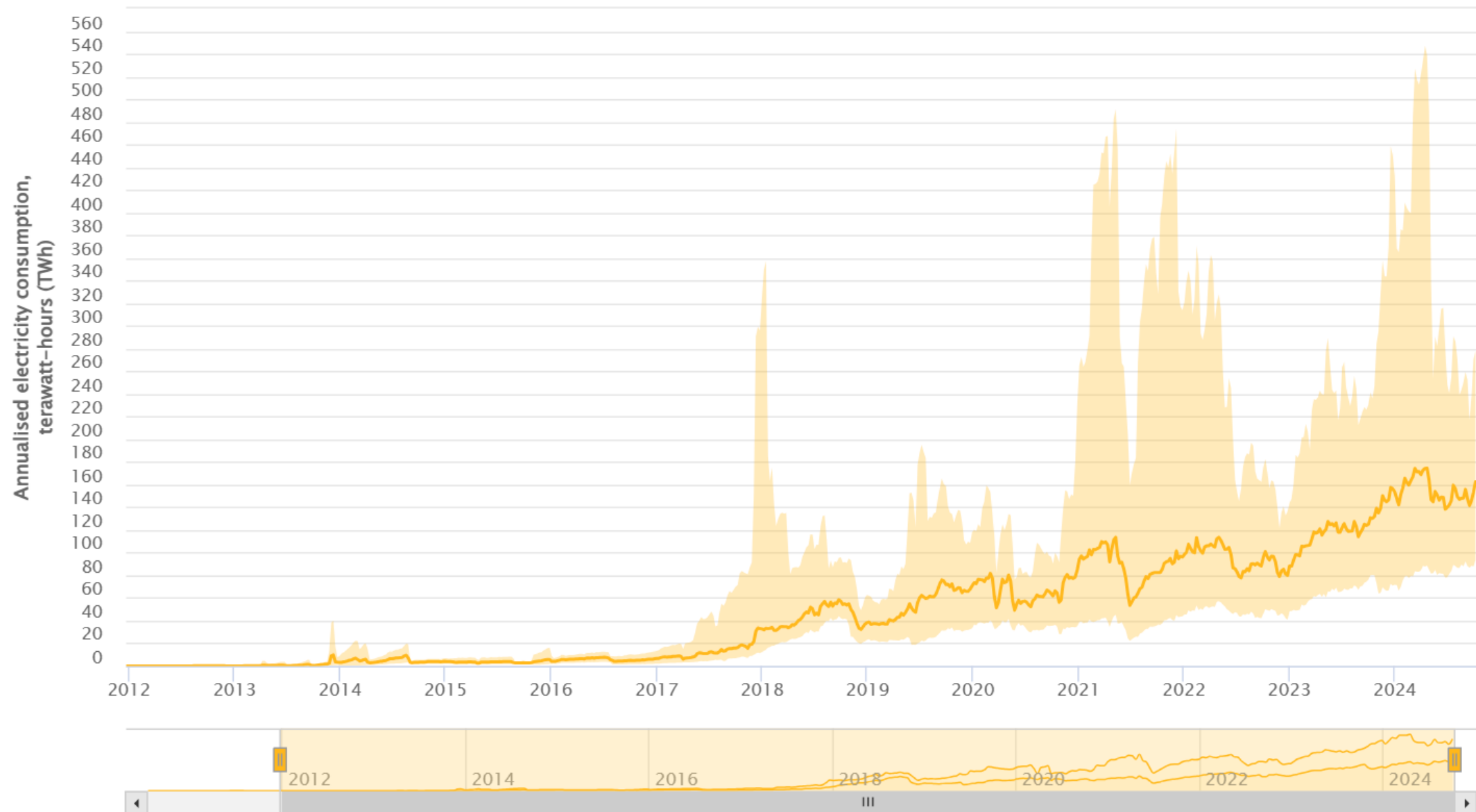
1y

All

Custom

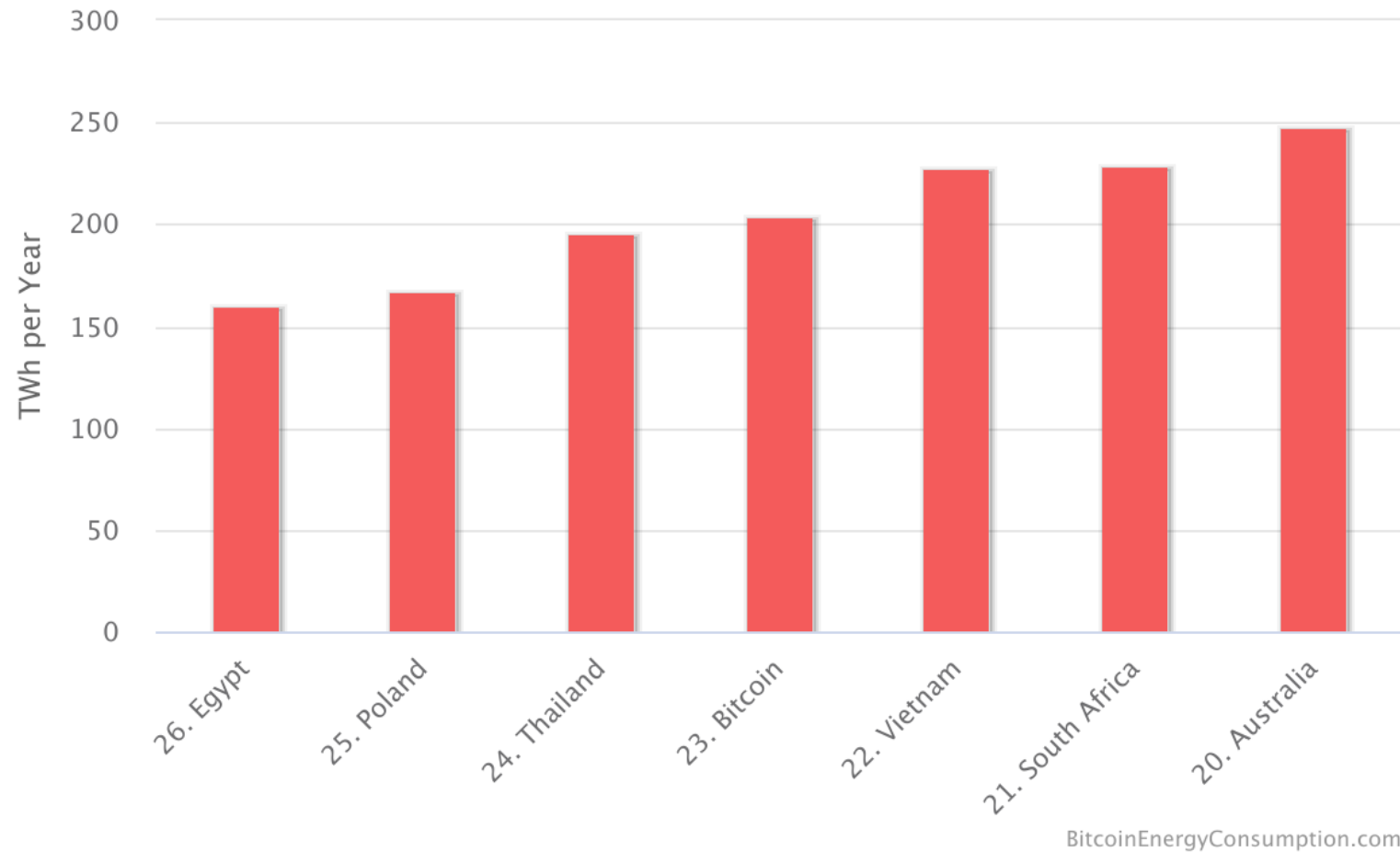


2011-12-22 - 2024-10-13



Blockchain – Proof of Work Energy Impact

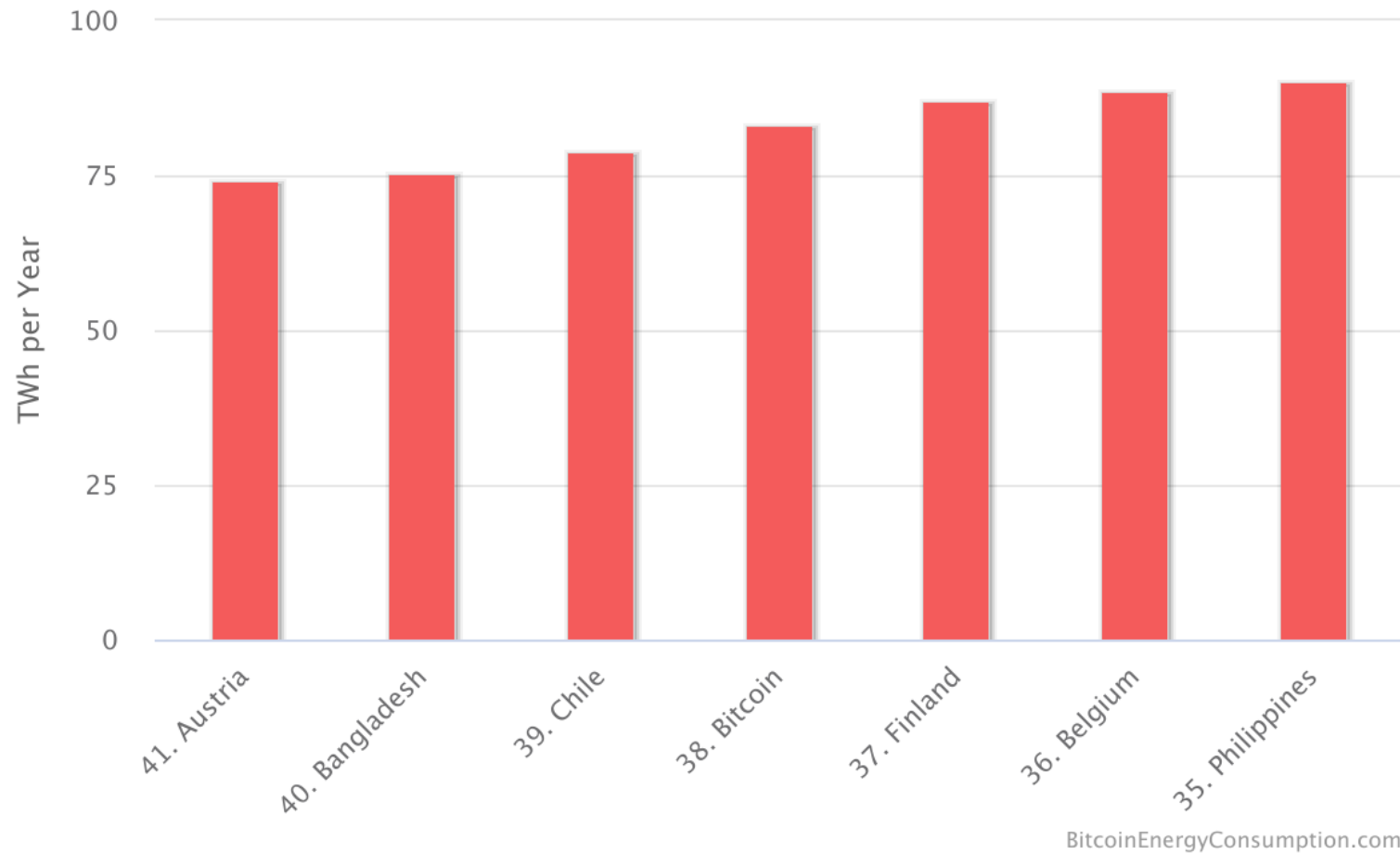
Energy Consumption by Country



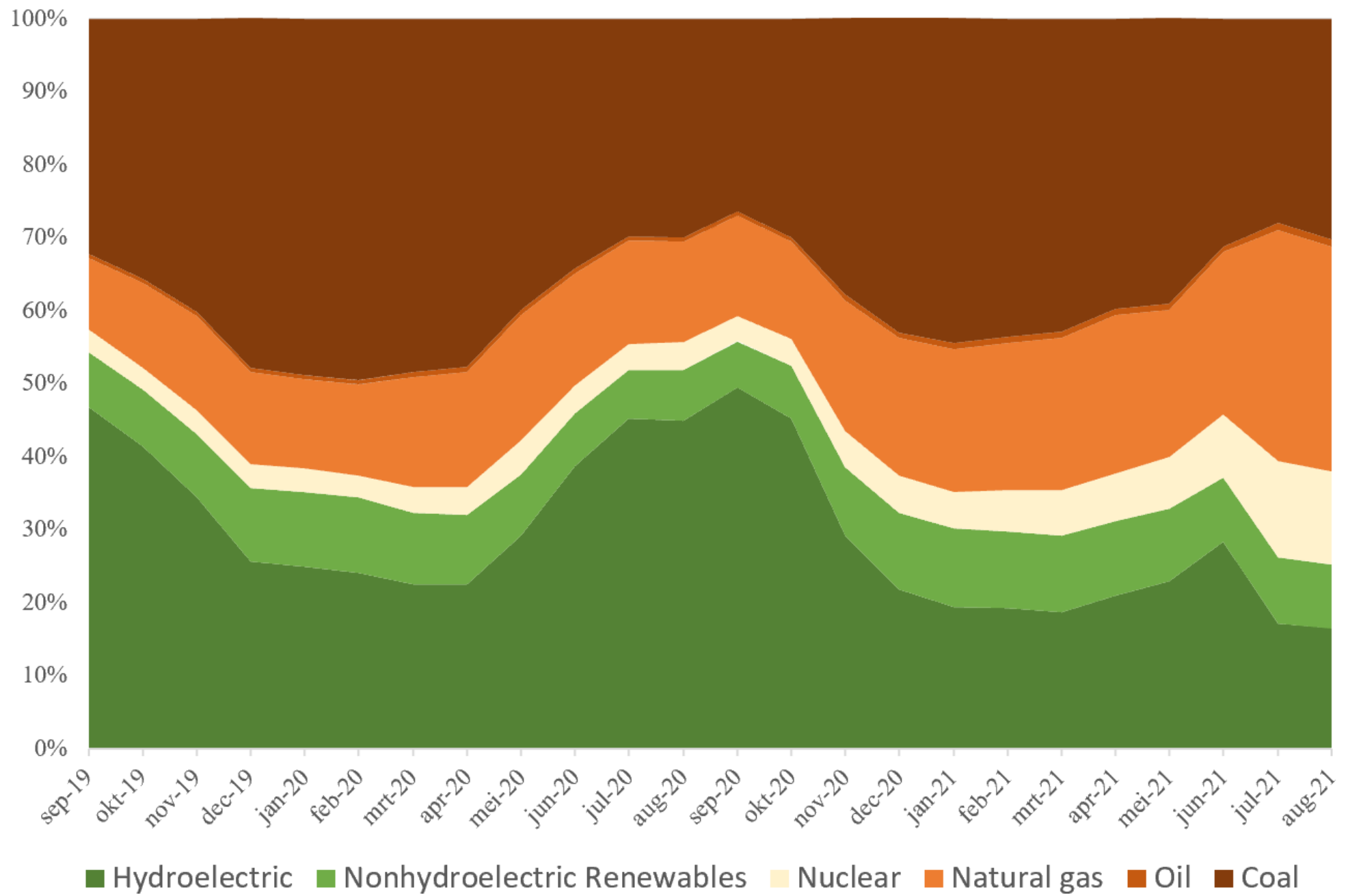
Source: <https://digiconomist.net/bitcoin-energy-consumption/>, 2021-01-28

Blockchain – Proof of Work Energy Impact

Energy Consumption by Country



Source: <https://digiconomist.net/bitcoin-energy-consumption/>, updated 2023



Non-Fungible Tokens (NFTs) (Let's best not talk about this particular scam)



For more information, check e.g. <https://youtu.be/XwMjPWOailQ>: “What the hell are NFT's?” by Josh Strife Hayes

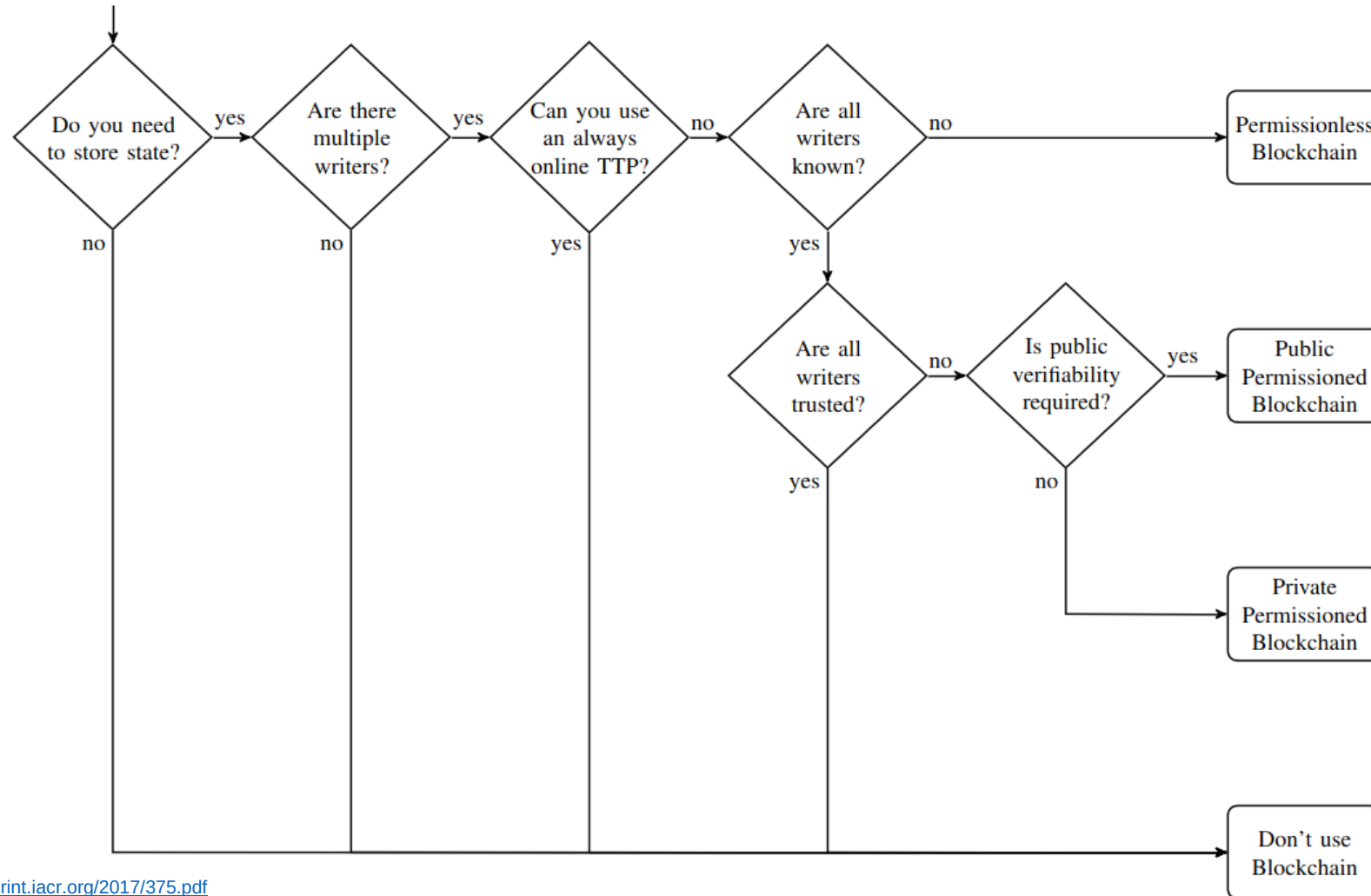
What about Blockchains without Proof-of-Work?



Correct! Don't uselessly waste enormous amounts of energy, but based on different assumptions:

- Do you really need irreversibility of all transactions?
 - Do **your** developers make no mistakes (“Code is Law”)?
- Do you really want to publish details of all transactions?
- Should every node mirror the whole history?
- Are there really no Trusted Third Parties (TTPs)?
- How many transactions/second do you need?
- (Do we really want people with more money in the system to have more voting power over the rules?)

Do you need a Blockchain?



Source: <https://eprint.iacr.org/2017/375.pdf>

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1 Bitcoin transaction: >2000kWh

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- 2021/2022: All **data centers**: annually ca. **200 TWh + 250 TWh** network → ~2% of global electricity

Bitcoin: 100-200TWh

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What about GenAI?



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- Estimate 2026: **data centers 620–1050 TWh** because of GenAI [IEA 2024, p .31]

Bitcoin: 100-200TWh

Note: Data collected from different sources in summer 2021 and fall 2024; <https://www.utilitybidder.co.uk/business-electricity/zoom-emissions/>, <https://www.carbonbrief.org/factcheck-what-is-the-carbon-footprint-of-streaming-video-on-netflix>, <https://www.sciencedaily.com/releases/2021/01/210114134033.htm>, <https://www.iea.org/reports/data-centres-and-data-transmission-networks>, <https://cbeci.org/cbeci/comparisons>, <https://www.iea.org/reports/electricity-2024>
Updated estimates for GenAI energy consumption: <https://www.sciencedirect.com/science/article/pii/S1364032125008329>, <https://arxiv.org/abs/2204.05149>

How good are these estimates?

- Short answer: we don't know – not even how big the error bars are
- E.g., network transfer consumption:
 - kWh/GB is obviously wrong when extrapolated!
 - **significant base level** of electricity required to keep equipment running, independent of transferred volume
 - dividing overall consumption by transferred bytes only reasonable for attributing past usage
- E.g., data center energy usage:
 - often based on indirect data (e.g., company reported costs for running a site)
 - definitely not comprehensive across the world, but only **extrapolated from few data points**
 - **changing rapidly**, e.g. because of massively increasing GPU power use for machine learning
- E.g., client device usage
 - depends on many factors: data transfer frequency, standby/saving modes, charging cycles, ...
 - improved efficiency often counteracted by highly increased usage

Questions?

*(Except: Do I need a Blockchain?
Answer: most likely, no)*



Web: <https://ins.jku.at/>
Email: rm@ins.jku.at
Signal: Rene.02

Wire: @rm
Twitter: @rene_mobile
Mastodon: @rene_mobile@infosec.exchange

