JOHANNES KEPLER UNIVERSITY LINZ

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

DIGiDOW

INSTITUTE OF NETWORKS AND SECURITY

Public Lecture Series „Sustainability in CS”, 2024-10-14 17:00 (UTC+2), Linz

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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 = 0.000075GB/s = 0.27GB/hr * 2 (up/down) = 0.54GB.
  - HD 720p = 0.00015GB/s = 0.54GB/hr * 2 (up/down) = 1.08GB.
  - HD 1080p = 0.000225GB/s = 0.81GB/hr * 2 (up/down) = 1.62GB
- For group video calling for 1 hour **per participant**:
  - HQ = 0.0001GB/s + 0.000125GB/s = 0.36GB/hr + 0.45GB/hr = 0.81GB.
  - Gallery view and/or HD 720p = 0.0001875GB/s = 0.675/hr * 2 (up/down) = 1.35GB.
  - HD 1080p = 0.0003125GB/s + 0.000375GB/s = 1.125GB/hr + 1.35GB/hr = 2.475GB

→ 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!*)

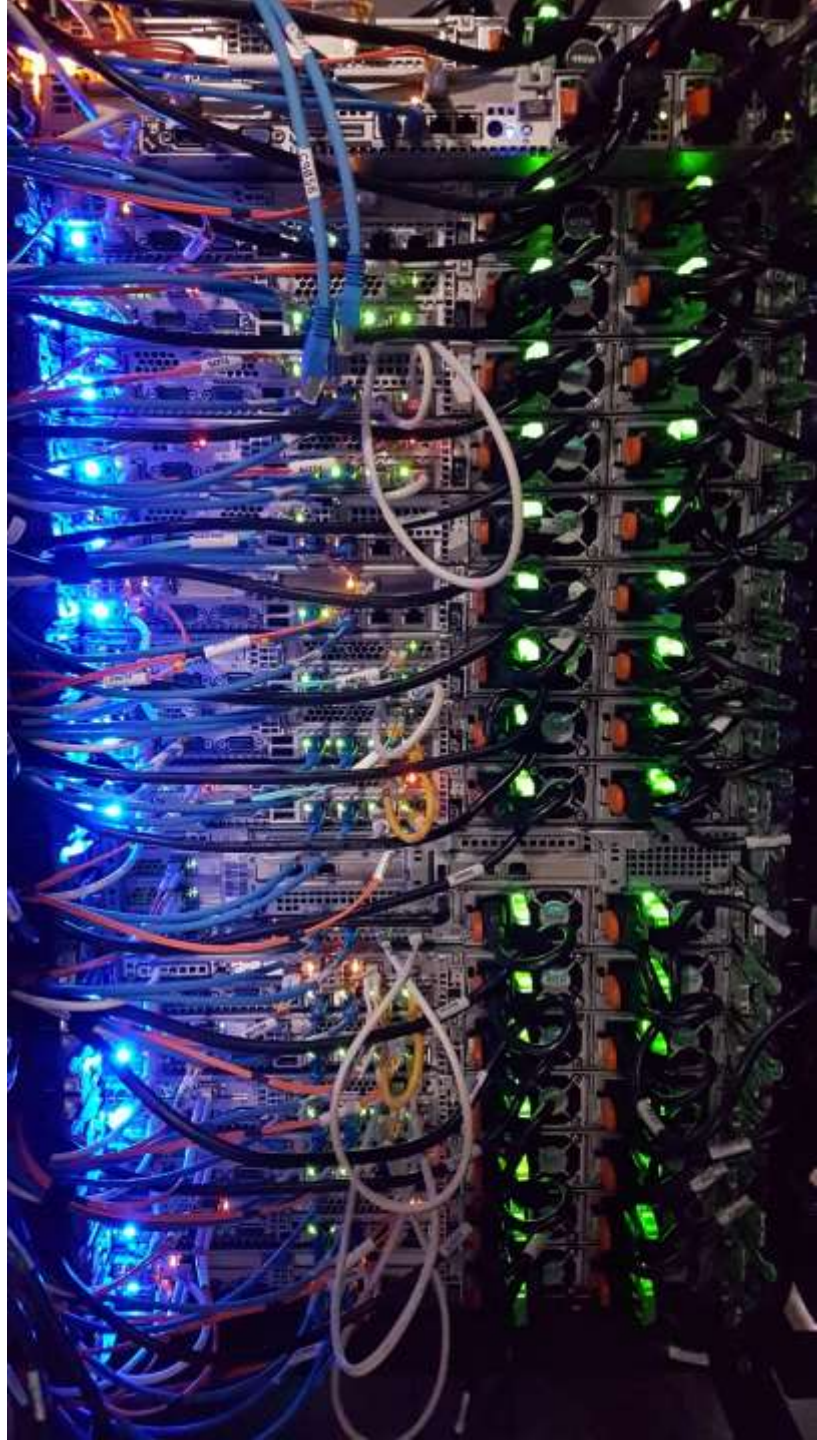
Source: https://davidmytton.blog/zoom-video-conferencing-energy-and-emissions/

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

Source: 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?

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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 between EU Commission and Parliament:
  ◦ `#chatcontrol` client-side scanning of content inside the E2EE messenger app clients?
  ◦ banning E2EE encryption again, or attacking devices?

See https://www.patrick-breyer.de/en/posts/messaging-and-chat-control/

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

2020

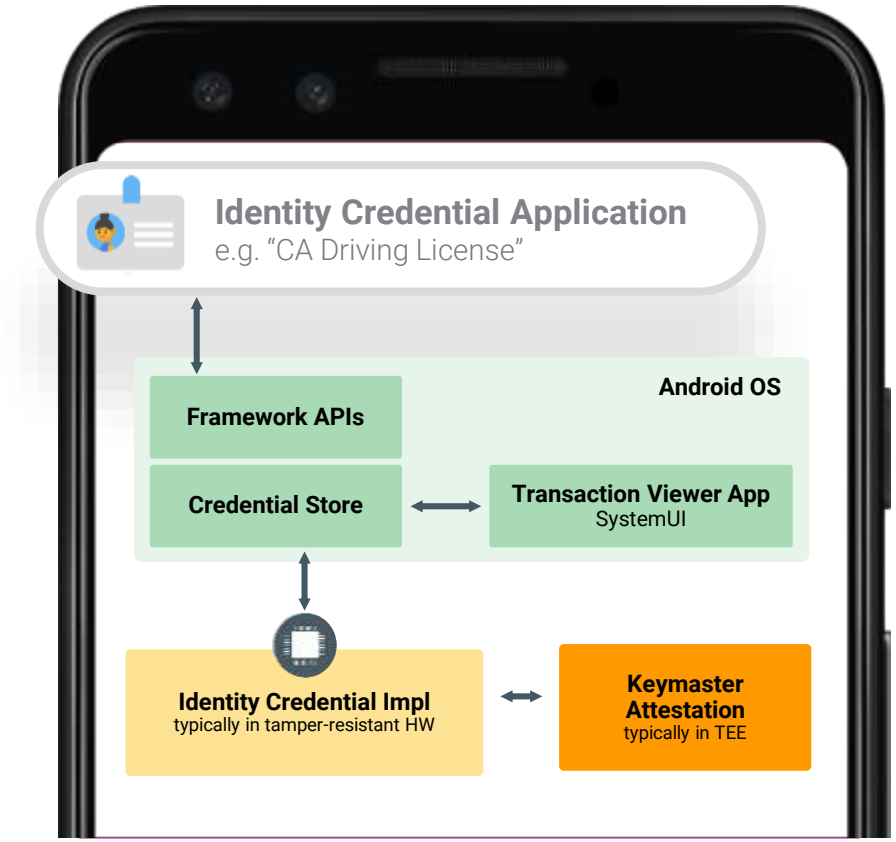
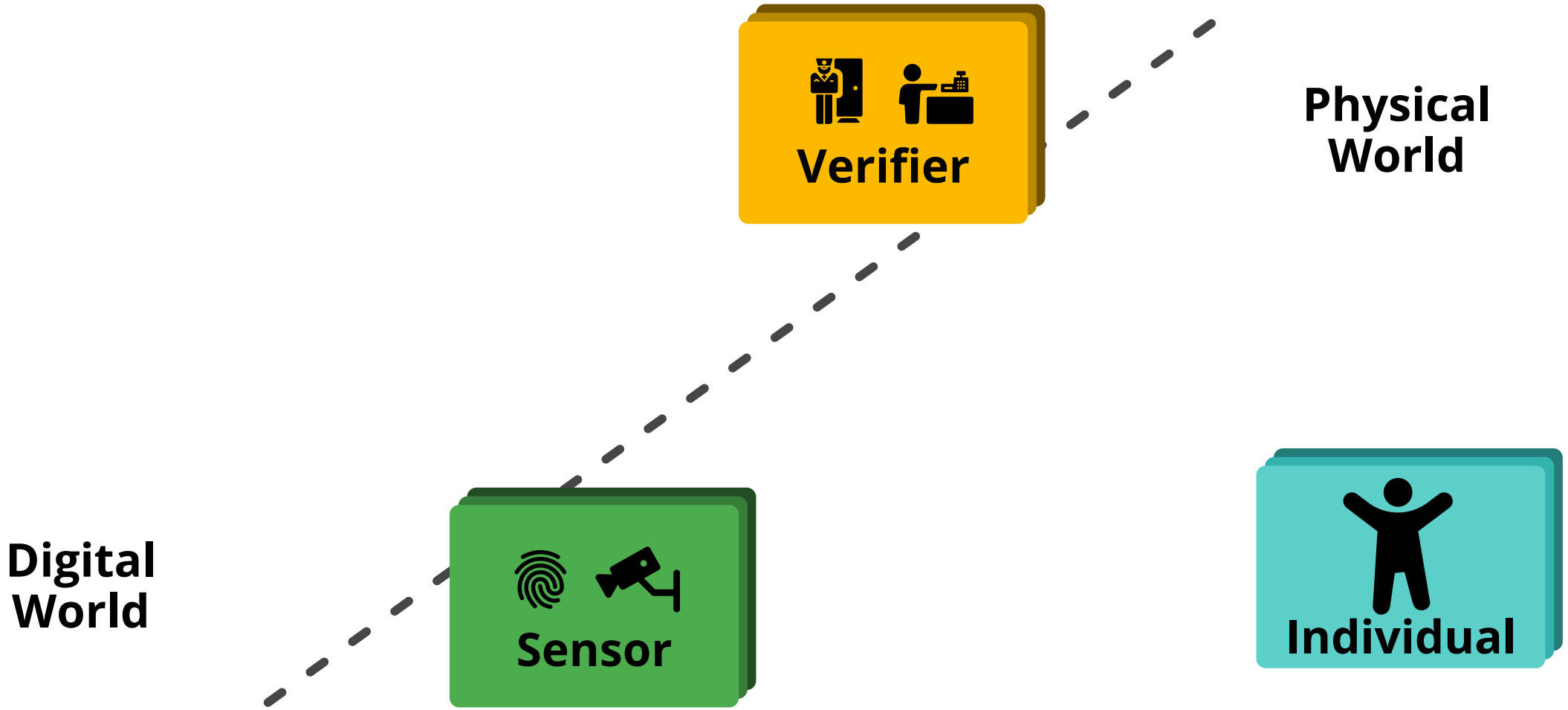
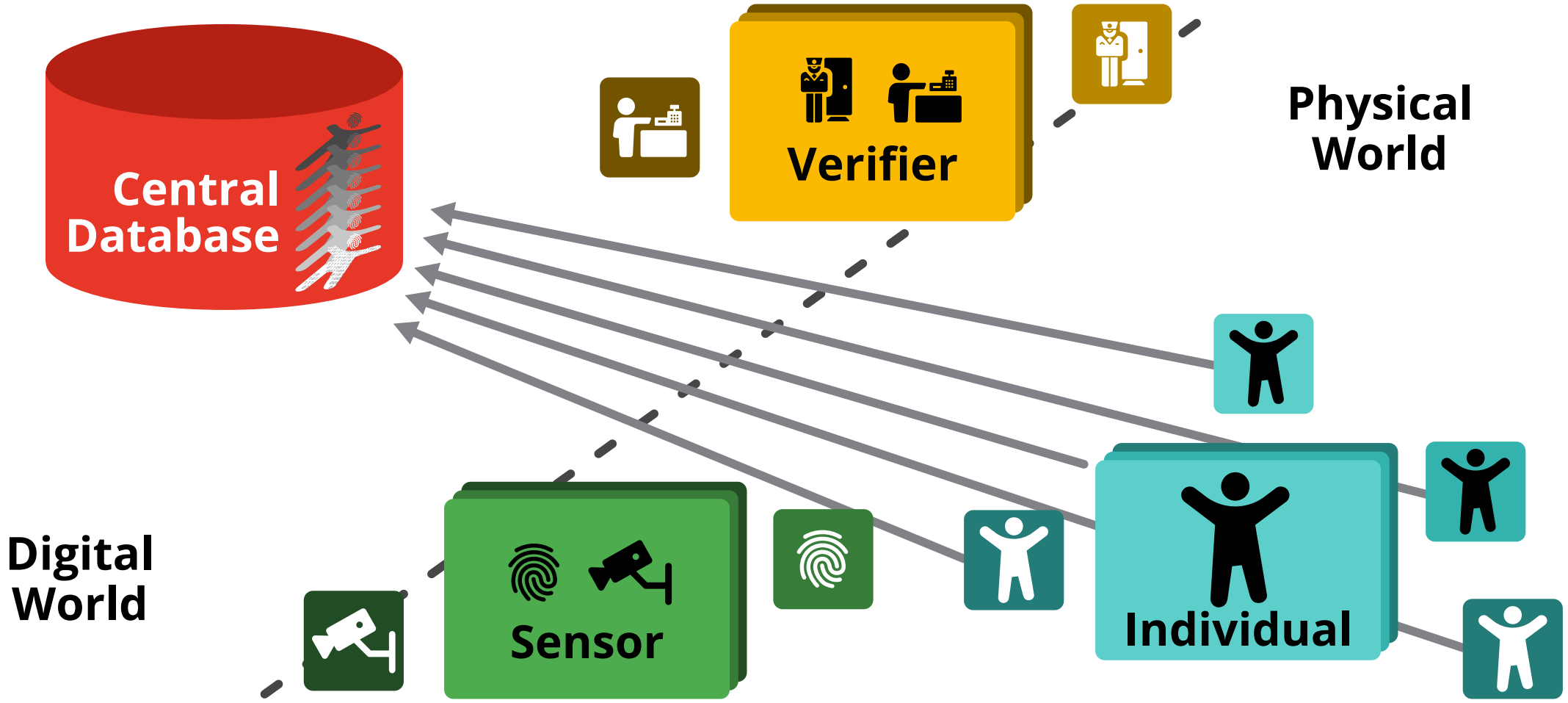


Image credit: Google

Digital Identity in the cloud – Vision



Digital Identity in the cloud – Centralized Approach

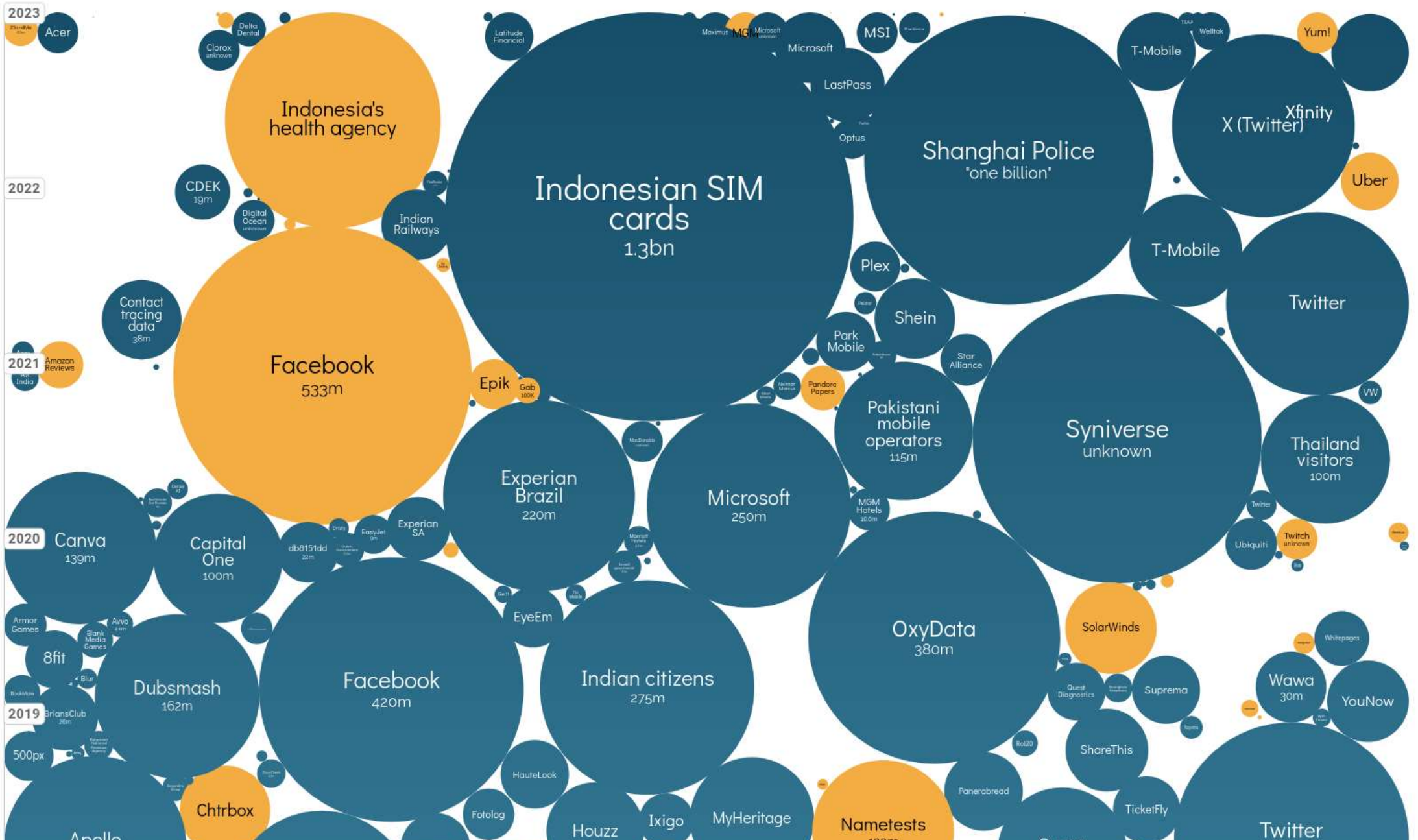


Selected events over 30,000 records stolen

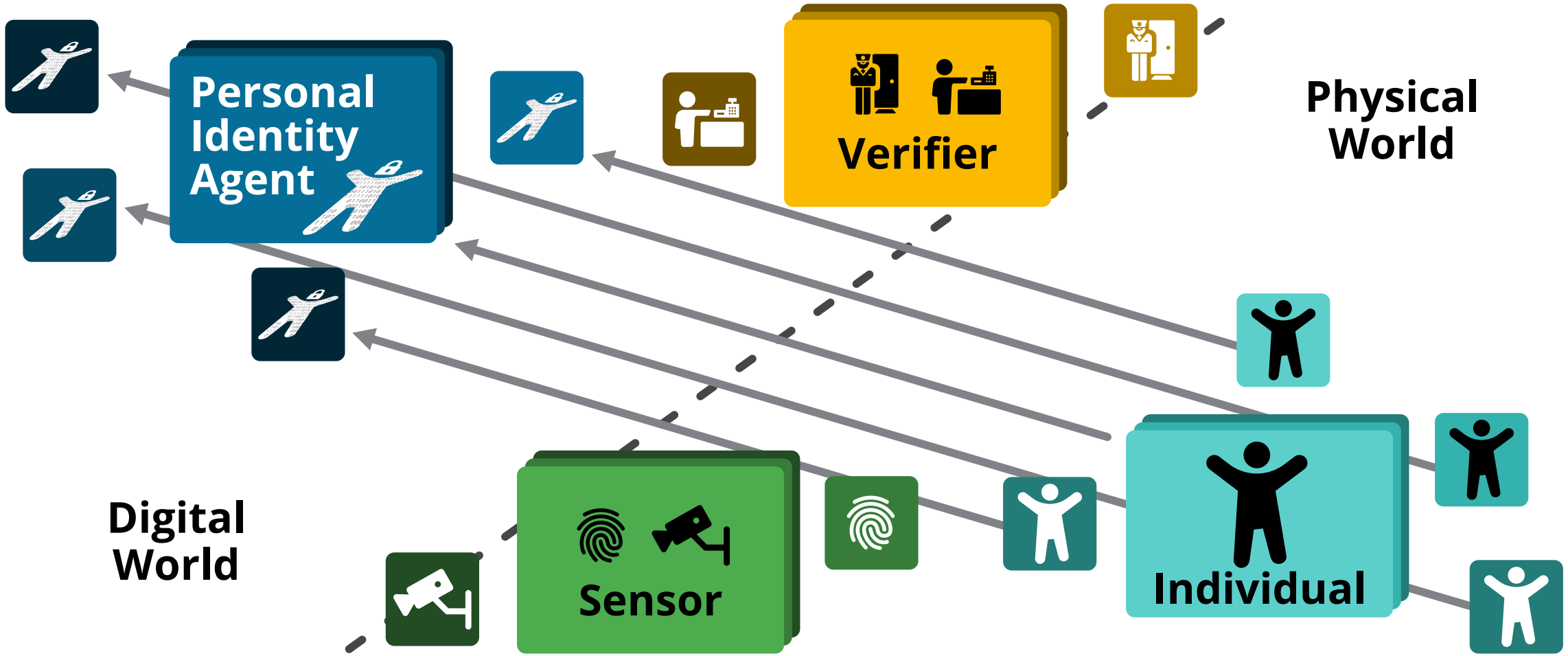
UPDATED: Jan 2024

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

size: records lost **filter** search...



Digital Identity in the cloud – Decentralized Approach



Supply Chain Security

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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**
  - Encryption
  - Signatures
  - Public Key Infrastructures (PKIs)
  - Fuzzing and other security testing
  - Auto-updates of large software packages
  - Public logs of software (libraries) for supply chain verification
  - …
- How much overhead do we produce with security mitigations?
  - → see talk by Daniel Gruss

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!

Source: 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]

Energy consumption of digital services?

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  - Textual communication (the old email…) much more efficient
- **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

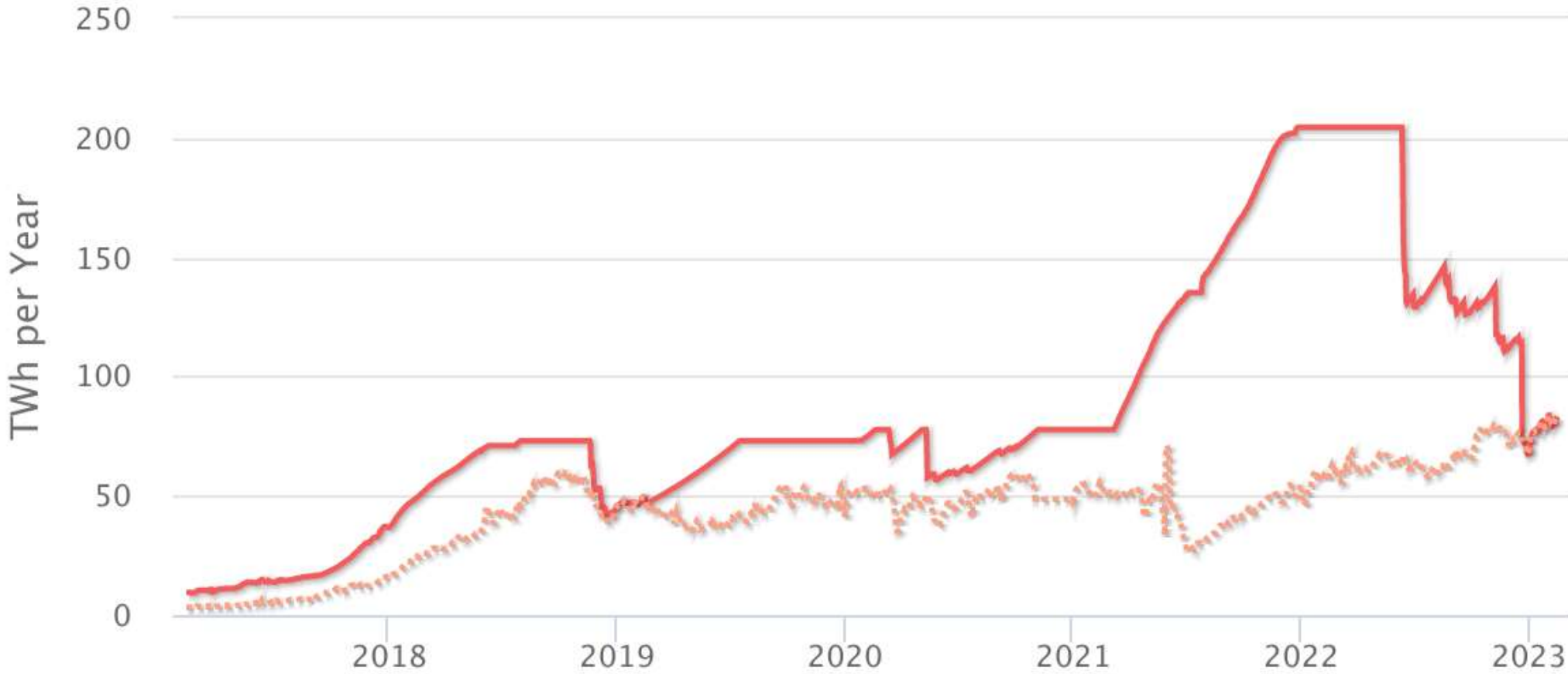
But beware: Vendor Lock-In

What about cryptocurrencies?

BLOCKCHAIN

Bitcoin Energy Consumption

Click and drag in the plot area to zoom in



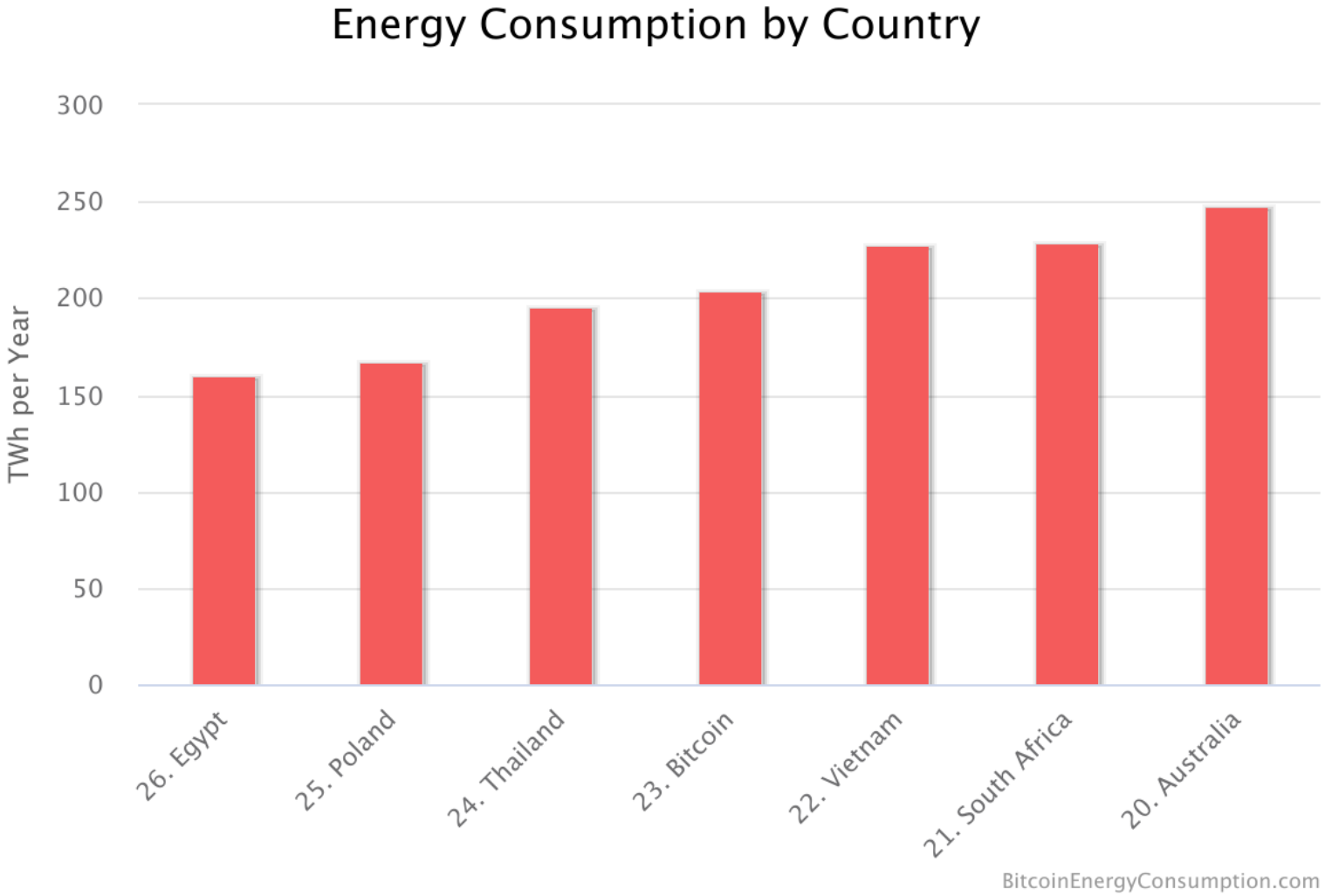
Zoom 1m 3m 6m YTD 1y **All** Jan 19, 2017 → Mar 8, 2023

Estimated TWh per Year **Minimum TWh per Year**

BitcoinEnergyConsumption.com

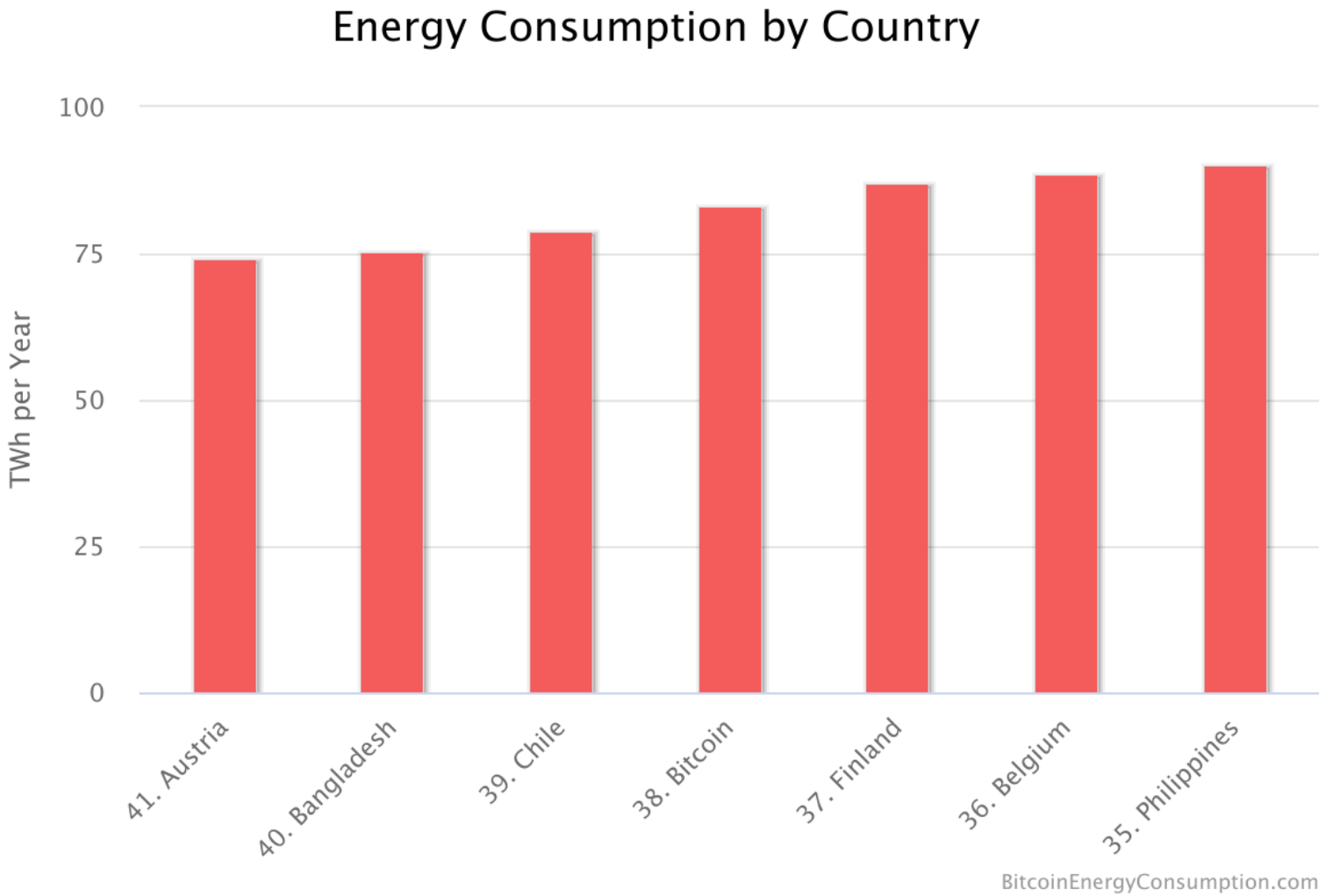
https://ccaf.io/cbnsi/cbeci

Blockchain – Proof of Work Energy Impact

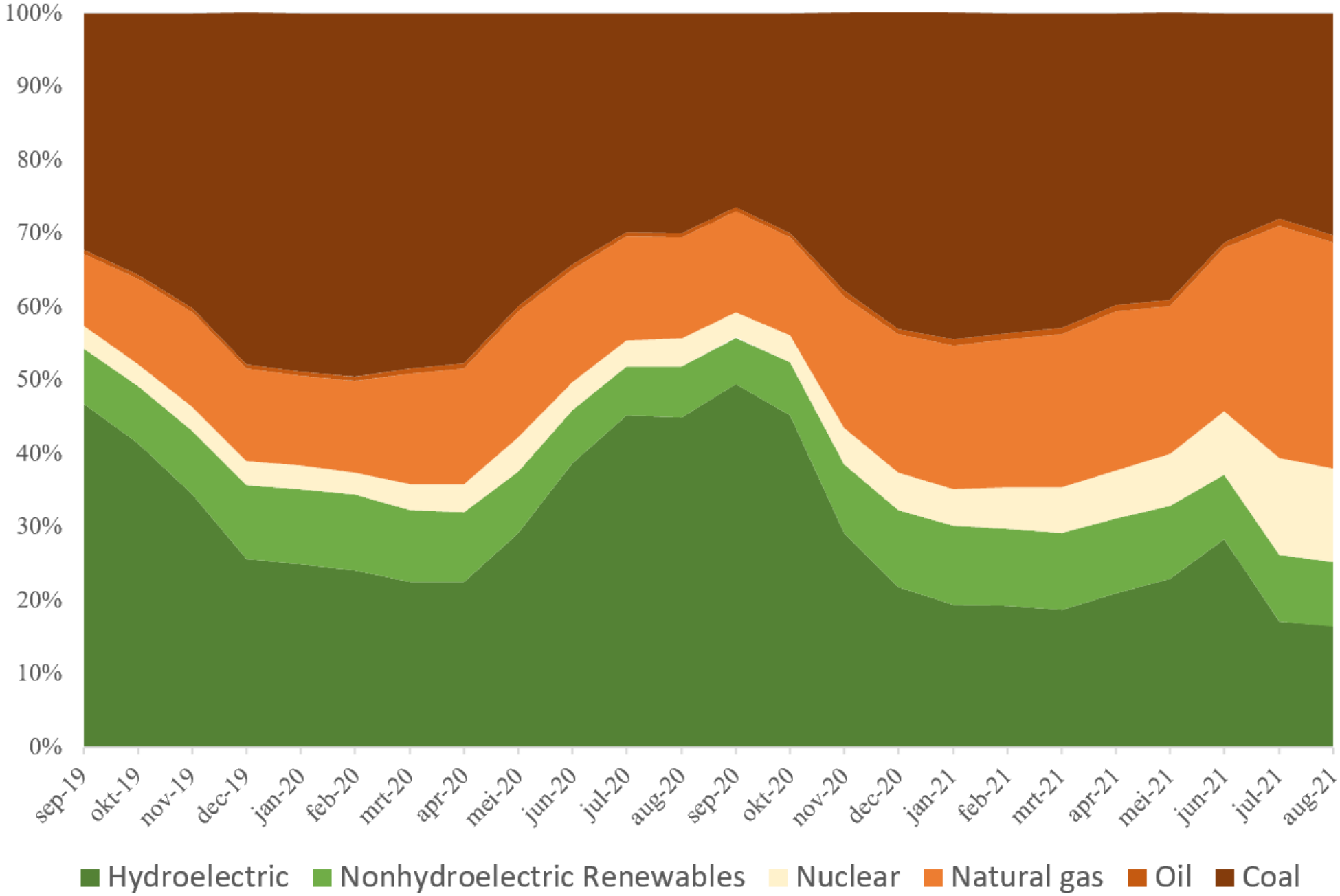


Source: https://digiconomist.net/bitcoin-energy-consumption/, 2021-01-28

Blockchain – Proof of Work Energy Impact



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

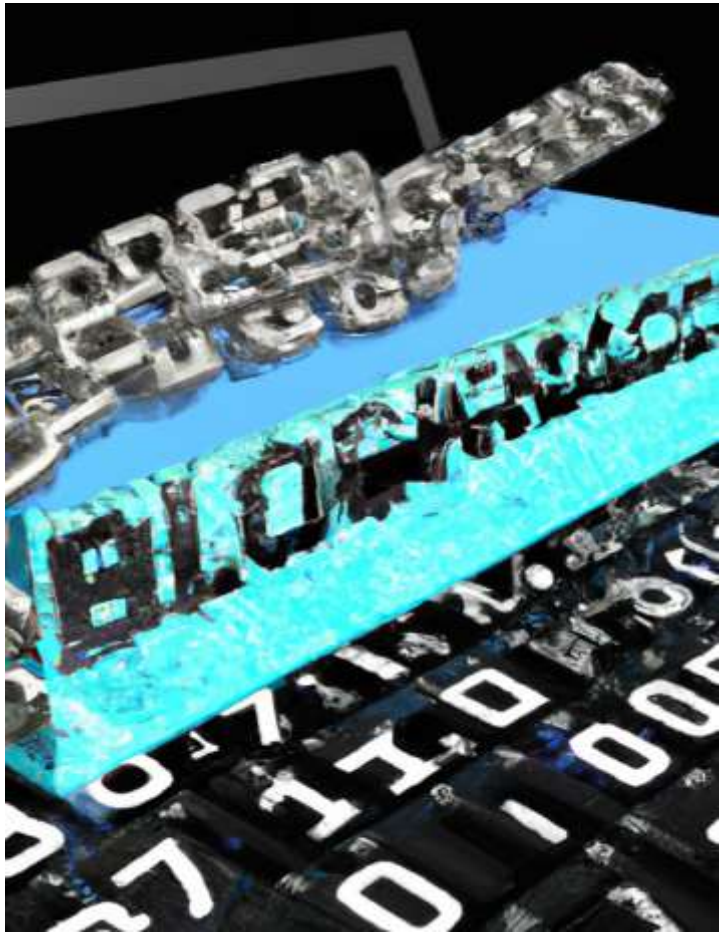


Source: https://digiconomist.net/bitcoin-energy-consumption/, 2023-02-16

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?

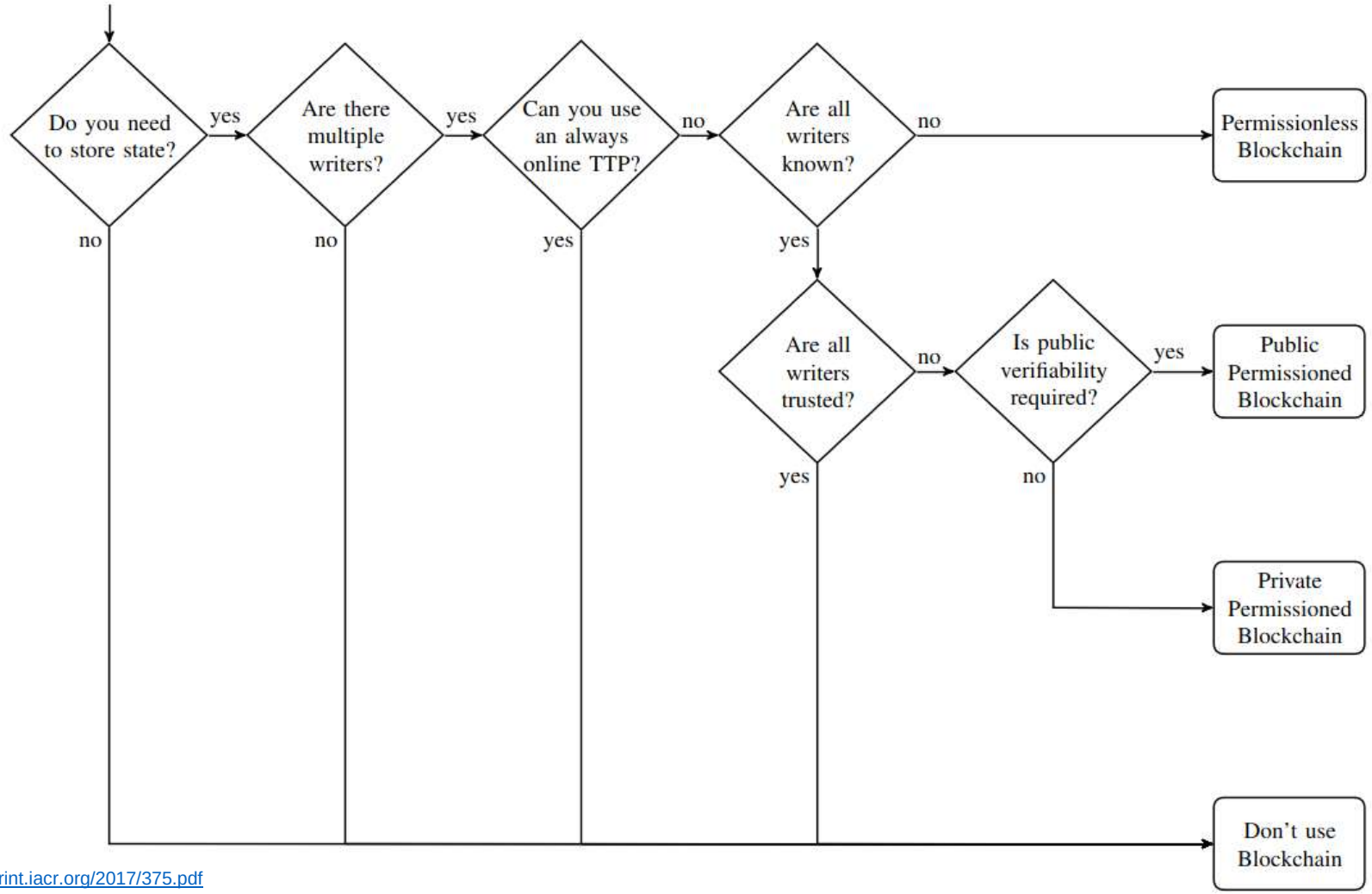


Correct! Don't uselessly waste enormous amounts of energy, but based on different assumptions:

- 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?)

Image source: DALL-E "rendering of a blockchain being hacked", 2022-08-11

Do you need a Blockchain?



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

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1 Bitcoin transaction: >2000kWh

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

What about GenAI?

Energy consumption of digital services?

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- Energy consumption of **devices**: **30%** for TVs, **80%** for smartphones **during production**
- 2021/2022: All **data centers**: annually ca. **200 TWh + 250 TWh** network → ~2% of global electricity
- Estimate 2026: **data centers** **620–1050 TWh** because of GenAI [IEA 2024, p .31]

1 Bitcoin transaction: >2000kWh

Bitcoin: 100-200TWh

GenAI: 100-x00TWh

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

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

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Questions?

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

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