Save the world, write more efficient code!

Bert Hubert
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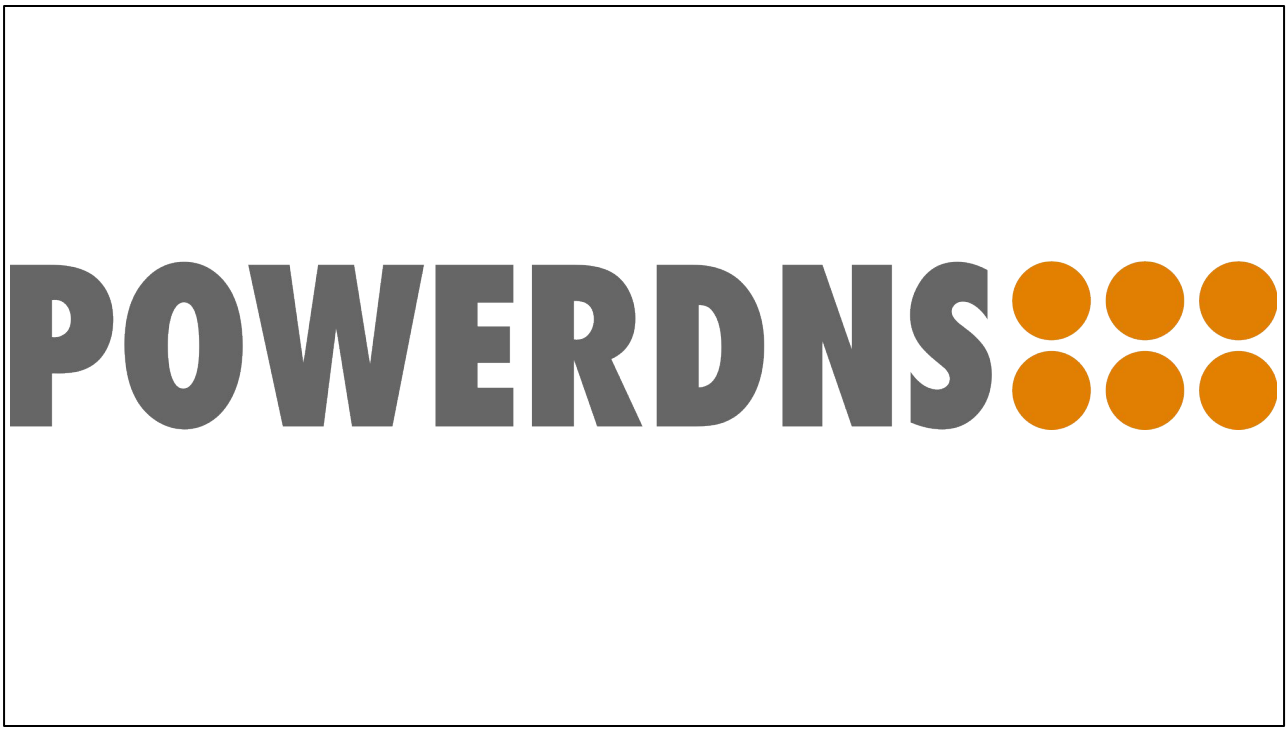
https://berthub.eu/joc



This is my relevant background on performance, energy use

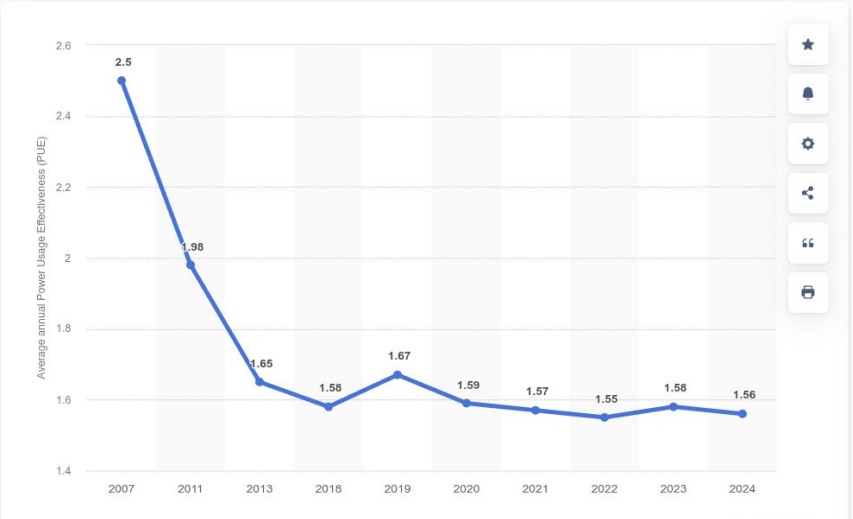
In 2006, AOL migrated to PowerDNS

..

And was able to turn off 120 servers

Although I wasn't that "eco" minded in 2006, this gave me some pause. Especially since this happened while I was on vacation, making me think my travel emissions where now taken care of

Data center average annual power usage effectiveness (PUE)



Additional Infe

Source: Statista *survey*, so don't take it too seriously.

Some "office datacenters" may have a PUE of 4.

Some cloud datacenters game the numbers and claim PUE of 1.01

$$\mathrm{PUE} = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}} = 1 + \frac{\text{Non IT Facility Energy}}{\text{IT Equipment Energy}}$$

https://www.statista.com/statistics/1229367/data-center-average-annual-pue-worldwide/ - don't trust this data too much. Oddly enough, if your PSU is 90% efficient, I don't see how this number can ever get below 1.1. Google &c however claim to reach PUE of 1.01.

Texas Instruments
www.ti.com

Trend No. 3: Efficiency

Efficiency specifications in the early 2000s were just above 65%; at the time, server PSU designers did not prioritize efficiency. Traditional converter topologies could easily satisfy the 65% efficiency target. But because a server needs to operate continuously, higher efficiency can greatly reduce total cost of ownership.

Since 2004, the 80 Plus standard has provided certifications for PC and server PSU systems that can achieve over 80% efficiency. Server PSUs in mass production today mostly achieve the 80 Plus Gold (>92% efficiency) requirement, and some can even achieve 80 Plus Platinum (>94% efficiency).

Server PSUs under development today mainly target the even higher 80 Plus Titanium specifications, which require over 96% peak efficiency at half loads. Table 1 shows the various 80 Plus specifications.

Table 1. The 80 Plus specification ensures above 80% efficiency.

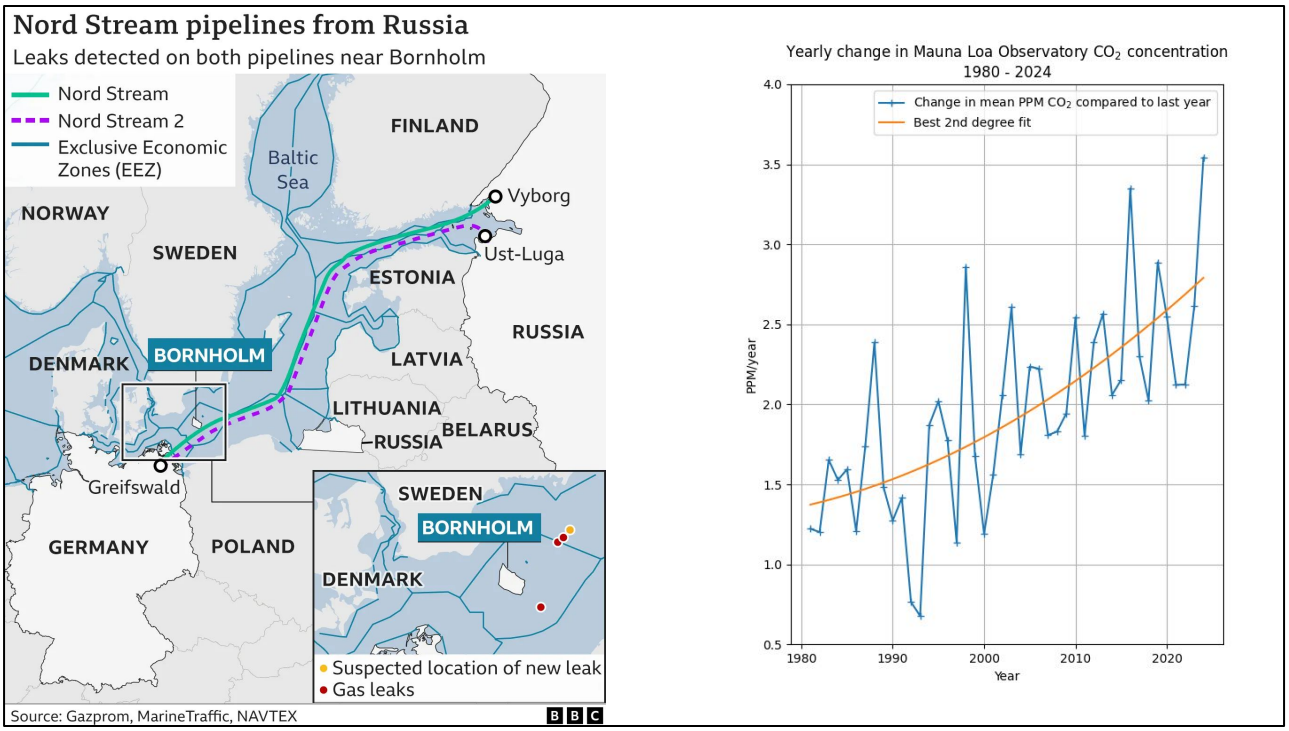
230 V internal redundant

	10%	20%	50%	100%
80 Plus				
80 Plus Bronze		81%	85%	81%
80 Plus Silver		85%	89%	85%
80 Plus Gold		88%	92%	88%
80 Plus Platinum		90%	94%	91%
80 Plus Titanium	90%	94%	96%	91%

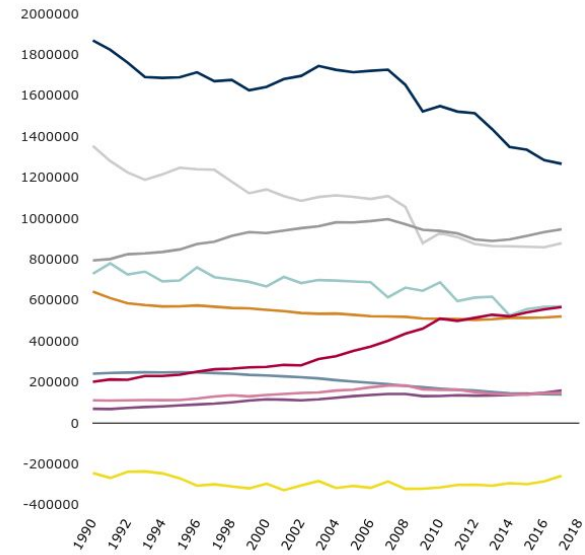
It is amazing we just used to piss away >35% of power on inefficient PSUs. But that's mostly fixed now.

The hardware people delivered!

Thanks. But this did not require people to change their operations a lot, just buy other stuff, optimize airflow etc.



https://berthub.eu/articles/posts/on-climate-change-and-management/ - energy is terrible both from a geopolitics perspective as well as a climate perspective. The graph on the right shows the increase in CO2 is still SPEEDING UP



Are servers a big deal? Computers?

Nothing on its own is huge. Lots of 4% chunks.

This means **everything** is important to work on

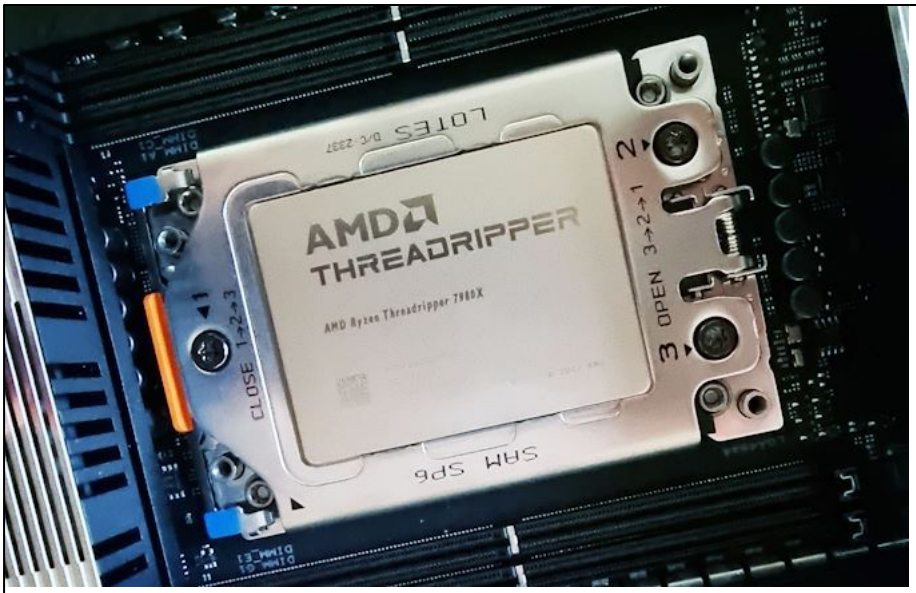
People love to say their field is only 4% of emissions. But almost all fields are only 4%. So every field needs to get moving!

Now it is our turn!

How efficient is the CODE that runs on the virtual machines in the servers in here?

© NorthC Groningen

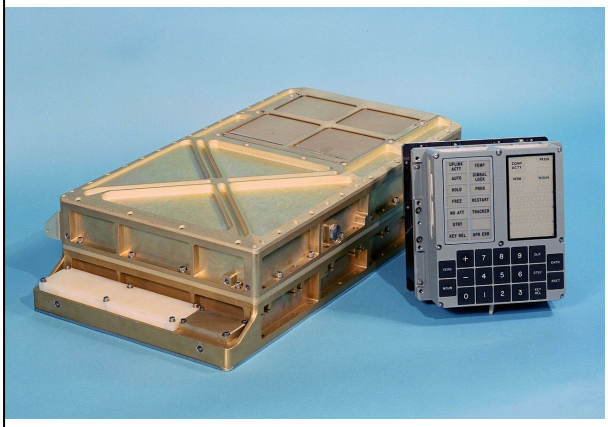
So much attention is devoted to the physical DC. But then we stop thinking somehow. We need a ‘gold standard’ for software as well, not just for PSUs!



“Software is getting slower more rapidly than hardware is becoming faster” - Niklaus Wirth

“Software efficiency halves every 18 months, compensating Moore's law” - David May

The astounding Apollo Guidance Computer



6000 transistors, 73 kilobytes of “rope” memory. **2MHz**. Could land you on the moon.

If a computer could cry, the AGC would. Do get the book “The Apollo Guidance Computer”! https://www.bol.com/nl/nl/f/the-apollo-guidance-computer/35953160/

There is easily a **factor 100** performance difference between **wasteful** and **highly optimized** code

This sounds big, but I come with data!

From data center to the data shed
(if only we had enough time, enough skills, **enough will**)

You can **buy** a more energy efficient power adapter.
Software efficiency you'll have to **build!**

If every computer would do 100 times as much work, you could fit your whole DC into a shed. But, you can't buy yourself this factor 100 efficiency. It has to lovingly be built.

Category 1: Everything is sluggish and dumb

Category 2: Snappy under reasonable load

Category 3: Single server is serving 196 gbit/s of video

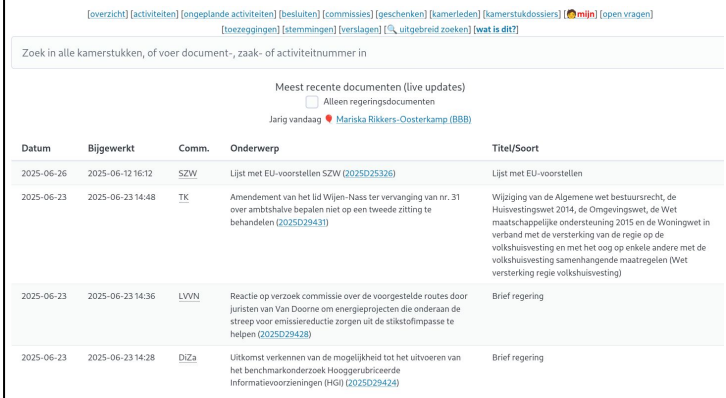
If your stuff is sluggish because your run on a Raspberry Pi, that is different of course. If you are building something and it isn't snappy even under no load, it is going to burn through tremendous amounts of energy when you scale up.

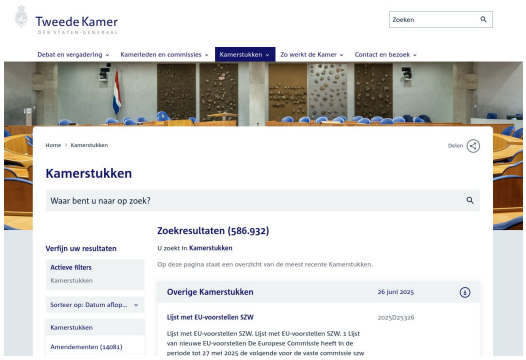
Anything where simple things are sluggish is **burning energy at an irresponsible scale.**

If something takes a while, it is either latency OR massive CPU burning (or IO) *somewhere*

(if you run on reasonable hardware) - if you see a spinner, *something* is doing big cpu or big io *somewhere*. The only exception is latency, which might get you some “free” slowness that does not burn energy.

opentk.nl versus tweedekamer.nl





Capgemini

OpenTK is very simple, it serves files, it reads data from a bunch of SQLite databases. The actual tweedekamer.nl infrastructure is a wild collection of Azure services that is sensitive and somewhat fragile.

ivo jansch

2 maanden

Alles Vragen & antwoorden Moties

Zoeken op **Joe Biden** vindt alle documenten met ergens *Joe* en ergens *Biden*. Zoeken op **"Joe Biden"** vindt alleen die twee woorden naast elkaar. Zoeken op **Hubert NOT Bruls** vindt documenten met daarin Hubert maar niet Bruls. De hoofdletters in **NOT** zijn belangrijk. Meer uitleg hier.

Datum	Bijgewerkt	Nummer	Onderwerp	Snip
2020-07-16	2024-02-19 10:56	2020D29967	Ethische analyse van de COVID-19 notificatie-app ter aanvulling op bron en contactonderzoek GGD	...Tijdens de bijeenkomst werd het panel van technische informatie voorzien door **Ivo Jansch**, technisch expert en lid van het bouwteam...
2020-08-28	2024-02-19 10:56	2020D32763	Ethische analyse van de COVID-19 notificatie-app ter aanvulling op bron en contactonderzoek GGD	...Tijdens de bijeenkomst werd het panel van technische informatie voorzien door **Ivo Jansch**, technisch expert en lid van het bouwteam...

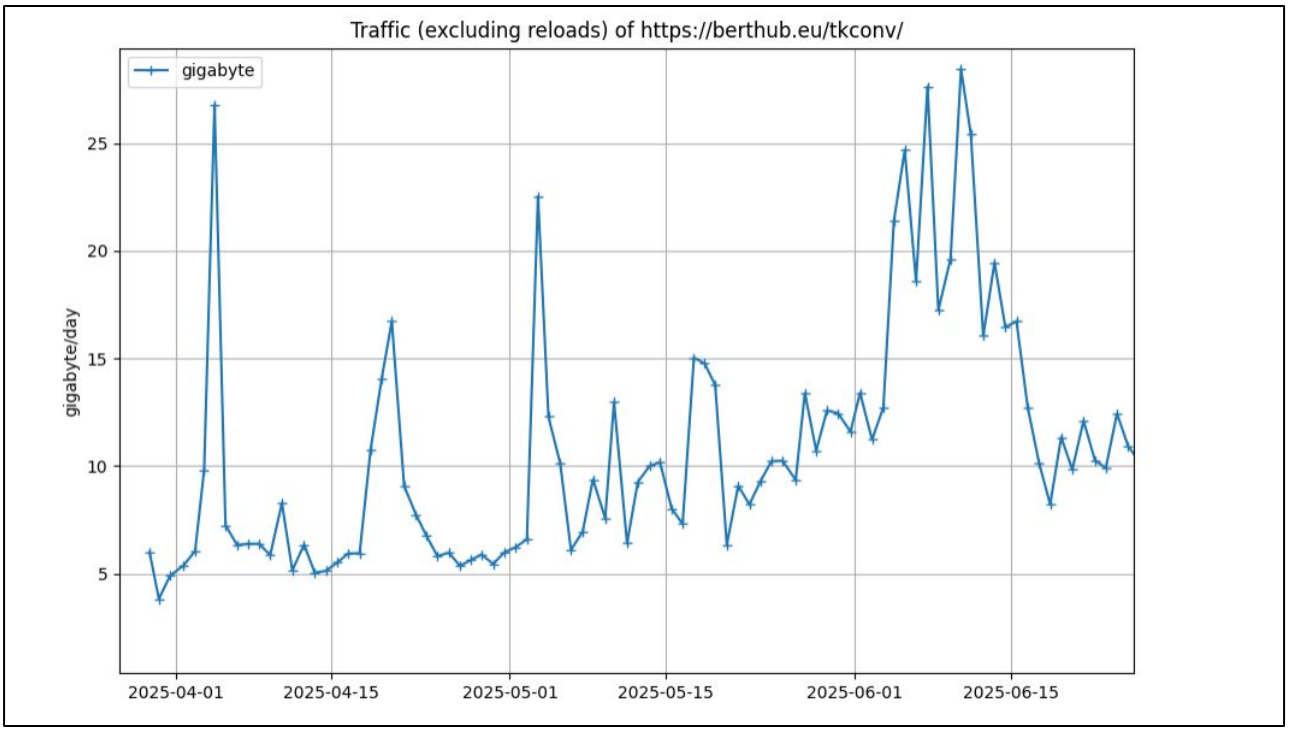
5.634 milliseconden

Statistics:

- 160 gigabytes of documents
- 800,000 documents
  - 3000 updates/week
  - Many of them need OCR help
  - Conversion to HTML
- Millions of meetings, agenda items, votes, official decisions
  - Data since 2008, thousands of changes/day
- 8000 weekly active users, 1700 configured monitors, 2000 notifications/day
- 300 GB of traffic/month, 100k queries/day
- Live updates 24/7, up to date within a single minute
- **Average latency, including search: 16 milliseconds**

- Advanced fulltext search
- Automated search term monitoring, alerts on changes
- **Maintenance free**

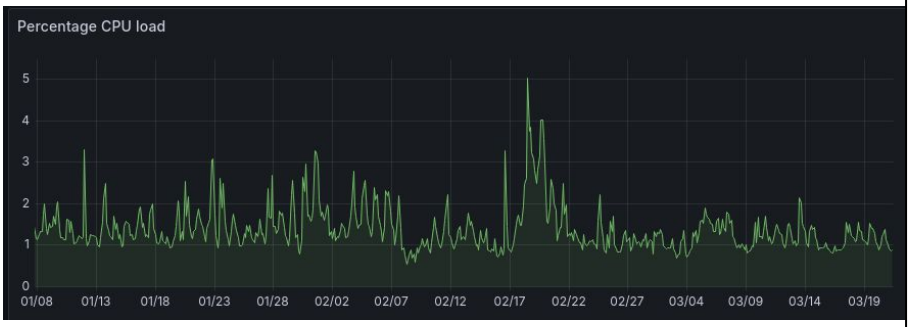
Wow such numbers!



It gets actual traffic. Mostly AI companies, in terms of gigabytes. Most of them are done slurping now.

And despite all the traffic and the large number of documents, latency is typically sub 20ms these days.

- Bare metal, 64 GB RAM, 1TB SSD
- Intel(R) Core(TM) i5-10500T CPU 6 cores
- “500 euro/year”
- <35W
- **ALSO RUNS GALMON.EU, BERTHUB.EU**



Behold, the server that powers _all_ of this

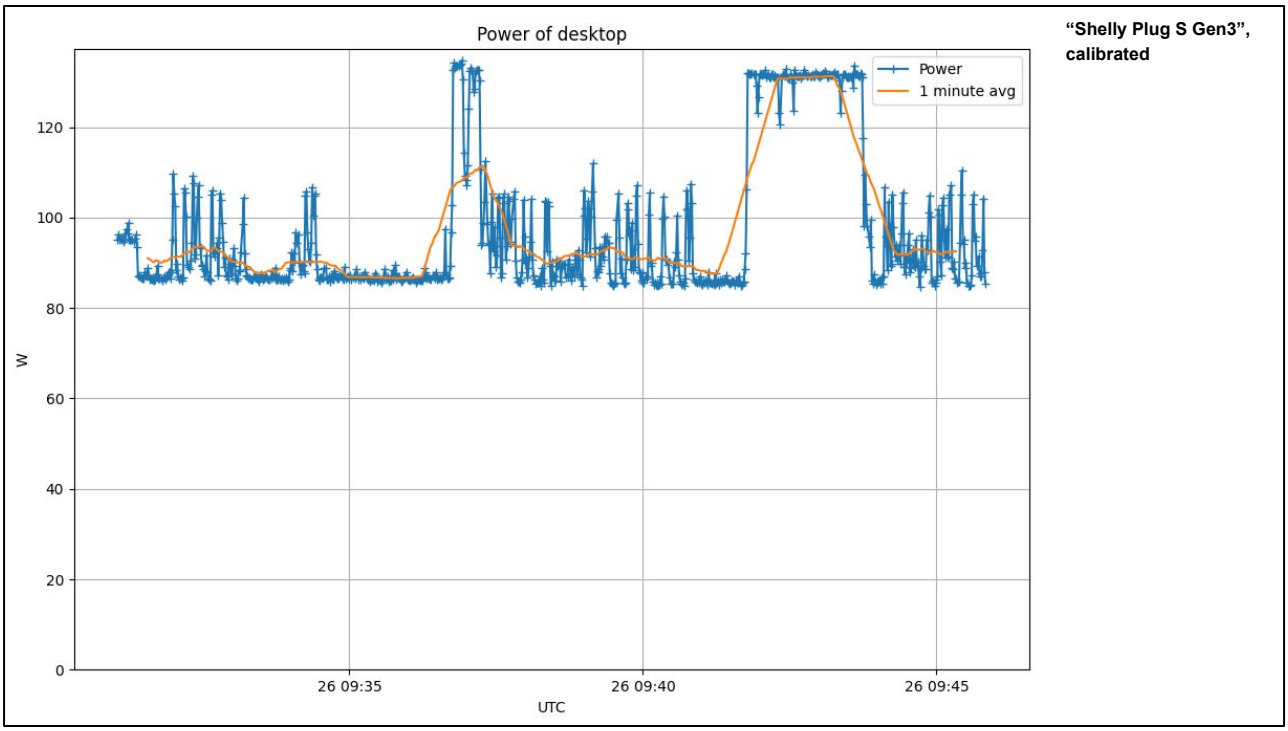
To measure is to know..

```
while true
do
        date +%s | tr "\n" ";"
        curl -s http://192.168.1.38/rpc/Switch.GetStatus?id=0  | jq .apower
        sleep 1
done | tee -a pow.csv
```

Shelly Plug S Gen3

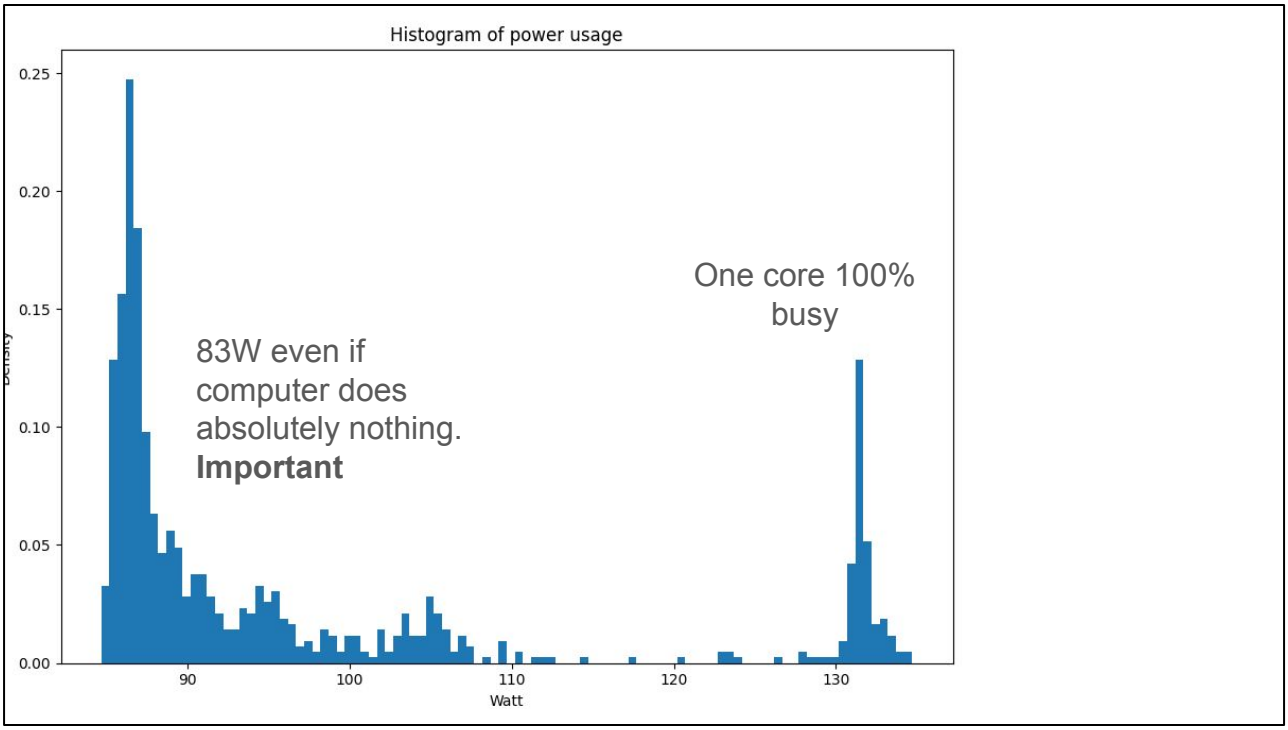
```
pow = pandas.read_csv("/home/ahu/content/joy-of-coding/pow.csv", names=["timestamp", "power"], sep=';')
pow["tstamp"] = pandas.to_datetime(pow["timestamp"], unit='s')
pow=pow.set_index("tstamp")
plt.figure()
plt.plot(pow.power, '+-', label='Power')
plt.plot(pow.power.rolling(60, center=True).mean(), label="1 minute avg")
plt.grid()
plt.ylabel("W")
plt.xlabel("UTC")
plt.ylim(0)
plt.legend()
plt.title("Power of desktop")
```

Not very advanced. I calibrated the Shelly against a real meter, and it checks out. 25 euros. Wifi, bluetooth, RiscV. What more do you want.

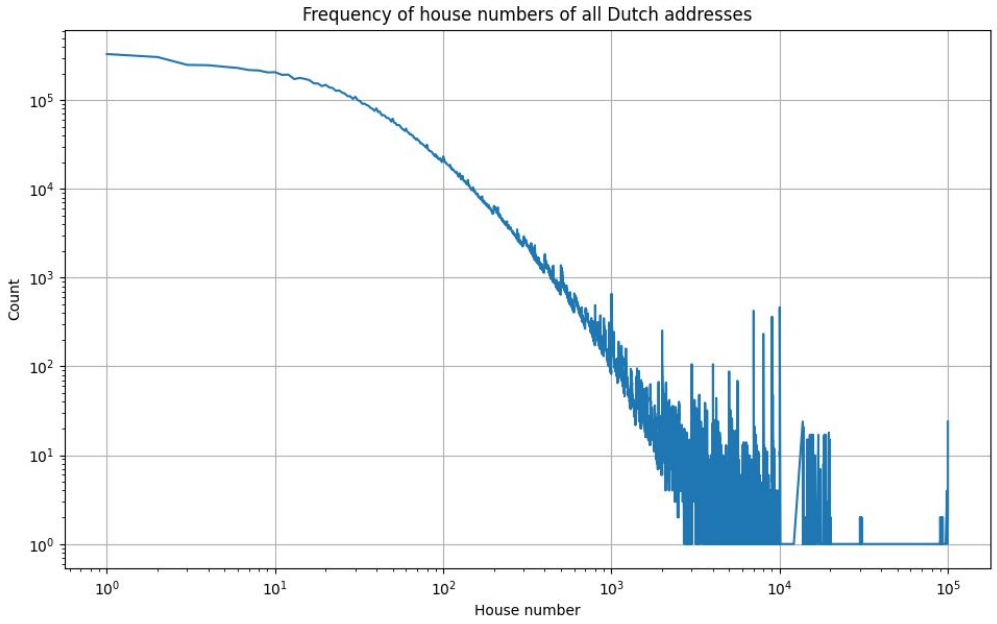


“Shelly Plug S Gen3”, calibrated

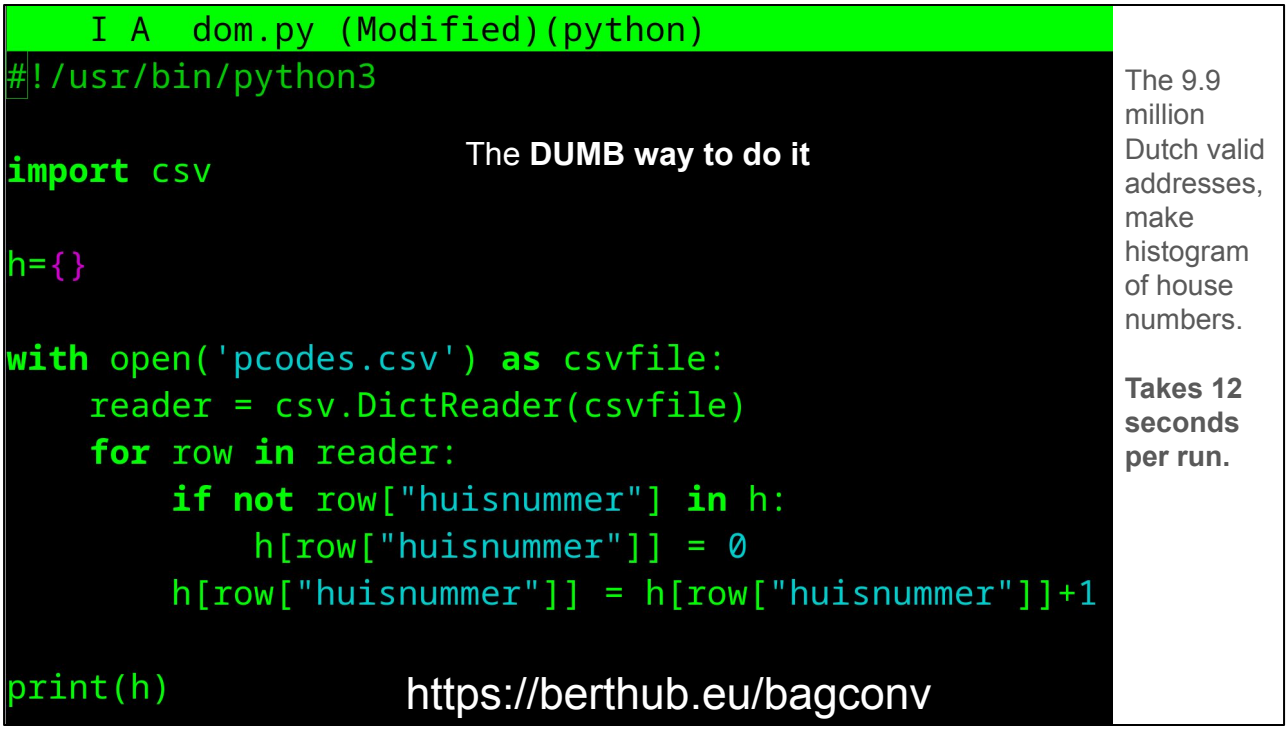
My Xeon Lenovo Desktop.


Histogram of power usage
0.25
0.20
0.15
0.10
0.05
0.00
Density
90
100
110
120
130
Watt
83W even if computer does absolutely nothing. **Important**
One core 100% busy

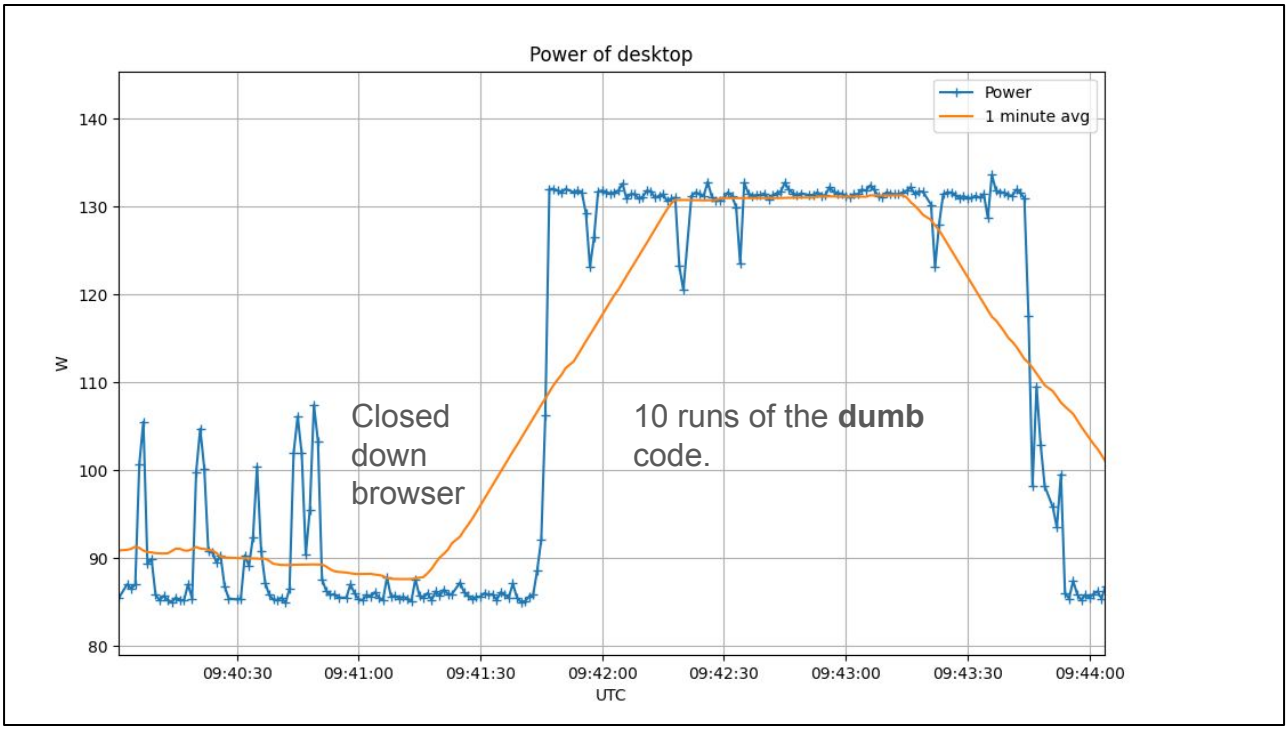
https://berthub.eu/bagconv



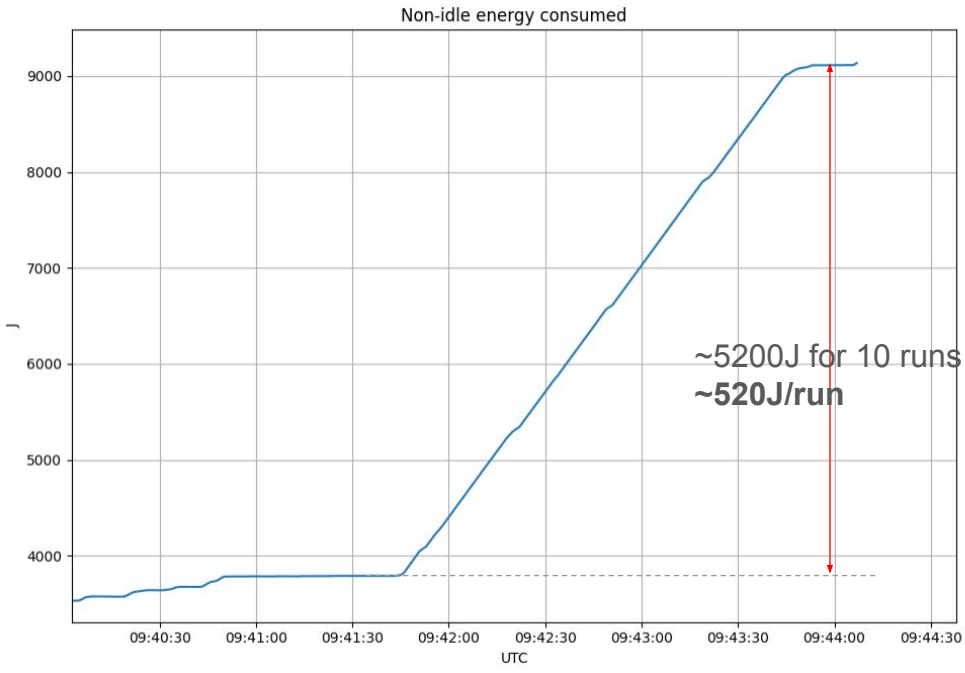
So here's a computational example. Plot for all 9.9 million Dutch addresses how often each house number appears. Note the fun spikes on somewhat round numbers, like 1000.



https://berthub.eu/bagconv - really dumb way to do it. I don't really know Python, which is why it ends up like this.



Note how simply having a browser open with some tabs causes 20W spikes

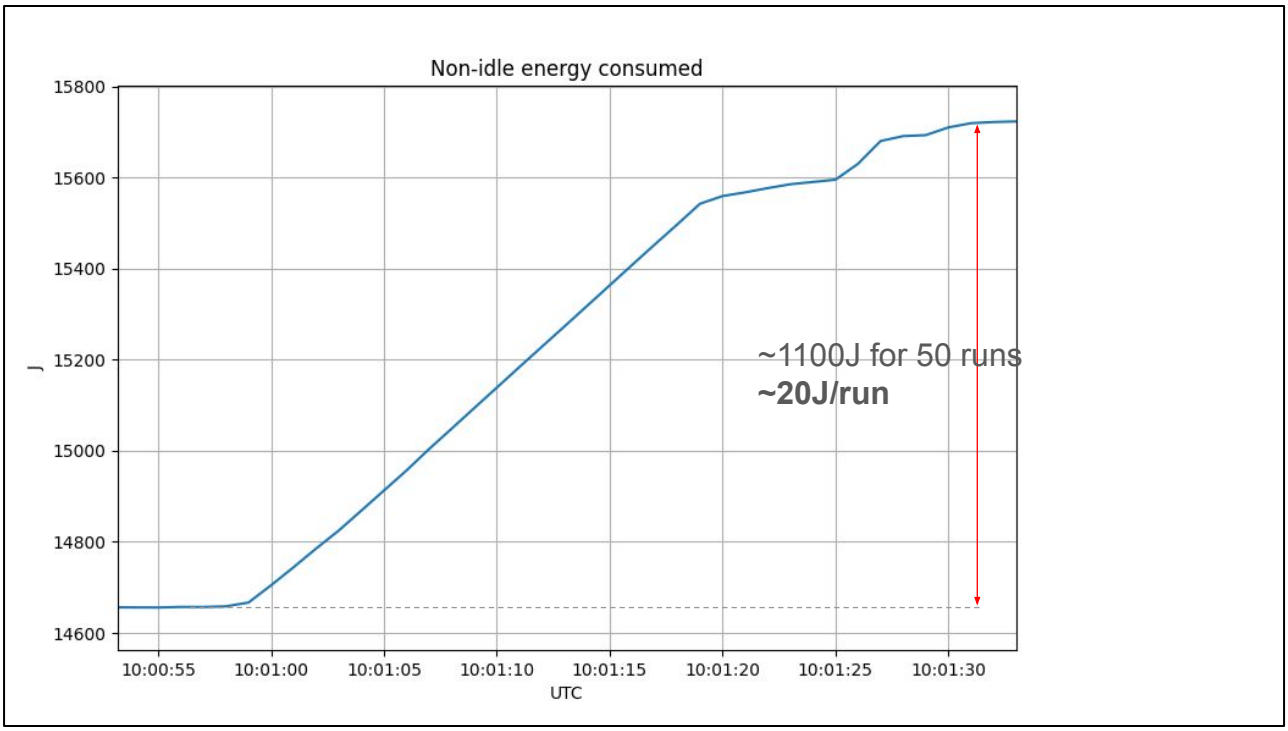


Integrated power
= Energy (J)

Category 2, normal code

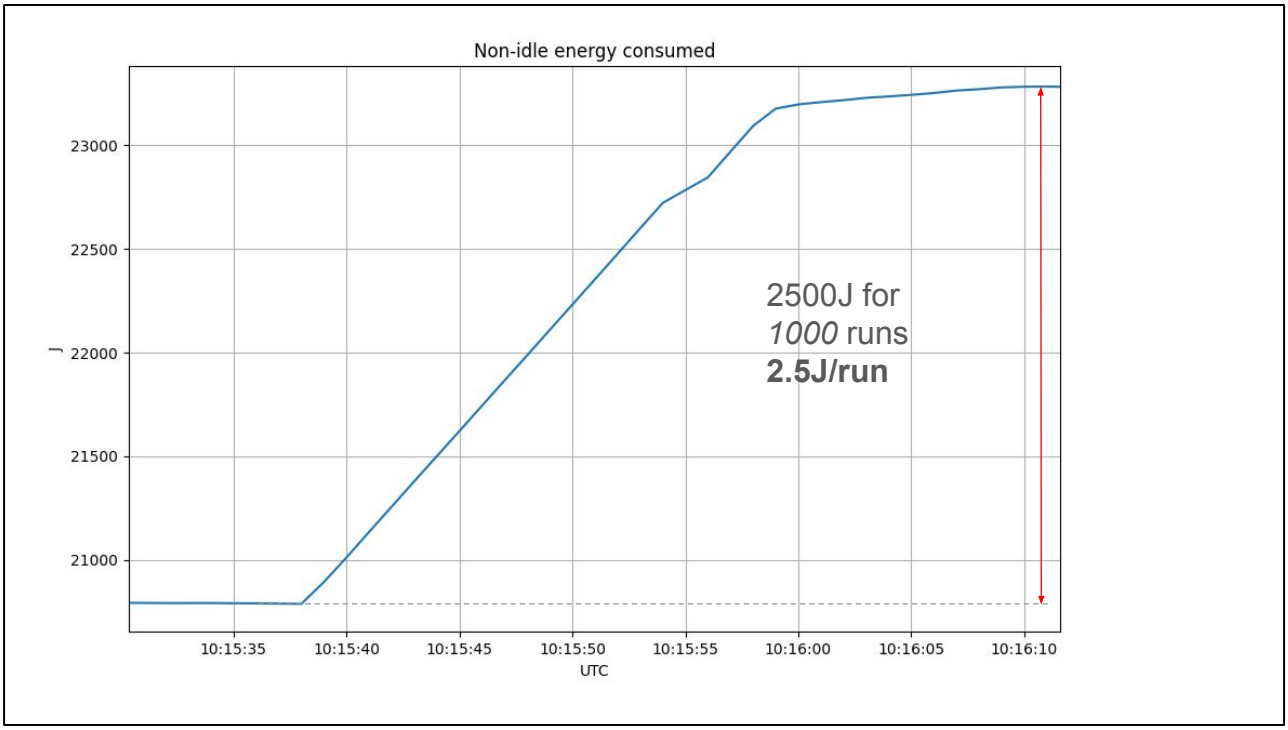
(or should be normal)

```
for a in {1..50}
do
    echo 'select huisnummer,count(1) from nums group by 1' |
    sqlite3 bag.sqlite
done
```


Non-idle energy consumed
15800
15600
15400
15200
15000
14800
14600
J
10:00:55
10:01:00
10:01:05
10:01:10
10:01:15
10:01:20
10:01:25
10:01:30
UTC
~1100J for 50 runs
~20J/run

Using superior technology & some thinking

```
for a in {1..1000}
do
    echo "select huisnummer,count(1) from bag group by 1;"
done | duckdb test.ddb
```


Non-idle energy consumed
23000
22500
22000
21500
21000
J
10:15:35
10:15:40
10:15:45
10:15:50
10:15:55
10:16:00
10:16:05
10:16:10
UTC
2500J for
1000 runs
2.5J/run

520J dumb -> **20J** normal -> **2.5J** by thinking more & superior technology

User also happier, from 12 seconds, to 0.5 seconds to dozens of milliseconds!

Factor >200 less energy, ~1000 times faster

What's not to like?

Flash appliance high-level specifications

Option	Vendors
Chassis	Supermicro
Motherboard	Tyan
Processor	AMD
Memory	Micron
Solid State Drive	SanDisk
Network Controller	Nvidia (Mellanox)
Power draw operational (peak)	~400W
Power Supply Unit	Redundant Hot Swap AC/DC
Operational throughput	~190 Gbps
Raw storage capacity	24 TB

Netflix Open Connect Flash Appliance:

Very rough numbers, 190 Gbps = ~45000 streams
At 400W that means <10 mW per stream.

<10 mW

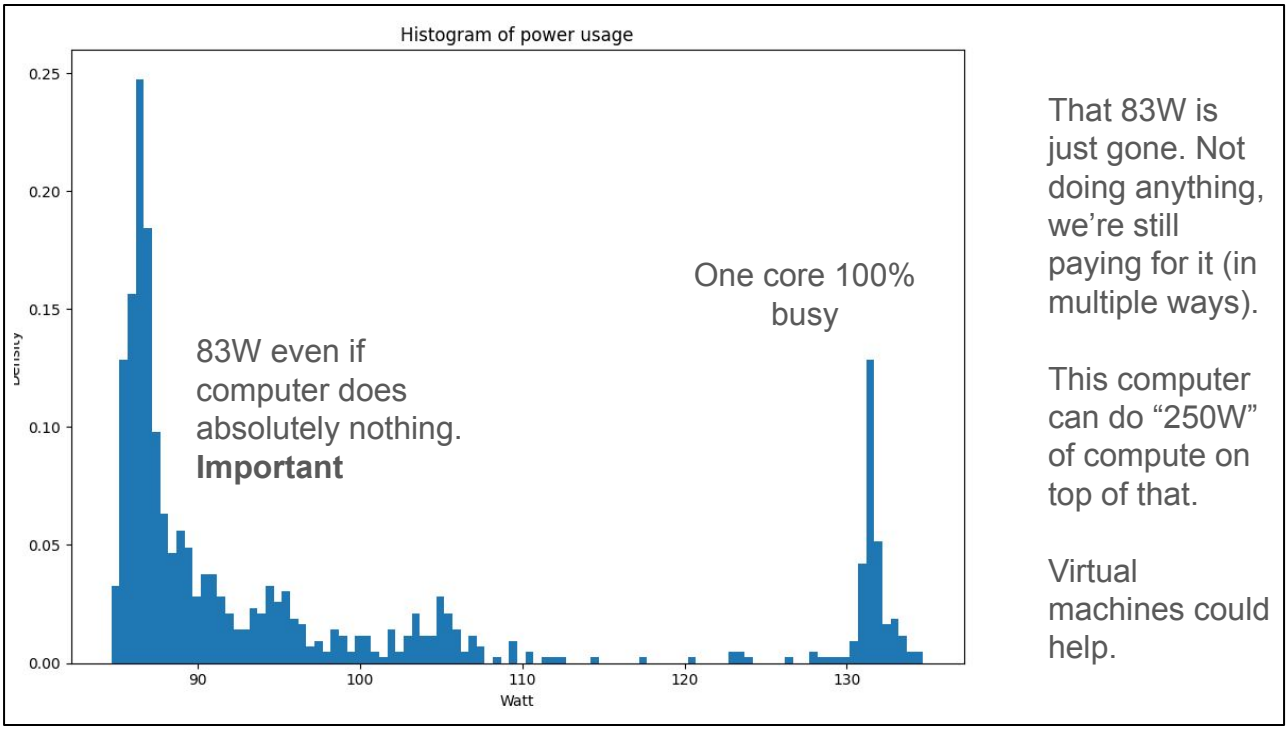
https://openconnect.netflix.com/en/appliances - Netflix invested HEAVILY to make this happen. But with so many customers, it is worth spending almost any kind of money on making this energy efficient & dense. They still need thousands of boxes like this by the way!

Doesn’t seem so weird now anymore…

If we could all “do a Netflix” we could turn the DC into the data shed…

Non-code things

briefly

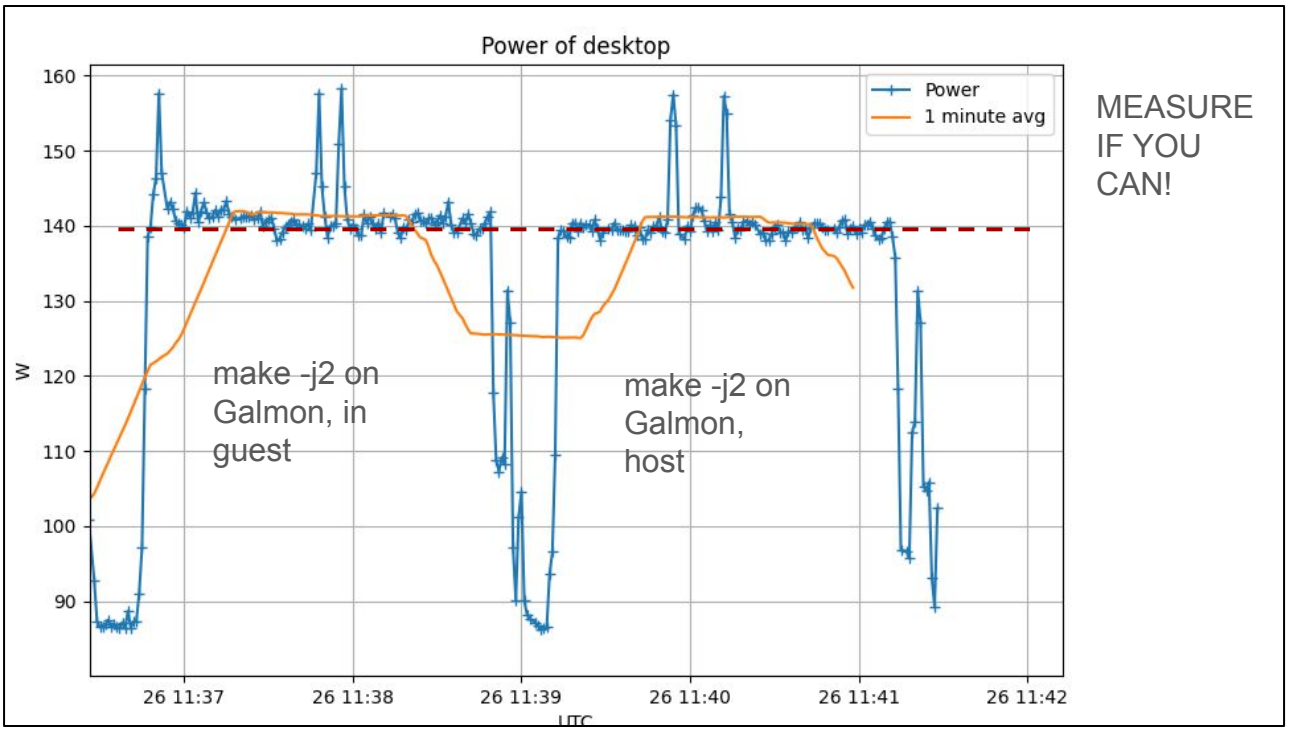


That 83W is just gone. Not doing anything, we're still paying for it (in multiple ways).

This computer can do "250W" of compute on top of that.

Virtual machines could help.

My desktop computer always uses 83W. Always.



In the best case a virtual machine imposes no measurable overhead. Here compilation of the same software project on host and guest, the energy use is not statistically different. This is the best case though.

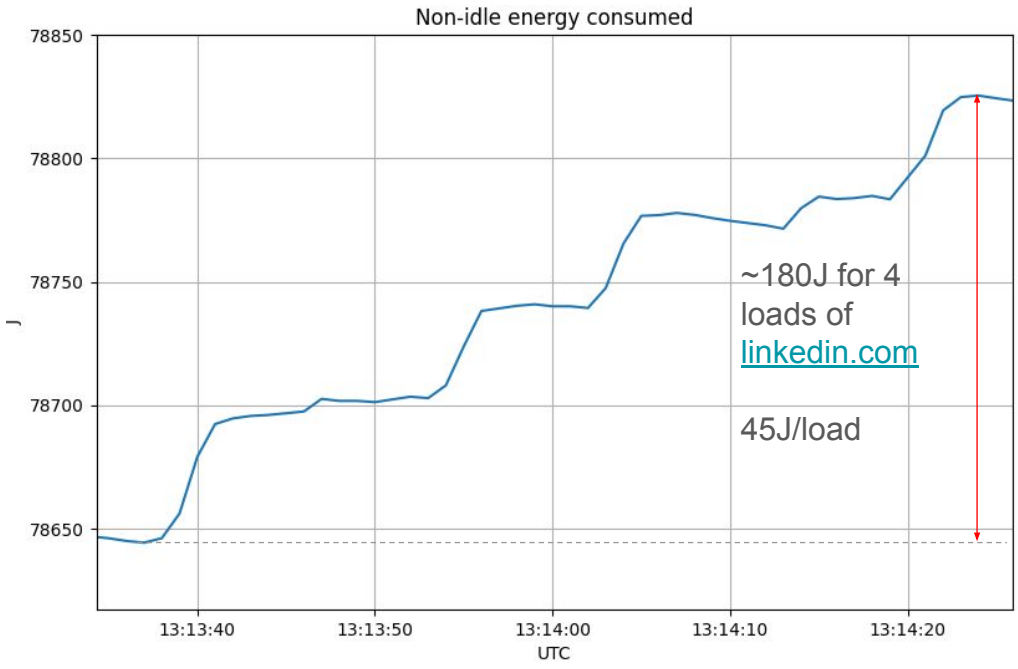
HOWEVER

That platform is not free..

This is not necessarily always so. I've been in multiple projects where the VM platform supposedly had no overhead. Yet somehow during the migration we went from 6 modest servers to 1000 virtual cores. And even when you point this out the platform owner/operator will claim there is no overhead because the vendor said so. Always measure. If performance is less than on similar bare metal, someone is burning energy

But what about the client side? Desktops, tablets, phones go through less power

But wow there are BILLIONS of these things!



Linkedin is a well known sluggish site.

Is its client side energy use significant on the desktop?

Bit of a noisy plot, which is because this is about small amounts of energy. It takes 45J on my desktop to load linkedin, more or less.

“Welcome to LinkedIn, the world's largest professional network with more than **1 billion** members”

But, they have a BILLION users! Might that add up to a lot of client side power use?

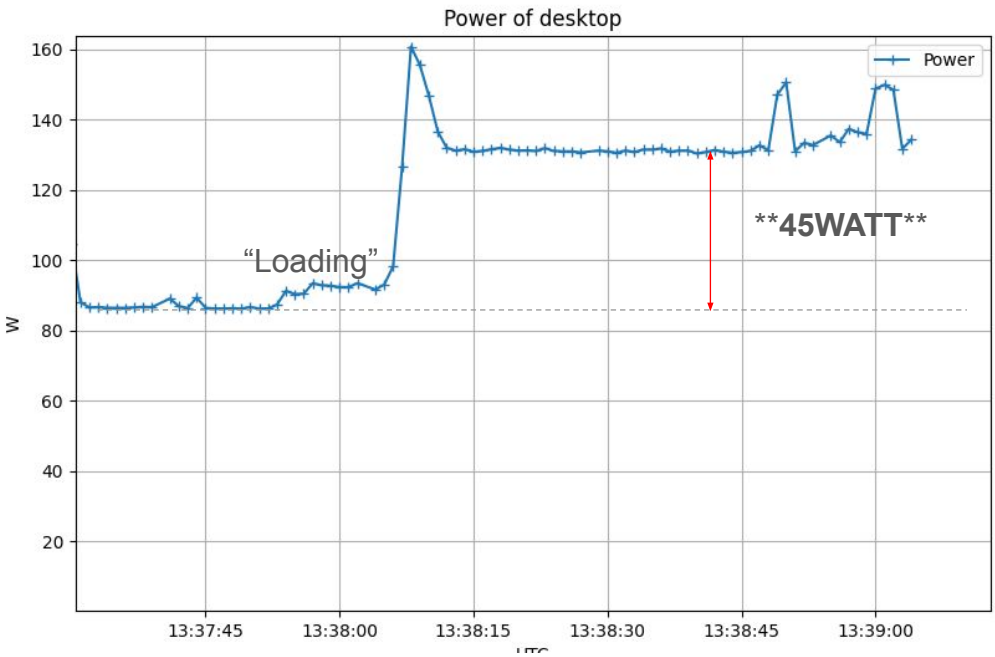
Let’s say 20% actually use it, and when they do they click 5 times/day.

This ends up as as **half a megawatt** of power worldwide, client side

(not that bad, but still somewhat sad.
Ponder the global energy usage by React!)

But wait…

It does not appear to add up to a lot of additional energy usage, but perhaps I have the numbers wrong. The numbers for “all React sites” however might be bigger.



open.spotify.com

"more than 678 million users, including 268 million subscribers"

👀

So this is https://open.spotify.com on my desktop. It uses a few seconds to load in the first place and then it launches some kind of worker thread that CONTINUOUSLY uses 45W of power (!!!!). With hundreds of millions of users, it might be worth looking into this one day…

“Powering your music”

Doesn’t anyone measure this?! Hundreds of megawatts on the table here!

I urge everyone else with long running web apps to also measure this

The Cloud Problem

“Our birthday calendar is consuming 1000 cores”

If you run your own servers, your failure mode is finding out your software is not efficient enough to run on the amount of servers you have. This prompts reengineering because otherwise things plain just don’t work. In the cloud however you can just scale until enough CPUs have been recruited. This might even be regarded as acceptable by management. However, meanwhile you might be using 1000s of cores and boiling the ocean.

What to do?

Some suggestions

Anything where simple things are sluggish is **burning energy at an irresponsible scale.**

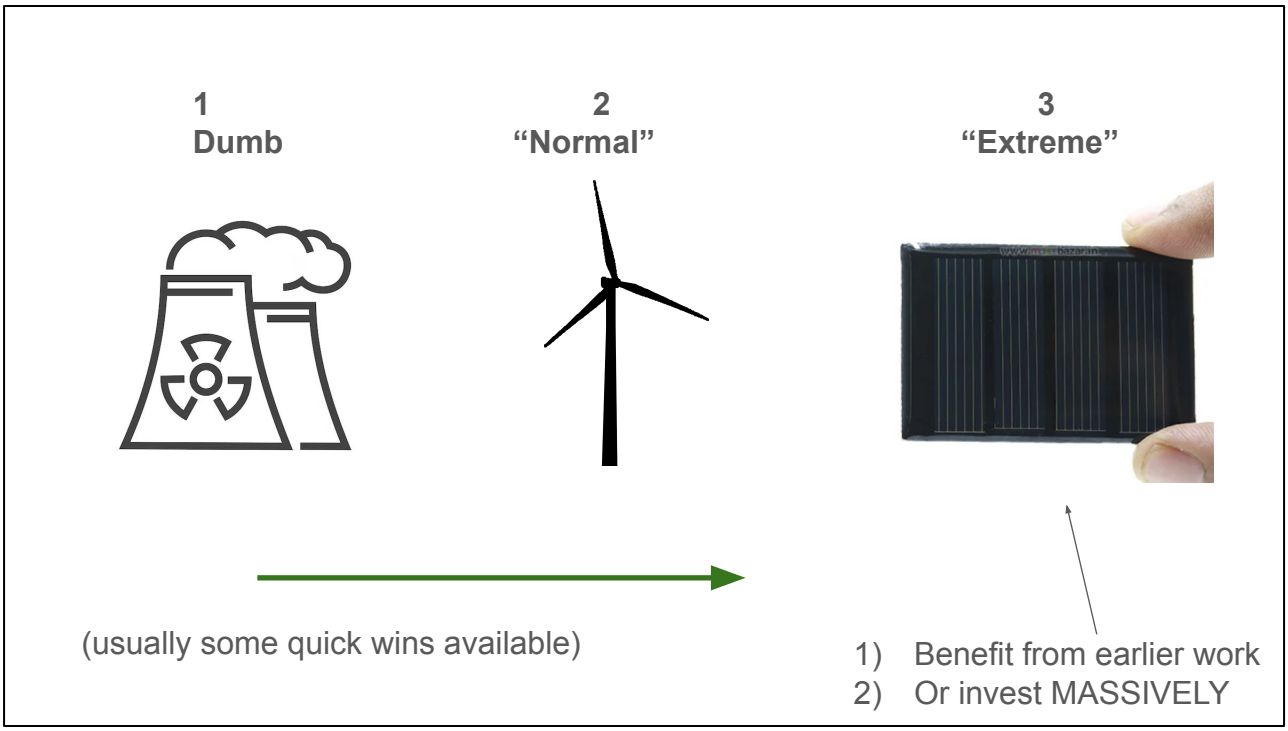
Get it SNAPPY <u>early</u>

I can’t stress this enough. Early sluggishness never goes away and assures you’ll be burning the megawatthours later in your project when it is live. Distrust anyone who says this is just a development phase thing. If it doesn’t snap at the beginning, it never will.

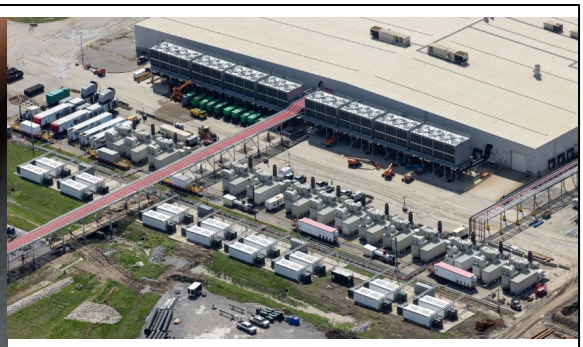
Make something where users have your thing open all day long?

Measure client-side energy use on popular platforms.

Please



The three development modes, where a lot of software is stuck in phase 1. There is usually sufficient low hanging fruit of stuff you can fix so it runs at “normal” efficiency. This also tends to make things _simpler_, so I can recommend moving stuff from ‘1’ to ‘2’ a lot.
Moving from ‘normal’ to ‘ludicrous efficiency’ is tremendously hard work. Best left for experts. Sometimes you can luck out and use someone else’s great work (like DuckDB). But think REAL hard before you start to care about the stepping level of CPUs.



By all means use AI if you find a good use case for it. But if you succumb to the current trend of stuffing AI into everything, you are going to roast the planet. On the right the xAI data center powered by all kinds of illegal generators outside.

Huge cloud bills = Huge energy use

It is a decent proxy.
Maybe the euros are acceptable, but the CO_2 is not

Now, modern clouds might give you some kind of CO2 emission report for your usage (if you ask for it), and this could be useful. If you can't get such reporting, or don't trust it, the sheer money value of your bill is a decent proxy. Save money there and you are probably saving emissions too.

25 euro (company) gift idea! Wifi/bluetooth enabled power plug that accurately measures power.

In one day this helped me find:

- 25 Watts wasted on open.spotify.com
- My main computer uses 8W even when it is “off”
- Even Spotify app uses 5W of power, I use my phone now

I just love this thing. Shelly makes some great stuff. From Bulgaria with Love.

Good luck! “We” have as much of an impact as the airplane business

Time to green up our software!

Save the world, write more efficient code!

Bert Hubert
bert@hubertnet.nl

https://berthub.eu/joc