Energy measurements in HPC Architectures

[CMP223] Computer Systems Performance Analysis
[INF01146] Análise de Desempenho

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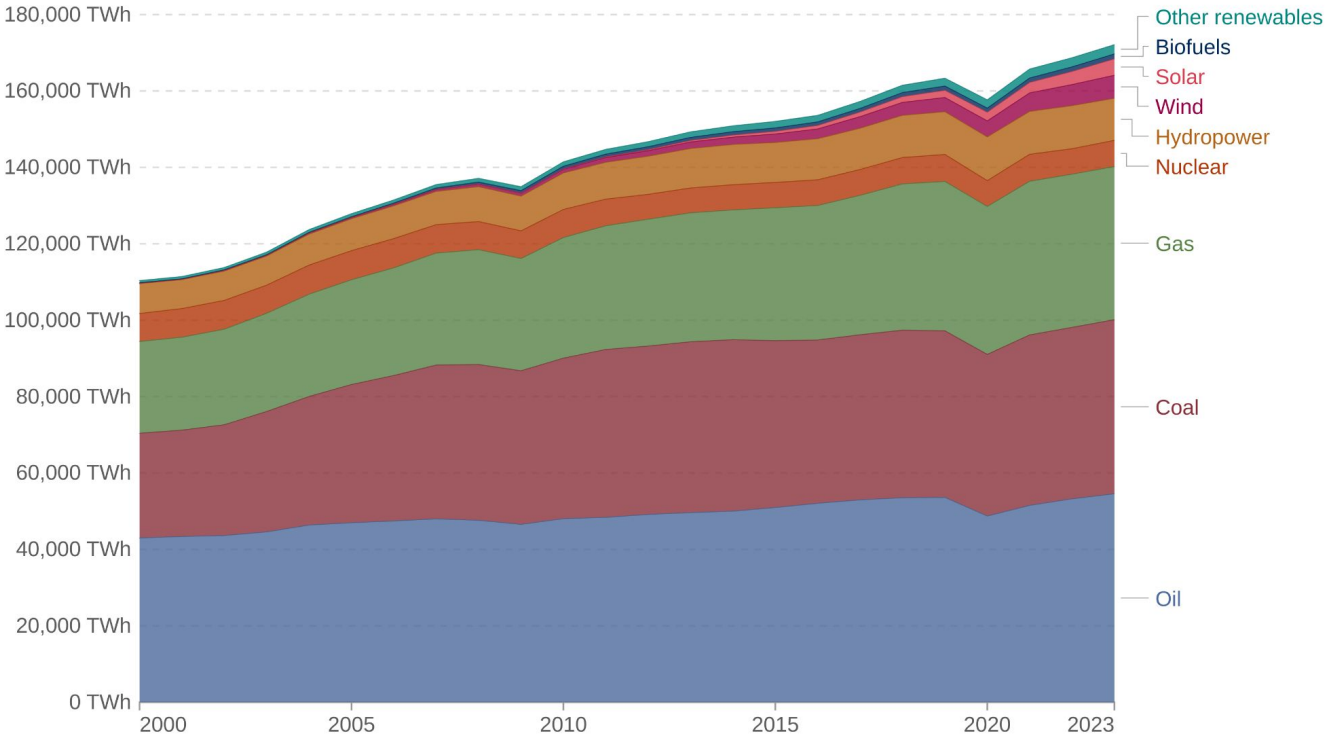
Setembro/25

Agenda

- Context & Motivation
- Computational Object
- Application, Instrumentation, Metrics
- Measurement Examples
- Next Steps

Energy consumption by source, World

Measured in terms of primary energy using the substitution method.



Data source: Energy Institute - Statistical Review of World Energy (2024)

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Note: "Other renewables" include geothermal, biomass, and waste energy.

[energy mix]

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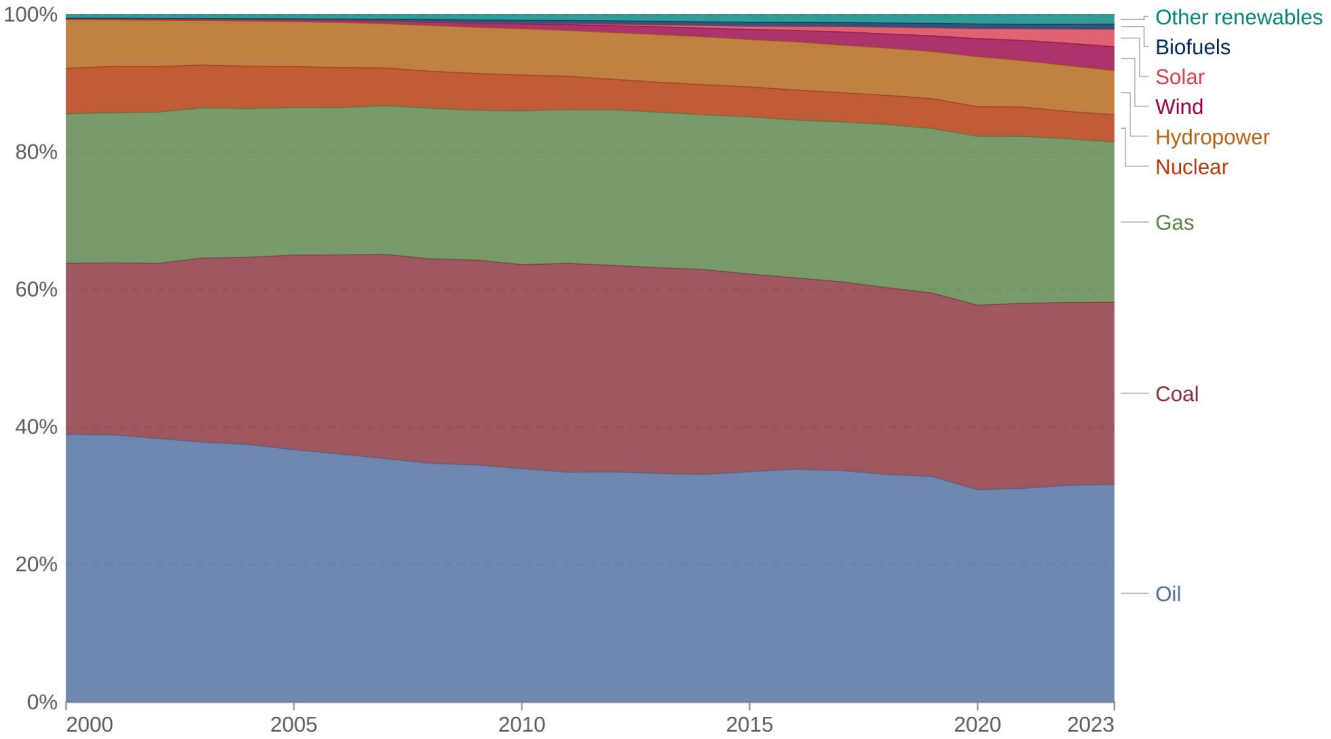

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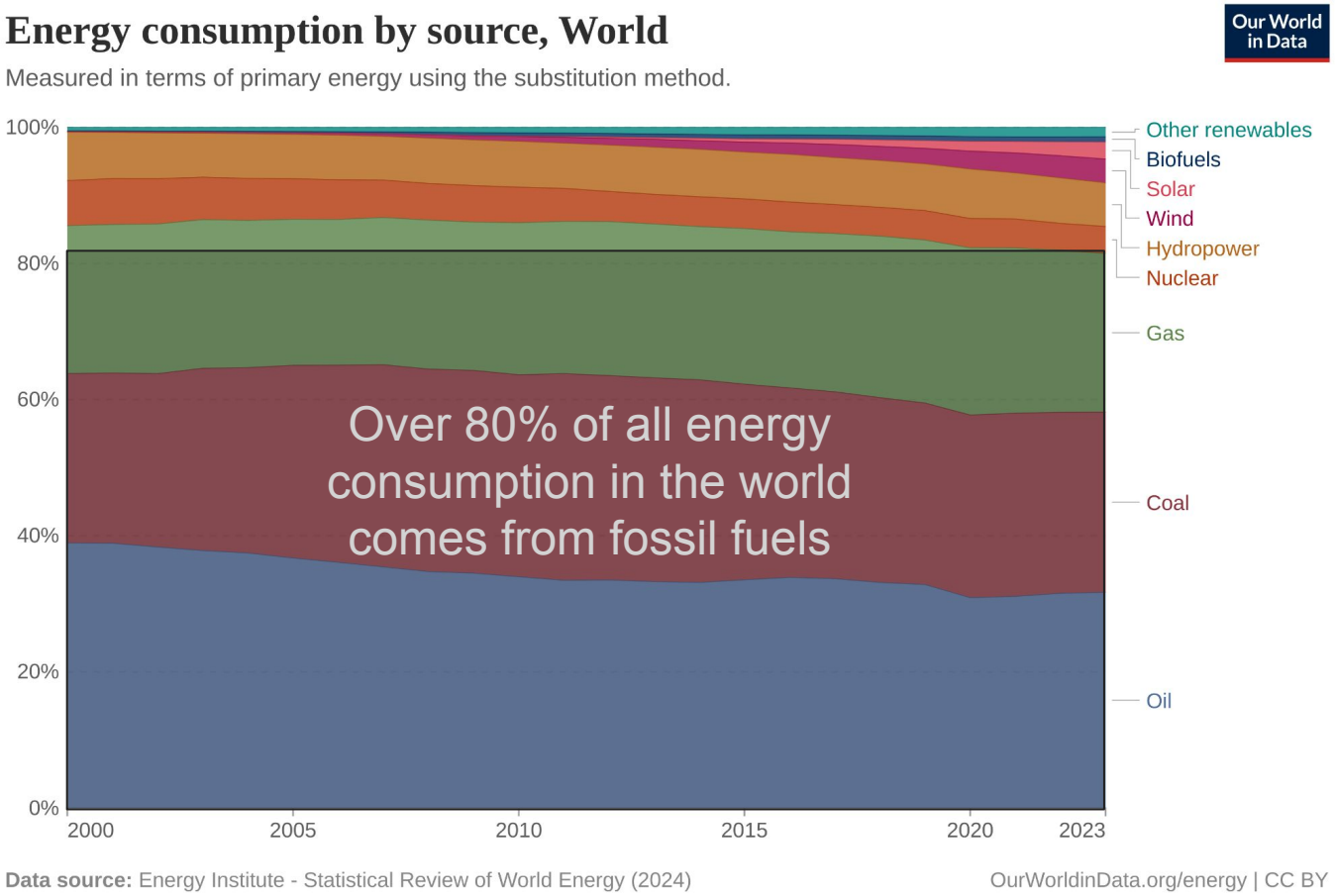
[energy mix]


Energy consumption by source, World
Measured in terms of primary energy using the substitution method.
Our World in Data
100%
80%
60%
40%
20%
0%
2000
2005
2010
2015
2020
2023
Other renewables
Biofuels
Solar
Wind
Hydropower
Nuclear
Gas
Coal
Oil
Over 80% of all energy consumption in the world comes from fossil fuels
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[energy mix]

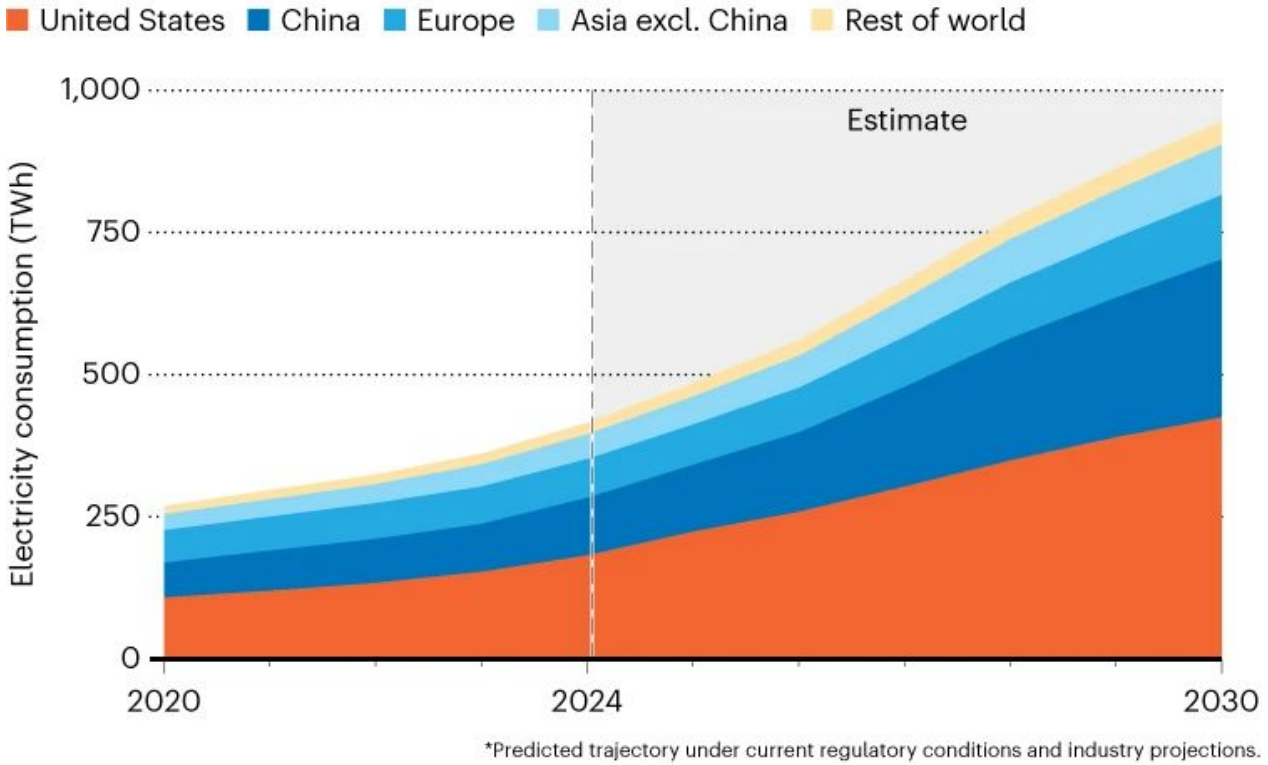
Energy consumption in data-centres

- Data-centres in 2024 consumed 415 TWh, about 1.5% off all energy consumed in the world
- This number might reach 945 TWh in 2030

[nature]

DATA-CENTRE ENERGY GROWTH

China and the United States are predicted to account for nearly 80% of the global growth in electricity consumption by data centres up to 2030*.



[nature]

DATA-CENTRE ENERGY GROWTH

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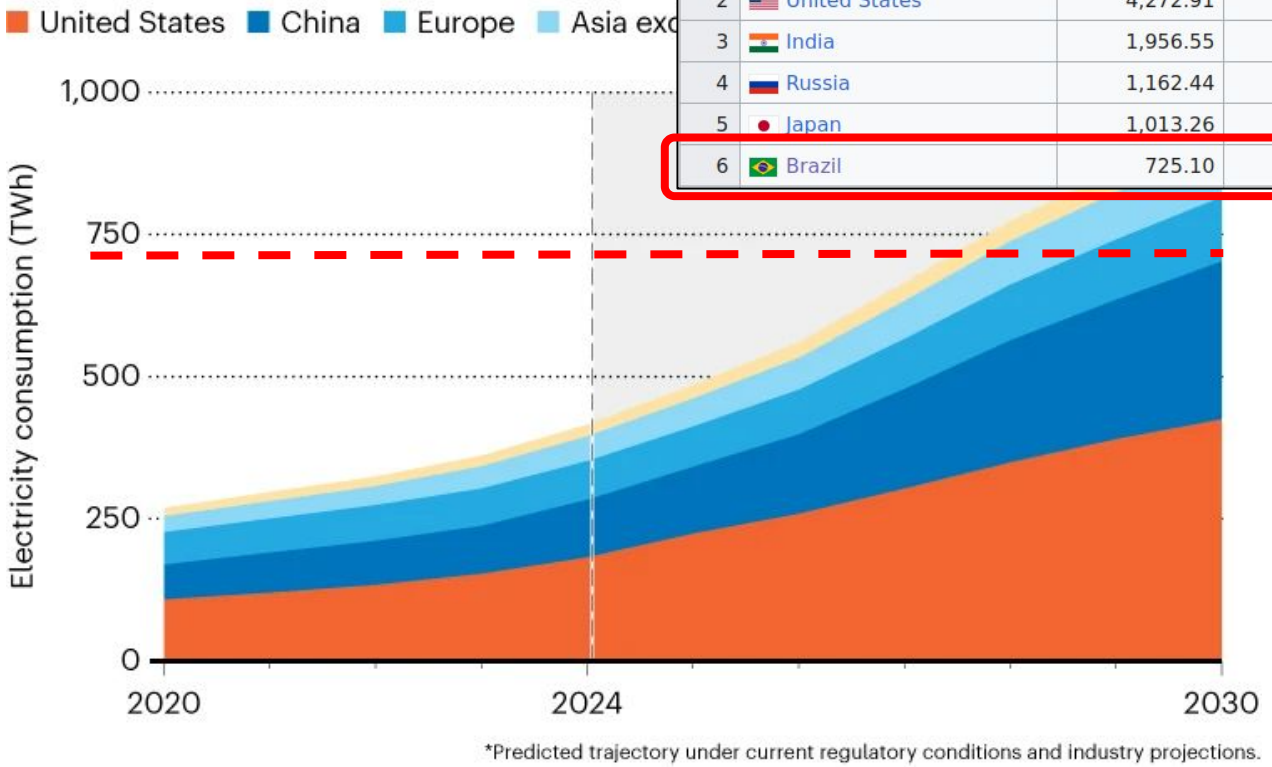


	Location	Consumption (TWh)	Per capita (MWh)	Year
	World	29,664.60	3.67	2023
1	China	9,443.07	6.64	2023
2	United States	4,272.91	12.44	2023
3	India	1,956.55	1.36	2023
4	Russia	1,162.44	7.99	2023
5	Japan	1,013.26	8.15	2023
6	Brazil	725.10	3.43	2023

[nature | wikipedia]

Energy measurements in HPC architectures

- It is increasingly critical to have energy monitoring tools in data-centres
- Optimizing energy performance depends on monitoring
- Allows power management initiatives

Energy measurements in HPC architectures

- Perform energy measurements on a cluster (computational object)
- Utilize an application/program to stress the machines
  - LU factorization (StarPU + Chameleon)
  - Stress package (lacks GPU support)

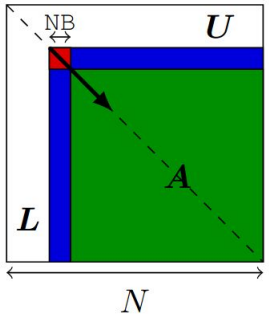
Partition	CPU	RAM	Accelerator	Disk	Motherboard
poti[1,2,3,4,5]	Intel(R) Core(TM) i7-14700KF, 3.40 GHz, 28 threads, 20 cores	96 GB DDR5	NVIDIA GeForce RTX 4070	1.7 TB SSD, 119.2 GB NVME	Gigabyte Technology Co., Ltd. Z790 UD AX

LU Factorization

$$
\begin{aligned}
Ax &= b \\
(LU)\,x &= b \\
L\,(Ux) &= b
\end{aligned}
$$

$$Ly = b \quad \text{e} \quad Ux = y$$

```
for (k = 0; k < N; k++)
  DGTRF-NOPIV(RW, A[k][k]);
  for (m = k+1; m < N; m++)
    DTRSM(RW, A[m][k], R, A[k][k]);
    DTRSM(RW, A[k][m], R, A[k][k]);
  for (n = k+1; n < N; n++) // Update
    for (m = k+1; m < N; m++)
      DGEMM(RW, A[m][n], R, A[m][k],
                        R, A[k][n]);
```

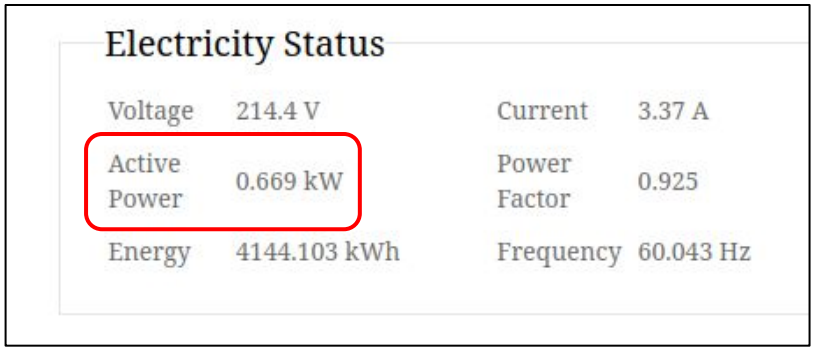


Instrumentation: Network-manageable Rack Power Distribution Unit (PDU)

- The PDUs (the power outlet) used by the nodes are connected to the internal network of the cluster
  - Access using SSH
  - Answers to SNMP requests
- Provide energy measurements

Metrics: Active Power vs. Energy

- Active Power: electrical energy consumed in a circuit, in watts (W ou kW)
- “the energy actually used in load”
- P= V × I × cosϕ



[Schneider Electric]

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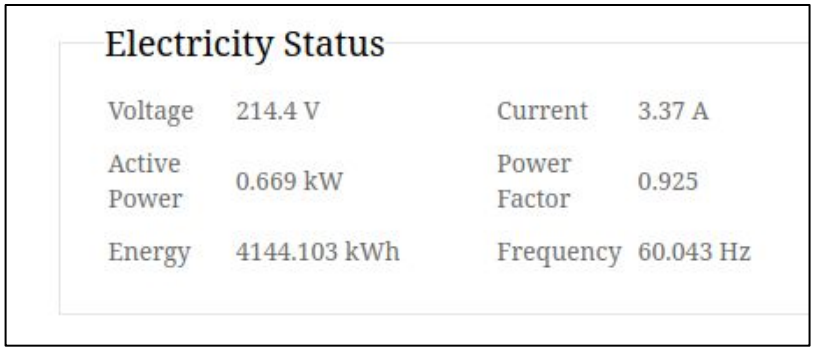

voltage root mean square*

*** the square root of the mean square of a set of values**

(o valor eficaz é a raiz quadrada da média aritmética dos quadrados dos valores)

[Schneider Electric | wikipedia 2]

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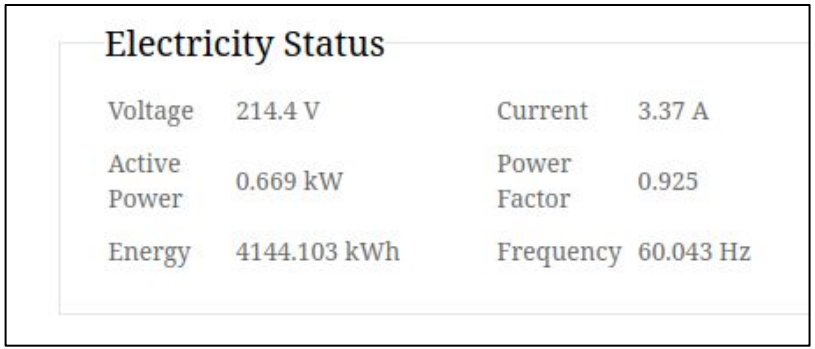

current root mean square*

*** the square root of the mean square of a set of values**

(o valor eficaz é a raiz quadrada da média aritmética dos quadrados dos valores)

[Schneider Electric | wikipedia 2]

Metrics: Active Power vs. Energy

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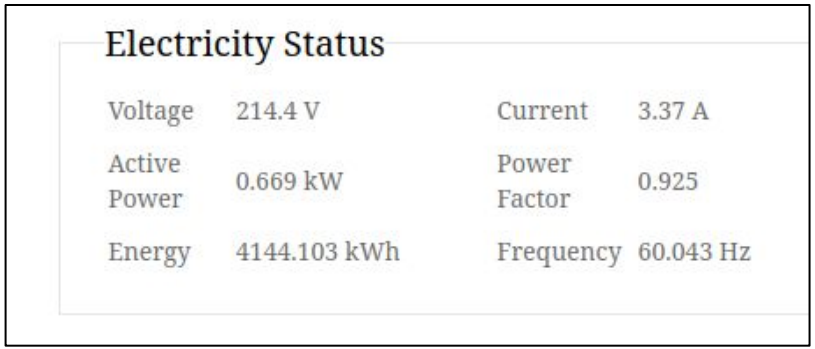
power factor



[Schneider Electric]

Metrics: script making SNMP requests

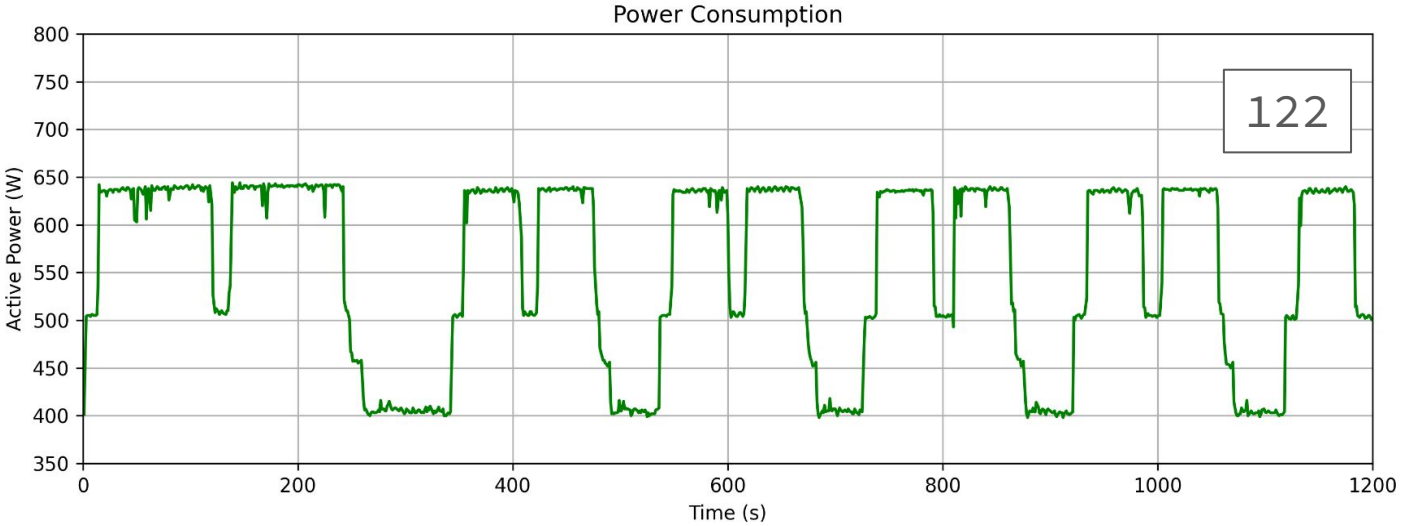
```
while $SECONDS -lt $run_time
    echo `date`
    snmpget etc $IP PowerNet-MIB::ePDUDeviceStatusEnergy.1
    snmpget etc $IP PowerNet-MIB::ePDUDeviceStatusActivePower.1
    sleep $sleep
done
```

time (YYYY-MM-DD HH:MM:SS)
energy (kWh, cumulative)
active power (kW)

Measurement example I

tupi[**5**-6] multinode_pcept_train
tupi**3** i9_parquet_analysis_fix

OR

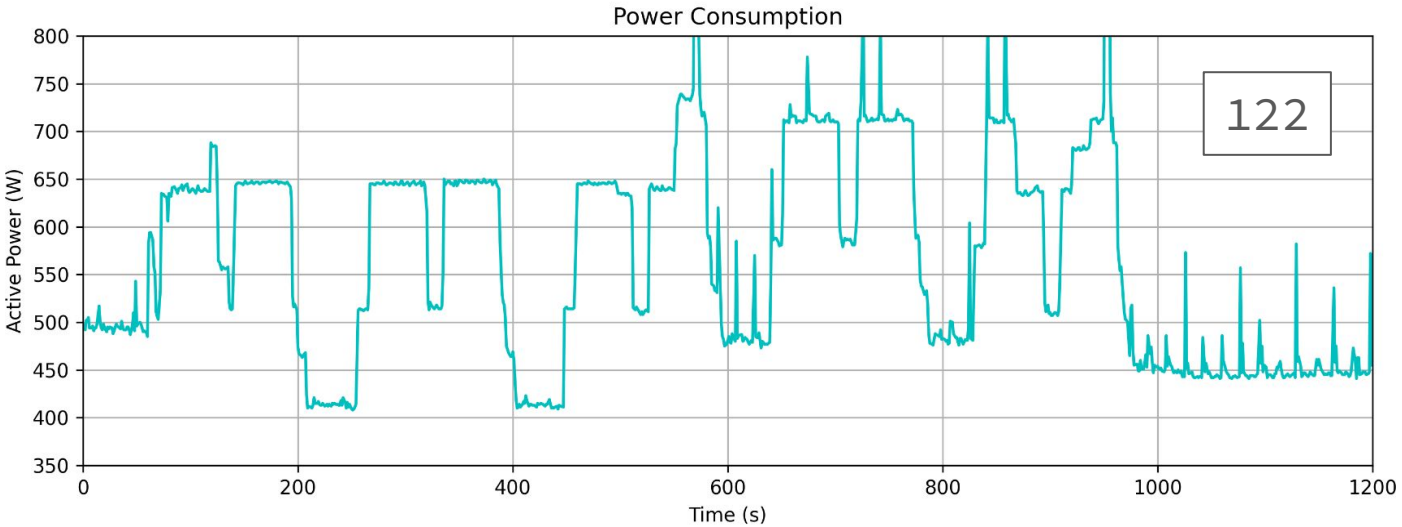


Measurement example I

tupi[**5**-6] multinode_pcept_train
tupi**3** i9_parquet_analysis_fix

AND

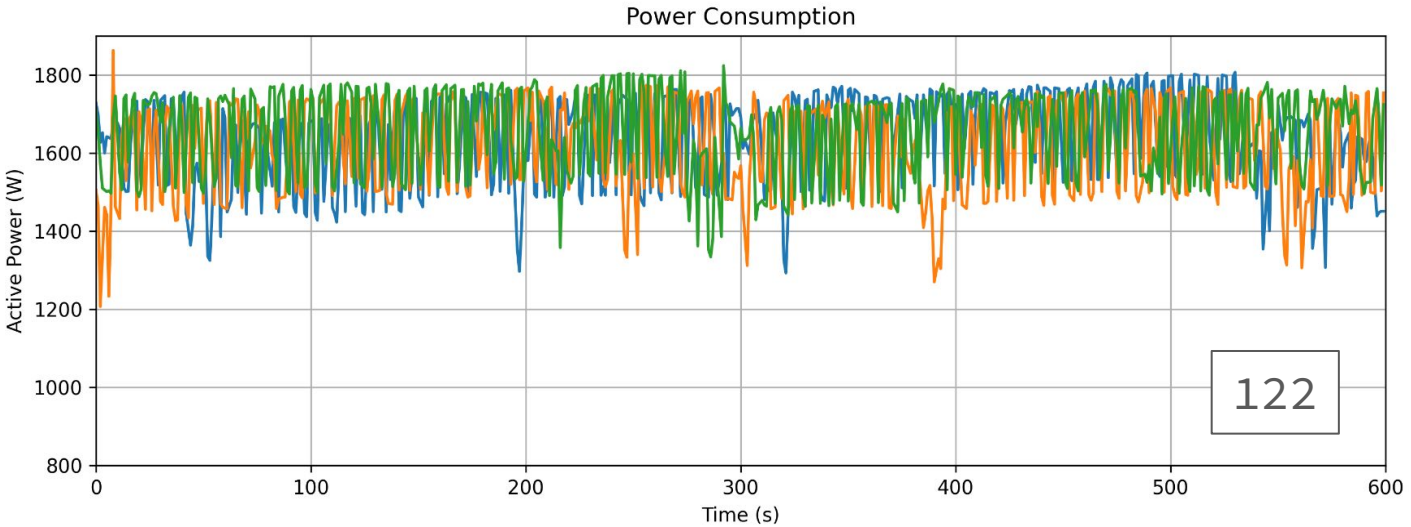
we need to allocate all the machines in the same PDU so other users' experiments don't show up in our measurements



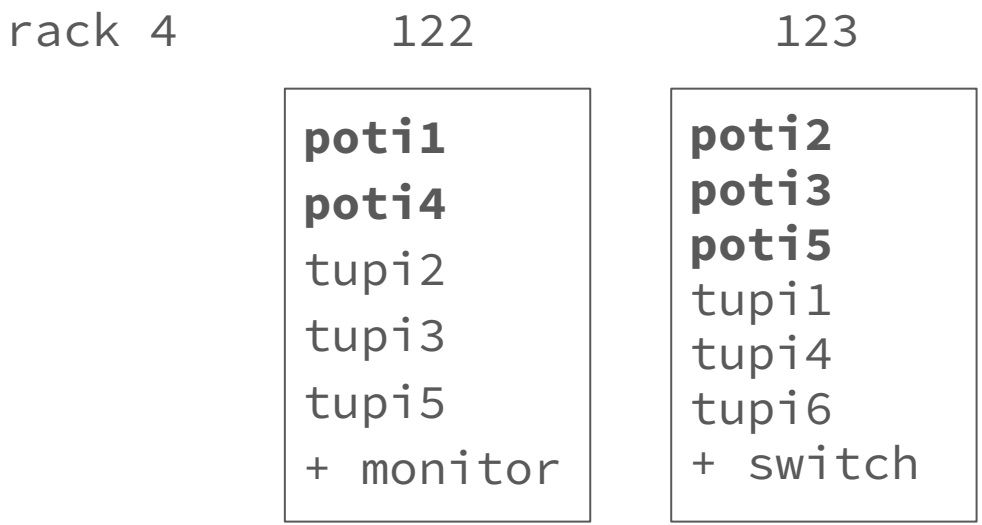
Measurement example II

LLM inference (Qwen3-4B), 300 planning tasks in two batches with long-context answers (32k tokens)

tupi[**2,3**,6]	progressive
poti[**1**,2,3,**4**,5]	e2e-plan



Problem: electric topology



Next steps

- Re-work the electrical topology of the cluster
  - Have all the nodes of a partition in the same PDU
  - Isolate the network switches

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- Re-work the electrical topology of the cluster
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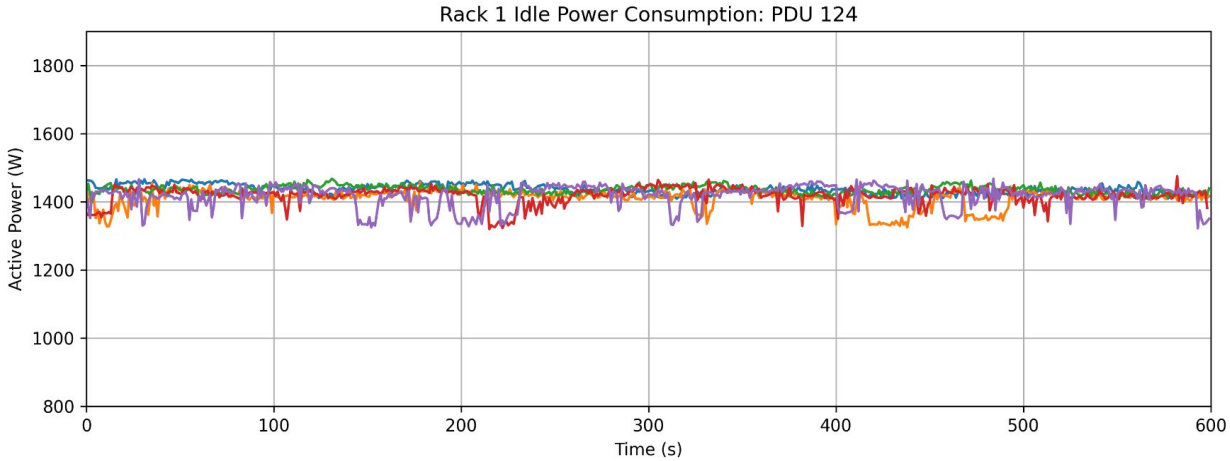
```
tsubasa
hype[1-5]
knl[1-4]
bali2
beagle
turing
switch 1GB
switch infiniband
```



Next steps

- Re-work the electrical topology of the cluster
  - Have all the nodes of a partition in the same PDU
  - Isolate the network switches
- Plan the experiments (notebook, git)
- Execute, adjust, execute again

Thank you!! ✨🧑‍🎓🧠💖🔋

Any questions?

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luntek22@student.hh.se

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