

# How can we quantify ... the "green-ness" of code?



# Who am I

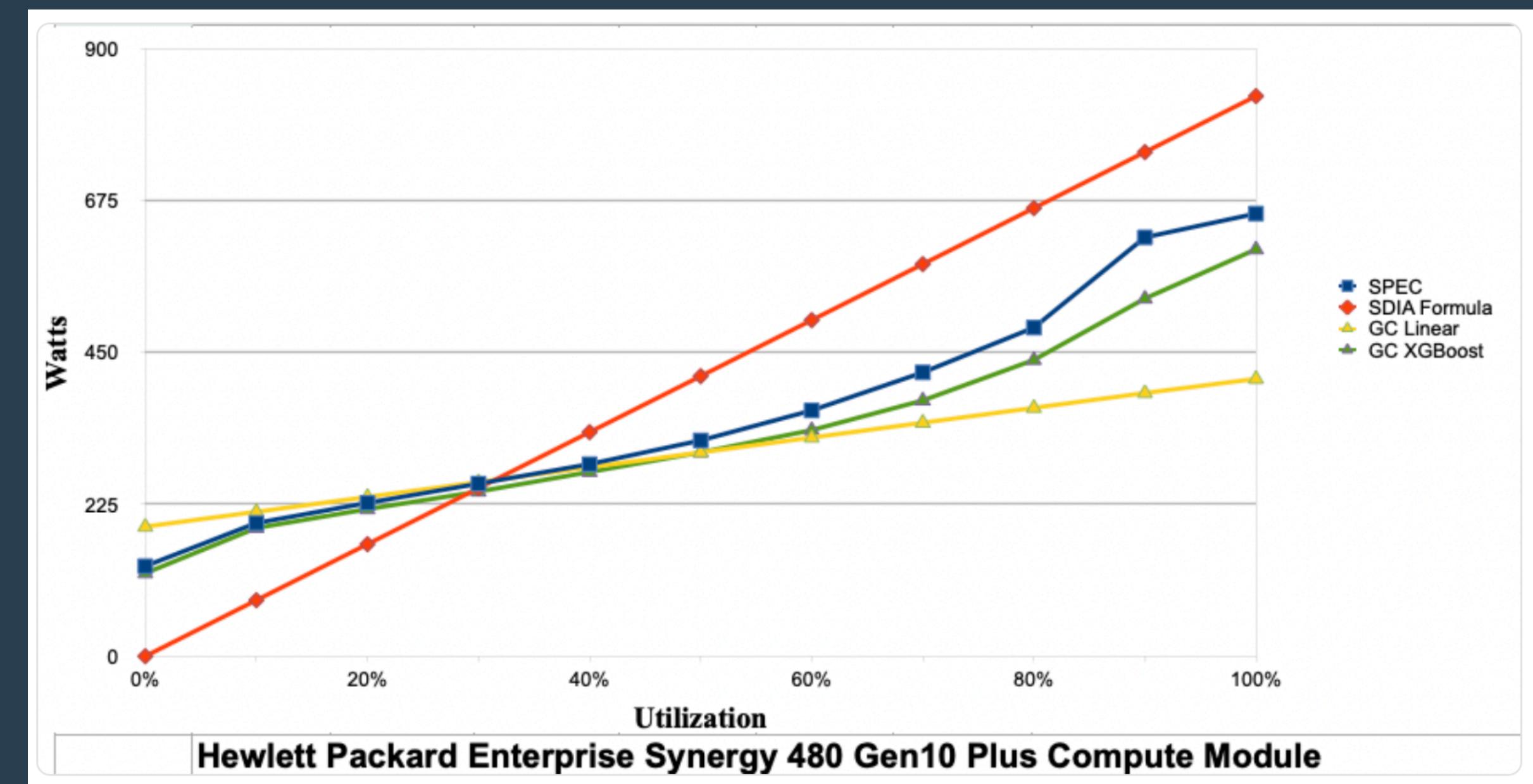
Arne Tarara / Green Coding Solutions GmbH

- Electrical Engineer by training
- Software-Dev 16+ years - CTO / CEO / Developer
- Founder and entrepreneur of GCS with 2 software company track record
- Current: **Green Coding Solutions GmbH**
  - R&D for sustainable software solutions



# Cloud Energy Estimation for Cloud and VMs

- The setup of the model is based on a research paper from Interact DC and the University of East London
- 90%+ Accuracy in/out-of sample
- Near 0% overhead
  - XGBoost + POSIX stream implementation



# Eco-CI

## Estimation in CI / CD Pipelines

- Integration into Github / Gitlab directly
- Export to central dashboard
- Statistical comparisons over time
- PR-triggered measurements



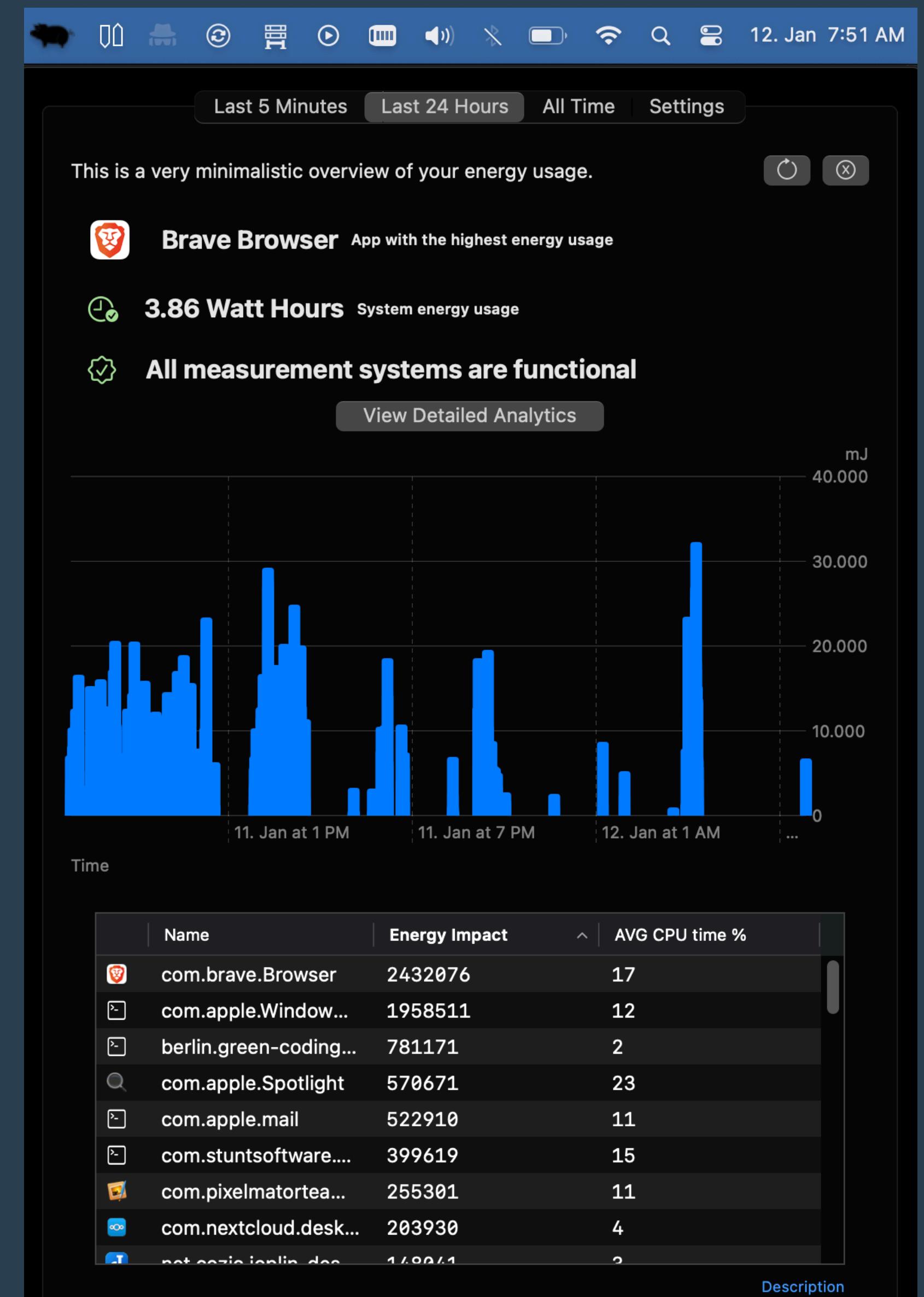
Example for Github PRs: <https://github.com/green-coding-berlin/green-metrics-tool/pull/653>

Example for Django Measurements over time: <https://metrics.green-coding.io/ci.html?repo=green-coding-berlin/django&branch=main&workflow=60545070>

# Power Hog

## Development Cost measurement

- Direct measurement of energy on the developer machine
- Granularity per process
- Aggregation per project
- API and drill-down option in dashboard
- Local database for quick analyses

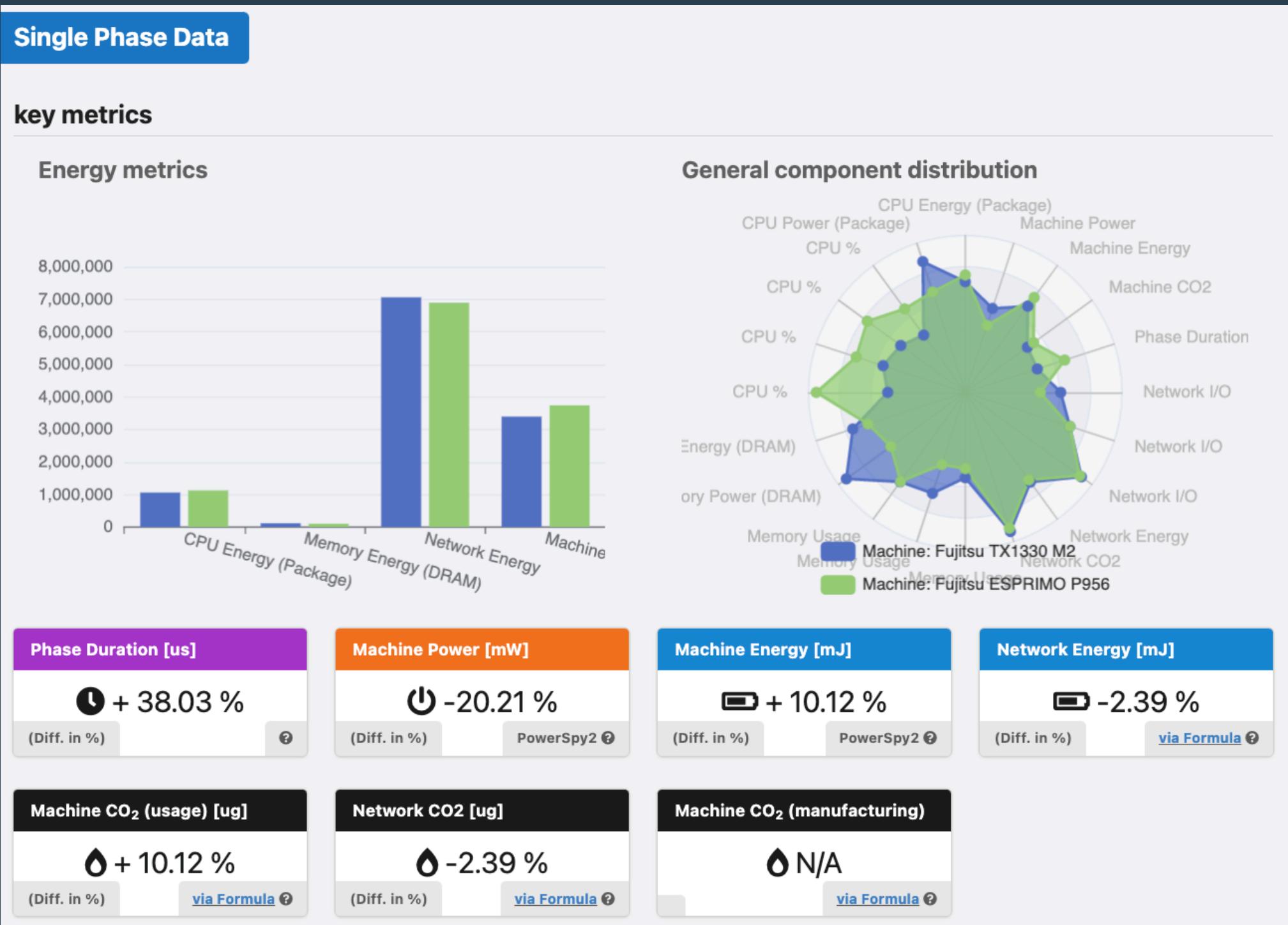


# Green Metrics Tool

## CO2- and Energy-Measurement

- Benchmarking via Standard-Usage-Scenarios (academia based via UCB / Öko-Institut e.V.)
- Reproducability / DevOps Integration via version control, orchestration and HW-Limits
- Dashboard with statistical comparison
- Modular / Extendable reporters for: Energy (Components, Machine), CO2 (Grid Intensity), Network, Memory, Temperature, Frequency, Embodied Carbon, VMs, distributed architectures ...
- SCI (ISO-Norm tbd 2024) / Blauer Engel compatible (German Eco Label)
- Cluster-Automation with Measurement-Accuracy-Control

Online Dashboard: <https://metrics.green-coding.io/index.html>



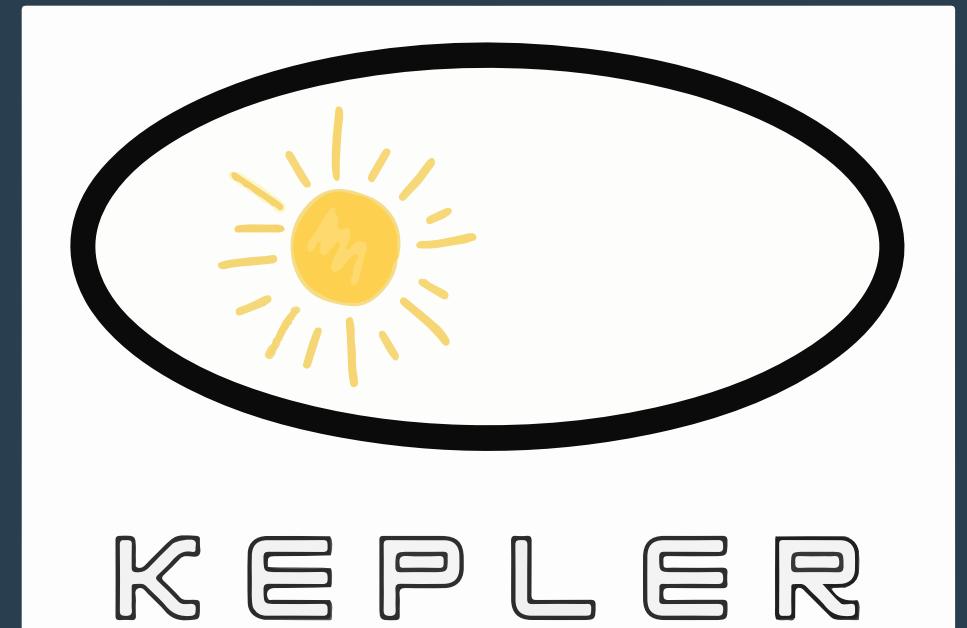
# Agenda

18.01.2024

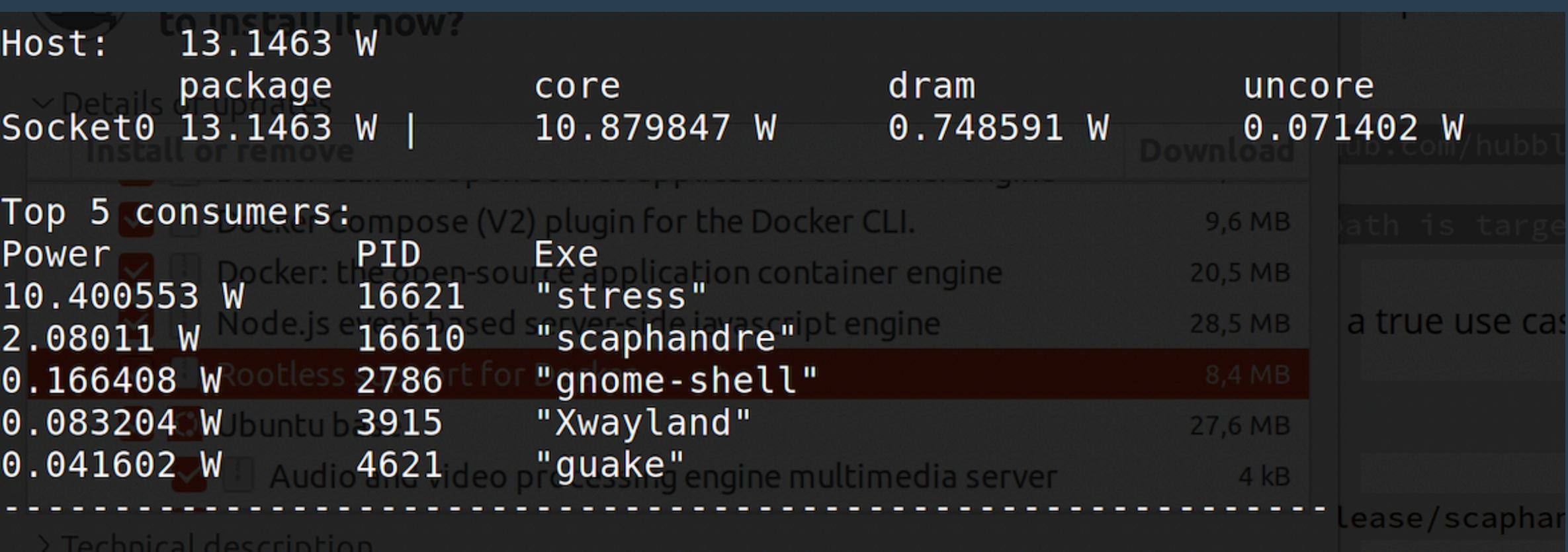
- **What quantifying tools do we have already?**
  - The basic tools Scaphandre, Kepler etc.
  - CloudCarbonFootprint, powertop
  - ecoCode / CAST
  - Green Metrics Tool, Eco-CI
  - The Green Web Foundation / Green Software Foundation
  - Did I miss anything?
- **Definition of sustainability as a proxy for green**
- **Let's try a greenfield approach**
- **Energy-ID project**
- **Summary and Outlook**

# Before we try do a greenfield approach

Let's see what others are already doing



# We have finally many tools That provide plain metrics output



# powertop

## List of hardware / os-settings tips

PowerTOP 2.12		Overview	Idle stats	Frequency stats	Device stats	Tunables	WakeUp
>>	Bad	Enable Audio codec power management					
	Bad	Runtime PM for I2C Adapter i2c-2 (i915 gmbus panel)					
	Bad	Runtime PM for I2C Adapter i2c-3 (i915 gmbus dpc)					
	Bad	Runtime PM for I2C Adapter i2c-0 (i915 gmbus ssc)					
	Bad	Runtime PM for I2C Adapter i2c-1 (i915 gmbus vga)					
	Bad	Runtime PM for I2C Adapter i2c-9 (SMBus I801 adapter at efa0)					
	Bad	Runtime PM for I2C Adapter i2c-4 (i915 gmbus dpb)					
	Bad	Runtime PM for I2C Adapter i2c-5 (i915 gmbus dpd)					
	Bad	Runtime PM for port ata3 of PCI device: Intel Corporation 8 Series SATA Controller 1 [AHCI mode]					
	Bad	Runtime PM for PCI Device Intel Corporation 8 Series SATA Controller 1 [AHCI mode]					
	Bad	Runtime PM for port ata1 of PCI device: Intel Corporation 8 Series SATA Controller 1 [AHCI mode]					
	Bad	Runtime PM for disk sda					
	Bad	Runtime PM for disk sdb					
	Bad	Runtime PM for PCI Device Intel Corporation Wireless 7260					
	Bad	Runtime PM for PCI Device Intel Corporation 8 Series USB EHCI #1					
	Bad	Runtime PM for PCI Device Intel Corporation Haswell-ULT Integrated Graphics Controller					
	Bad	Runtime PM for PCI Device Intel Corporation 8 Series USB xHCI HC					
	Bad	Runtime PM for PCI Device Intel Corporation Haswell-ULT HD Audio Controller					
	Bad	Runtime PM for PCI Device Intel Corporation 8 Series LPC Controller					
	Bad	Runtime PM for PCI Device Realtek Semiconductor Co., Ltd. RTS5227 PCI Express Card Reader					
	Bad	Runtime PM for PCI Device Intel Corporation 8 Series HD Audio Controller					
	Bad	Runtime PM for PCI Device Intel Corporation 8 Series HECI #0					
	Bad	Runtime PM for PCI Device Intel Corporation Ethernet Connection I218-LM					
	Bad	Runtime PM for PCI Device Intel Corporation 8 Series SMBus Controller					
	Bad	Runtime PM for PCI Device Intel Corporation Haswell-ULT DRAM Controller					
	Bad	Runtime PM for port ata2 of PCI device: Intel Corporation 8 Series SATA Controller 1 [AHCI mode]					
	Good	Enable SATA link power management for host1					
	Good	VM writeback timeout					
	Good	Enable SATA link power management for host0					
	Good	Enable SATA link power management for host2					
	Good	NMI watchdog should be turned off					

# Cloud Carbon Footprint

## Provides Recommendations in Demo - Do they work?

The screenshot shows the Cloud Carbon Footprint application interface. At the top, there are dropdown menus for 'Cloud Providers: 4 of 4', 'Accounts: 16 of 16', and 'Regions: 9 of 9'. Below these, a table lists cloud provider accounts and their regions, along with actions like 'Delete' or specific recommendation codes. A 'RECOMMENDATIONS' tab is selected, revealing a detailed view of a recommendation for a GCP account. The 'Recommendation Details' section includes fields for Cloud Provider (GCP), Account Name (gcp account 4), Account ID (gcp account 4), Region (us-east1), Resource Name (test-instance-9), and Resource ID (8928403120086348000). The 'Recommendation Type' is listed as 'STOP\_VM'. The 'Recommendation Detail' provides a description: 'Save cost by performing a STOP\_VM for instance: test-instance-9.' The final section displays 'Cost Savings (USD)', 'CO2e Savings (Metric Tons)', and 'Energy Savings (kilowatt hours)' all at 0.

	AWS	aws account 3	us-west-2	Delete
	AWS	aws account 4	us-west-1	Delete
	GCP	gcp account 0	us-west1	DELETE_IMAGE
	GCP	gcp account 1	us-west1	SNAPSHOT_AND_DEL...
	GCP	gcp account 2	us-west1	CHANGE_MACHINE_T...
	GCP	gcp account 3	us-east1	DELETE_ADDRESS
	GCP	gcp account 4	us-west2	DELETE_DISK
	GCP	gcp account 2	us-east1	STOP_VM
	GCP	gcp account 4	us-east1	STOP_VM

Cloud Provider	GCP
Account Name	gcp account 4
Account ID	gcp account 4
Region	us-east1
Resource Name	test-instance-9
Resource ID	8928403120086348000

Recommendation Type	STOP_VM
Recommendation Detail	Save cost by performing a STOP_VM for instance: test-instance-9.

Cost Savings (USD)	CO2e Savings (Metric Tons)	Energy Savings (kilowatt hours)
0	0	0

# Anwendungsfall Web: Statische Analyse

## Eco-Code / CAST etc.

- Based on recommendations from science and the French position paper Numérique Responsable
- No proven effect in larger software projects
- Recommendations such as `i++` instead of `++i` are often identical even in assembly code / byte code
- Overhead of the tools unclear



**Green Code Initiative**  
Let's write low-carbon software  
 84 followers    France    company/green-code-initiative

```
1  {
2    "title": "Limit the number of returns for a SQL query",
3    "type": "CODE_SMELL",
4    "code": {
```

# CAST

## Static Code Scanner for Enterprise

 **Green Deficiency**

Data Access Efficiency : [SQL] Avoid queries without WHERE condition 

Data Access Efficiency : [SQL] Avoid queries without WHERE condition 

Resource Economy : Avoid Programs not using explicitly OPEN and CLOSE for files or streams 

Resource Economy : Avoid Programs not using explicitly OPEN and CLOSE for files or streams 

Resource Economy : Prefer literal initialisation 

Resource Economy : Avoid using 'System.gc' and 'Runtime.gc' 

Avoiding Failure : Avoid empty catch blocks 

Resource Economy : Avoid using 'System.gc' and 'Runtime.gc' 



# More tools ... did we miss any?

Happy to talk about in Q&A !

- powertop
- powermetrics
- GreenFrame.io
- turbostat
- powerJoularX
- PAPI
- ...

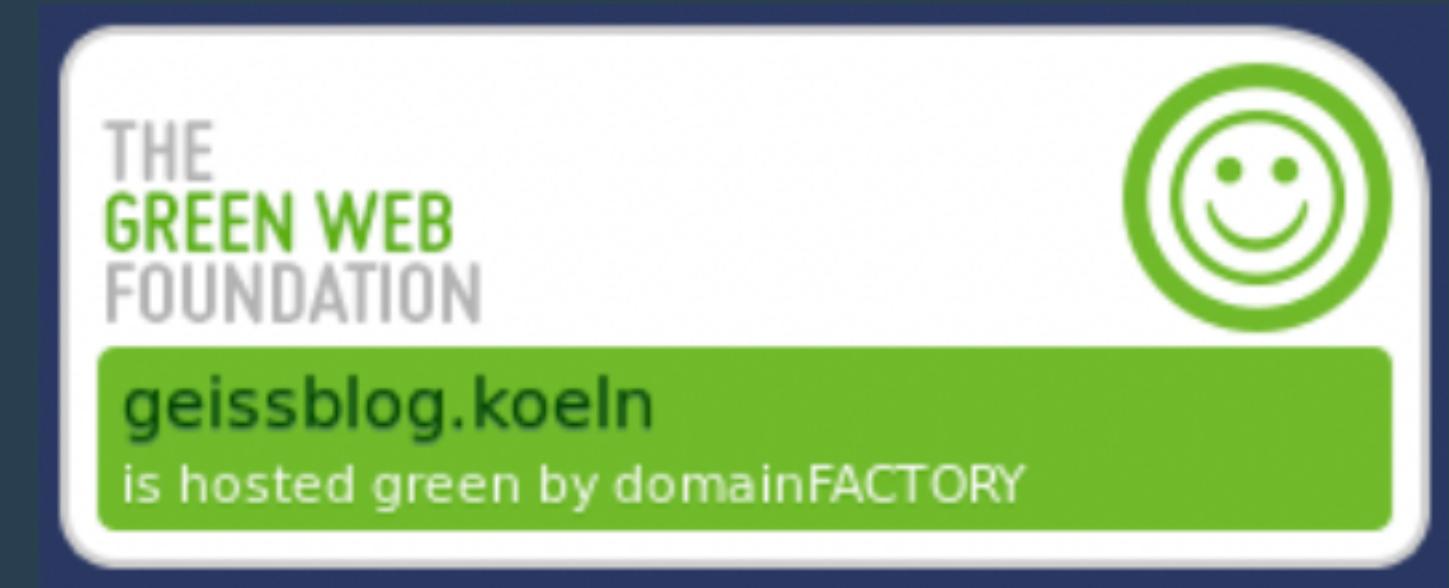
# Hmm, tools don't really help atm

Maybe labels, organizations and norms?

# The Green Web Foundation

## Green Energy Label for Datacenters / Servers

- The Green Web Foundation is pursuing and accelerating the transition to a fossil-free Internet
- Provides datasets/API for green hosting
- Label allows to show that your hosting is green
- If you are either connected to a green power plant or you have on-site generation or you buy PPAs



# Green Software Foundation 1/2

## SCI - An approach to quantify a software



$$\text{SCI} = (E * I) + M \text{ per R}$$

- (E) - Energy consumption (kWh) for various components:
  - Ex. CPU/GPUs, Data storage, Memory, Network
- (I) - Emission factor
- (M) - Embodied emissions
  - z.B. Data from servers, laptops, mobile devices, tablets etc.

# Green Software Foundation 2/2

<https://patterns.greensoftware.foundation/>



Green  
Software  
Foundation

- A collection of many tips from either common sense or performance engineering
- Many can also backfire
  - "Run AI models at the edge"
  - "Reduce transmitted data"
- Many provide no guidance
  - "Use energy efficient AI models"

- Cache static data
- Choose the region that is closest to users
- Compress transmitted data
- Delete unused storage resources
- Encrypt what is necessary
- Evaluate other CPU architectures
- Terminate TLS at border gateway
- Implement stateless design
- Match your service level objectives to business needs
- Match utilization requirements of virtual machines (VMs)

# CNCF - TAG ENV

## Cloud Native Computing Foundation eco group



**TAG** ENVIRONMENTAL  
SUSTAINABILITY

- For instance, programs written in energy efficient languages or running on more optimized runtimes are generally “greener”.
- So we use C and we are green?
- Automated scaling
- Only schedule pods when green energy is there

- **Green System Architecture**
- **Current Sustainable Cloud Computing Landscape**
  - **Data centers**
    - **Smart Data Centers**
    - **Cooling / BMC**
  - **Methodologies**
    - **Measurement Methodologies**
    - **Observability Methodologies**
  - **Observability Tooling**
  - **Infrastructure Tooling**
    - **Scheduling At The Cluster Level**
    - **Scaling**
    - **On-Node Power Management Tuning**

Source: <https://tag-env-sustainability.cncf.io/landscape/#green-system-architecture>

# Blue Angel - German Eco Label 1/2

## Ressource- and energy-efficient software products (DE-UZ 215)

- Software certificate from the (quite ?) well-known German eco-label
- Developed in collaboration with academia and research institutions in Germany
- Currently only for desktop applications without online functionality 😊
- Does require measurement, but no max resource consumption
- No technical reference implementation
- Criterias -> Page 2



**Good for me.  
Good for the environment.**

# Blue Angel - German Eco Label 2/2

## Ressource- and energy-efficient software products (DE-UZ 215)

- Code should be reusable
- Code should run on 5 year old hardware
- Code should survive a Hibernate
- Code should be un/installable without leaving files behind
- Code should not contain advertising
- Code should be documented
- ...



**Good for me.  
Good for the environment.**

# Normen

## Mostly focus on life cycle assessment

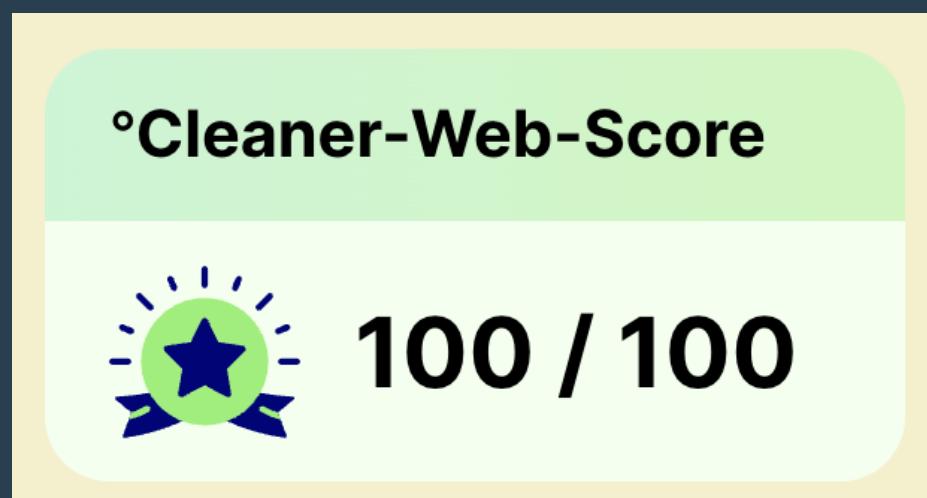
- ISO 140001
  - The standard for a life cycle assessment.  
But requires methodology reference for software
- GHG Protocol - Chapter 6
  - Concrete recommendations for software life cycle assessment. Even in VMs.
- So do we qualify as green if we just quantify?



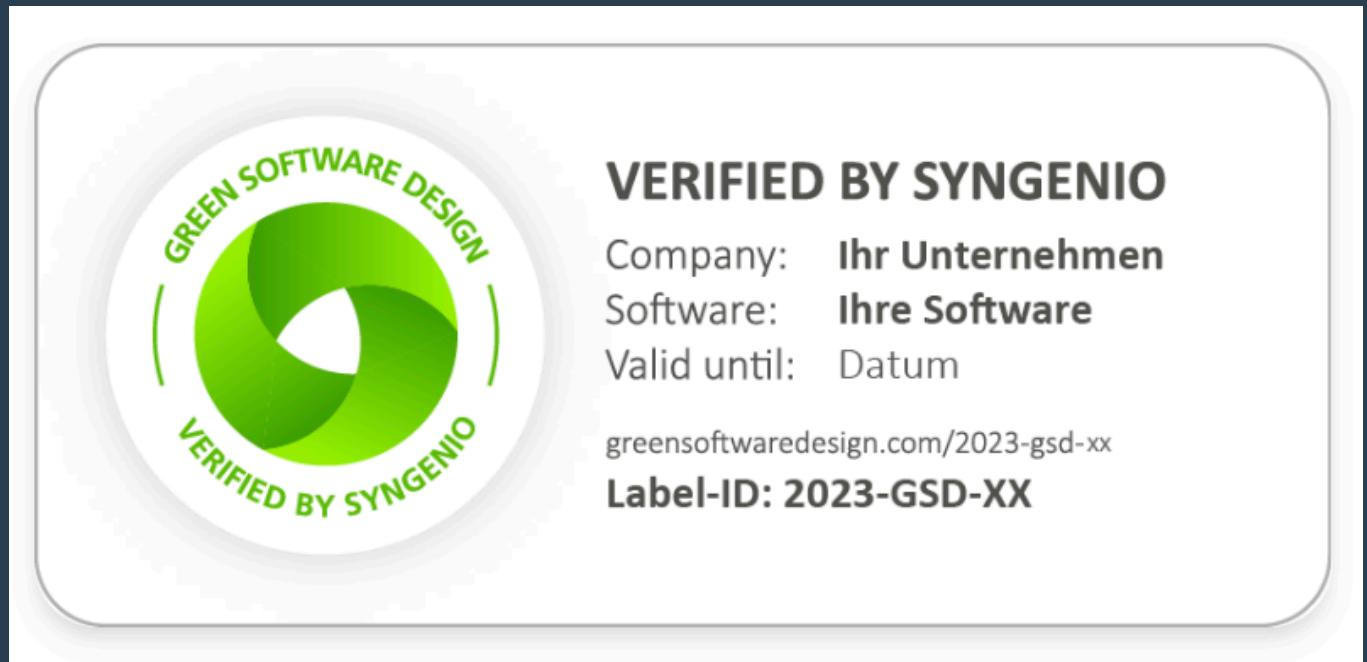
# And so much more ...

Did we miss anything?

## Website



## Application

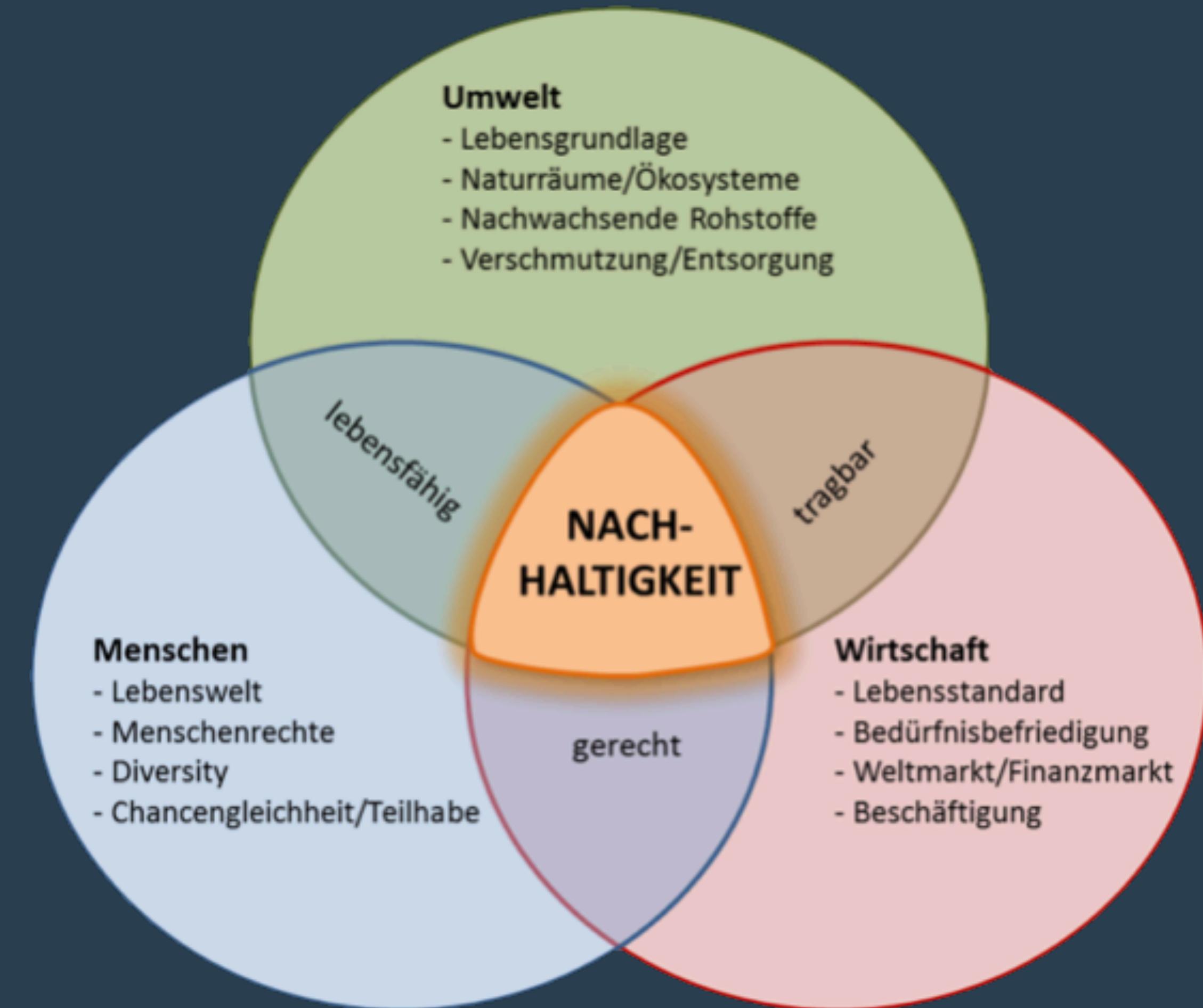


- i Gibt es ein definiertes Vorgehensmodell bei der Softwareentwicklung?
- i Werden die Stories konsequent vom Project Owner priorisiert?
- i Ist ein fachlicher Domänenexperte unter den Entwicklern?
- i Sind die Stories klar definiert und strukturiert?

# **Sadly we did not find the green-ness yet**

**Let's maybe take a step back and try to define green through  
sustainability as a proxy**

# What is the definition of sustainability ... in a more general way



# What actually is sustainability

The typical display via an ESG-like approach



Source: <https://www.anavis-solutions.com/>

# What actually is sustainability

ESG sees sustainability as a "risk" to mitigate. Alternative view:

## ESG vs Sustainability

Two distinctive perspectives

**Earth Systems and Society:** how to operate within a 'safe space for humanity' based upon environmental thresholds and societal foundations  
Quantifying the status of threshold issues such as climate, inequality and nature  
Quantifying the current performance of business and finance with respect to the safe operating space  
Identifying the societal value at risk and non-financial impact of current financial performance

Sustainability:  
'Inside-out'  
focus on earth  
and social systems

**Business & Finance:** how sustainability concerns impact enterprise value at risk  
Quantifying impact of sustainability concerns on financial performance  
Identifying financial investments needed to improve non-financial performance  
Identifying forward risks of current business model with respect to safe operating space

ESG: 'Outside-in'  
focus on enterprise  
value

# Sustainability - As used in this talk

Based on the definition of the UN-SDGs

- The Brundtland report from the **United Nations (UN)** defines sustainable development as the ability to :
  - “*meet the present needs without compromising the future generation abilities for their own needs*“
- General understanding often says:
  - ... *the ability to refill itself at a quicker rate than it is consumed / damaged ...*

# Let's do an intermediate summary

Of goods and bads so far

# What is good and bad of what we have seen so far

- Some tips mostly everybody would agree this is a green practice
  - Green Hosting. Deleting VMs you do not use. Deleting unused data ...
- Some tips require proper implementation and can backfire:
  - Location- / Time-Shifting; Switching to other algorithm; Running at edge
- Some have no data to back their claims:
  - Use `i++` instead of `++i` ...

# Let's do a greenfield approach then

What would we want from green code?

# Greenfield approach

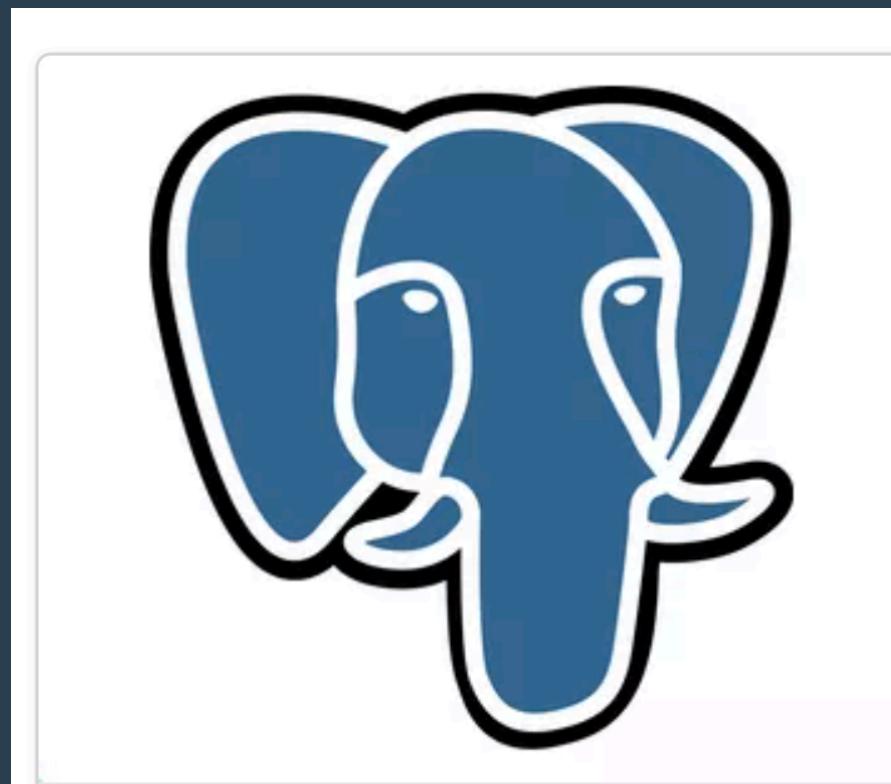
What would be the most green we can think of?

- In a truly "sustainable" code it would be
  - code that consumes only so much resources as we can provide "renewably"
  - or software that we can provide for future generations in the same way
- This means we can only use so much hardware as we can also recycle
- And we can only use regenerative power
- Furthermore we would have to distribute the allowed amounts globally for every software product
- Ok ... that is a "stretch goal" for now :)

**But can we find a best in class  
And create a gold standard?**

# Energy-ID project

Using standardized functional benchmarks for software



**PostgreSQL**

Relational Database

*click for details*

## BADGES

Energy Cost 58.93 kJ via PSU (AC)

Energy Cost 20.59 kJ via RAPL

SCI 29.46 mgCO<sub>2</sub>e/TPC-C SQL-op

Show measurements



**MariaDB**

Relational Database

*click for details*

## BADGES

Energy Cost 59.55 kJ via PSU (AC)

Energy Cost 21.82 kJ via RAPL

SCI 163.92 mgCO<sub>2</sub>e/TPC-C SQL-op

Show measurements



**Wagtail**

CMS

*click for details*

## BADGES

Energy Cost 1.14 kJ via PSU (AC)

Energy Cost 243.24 J via RAPL

SCI 18.84 mgCO<sub>2</sub>e/page request

Show measurements



**WORDPRESS**

**Wordpress**

Blog/CMS

*click for details*

## BADGES

Energy Cost 635.62 J via PSU (AC)

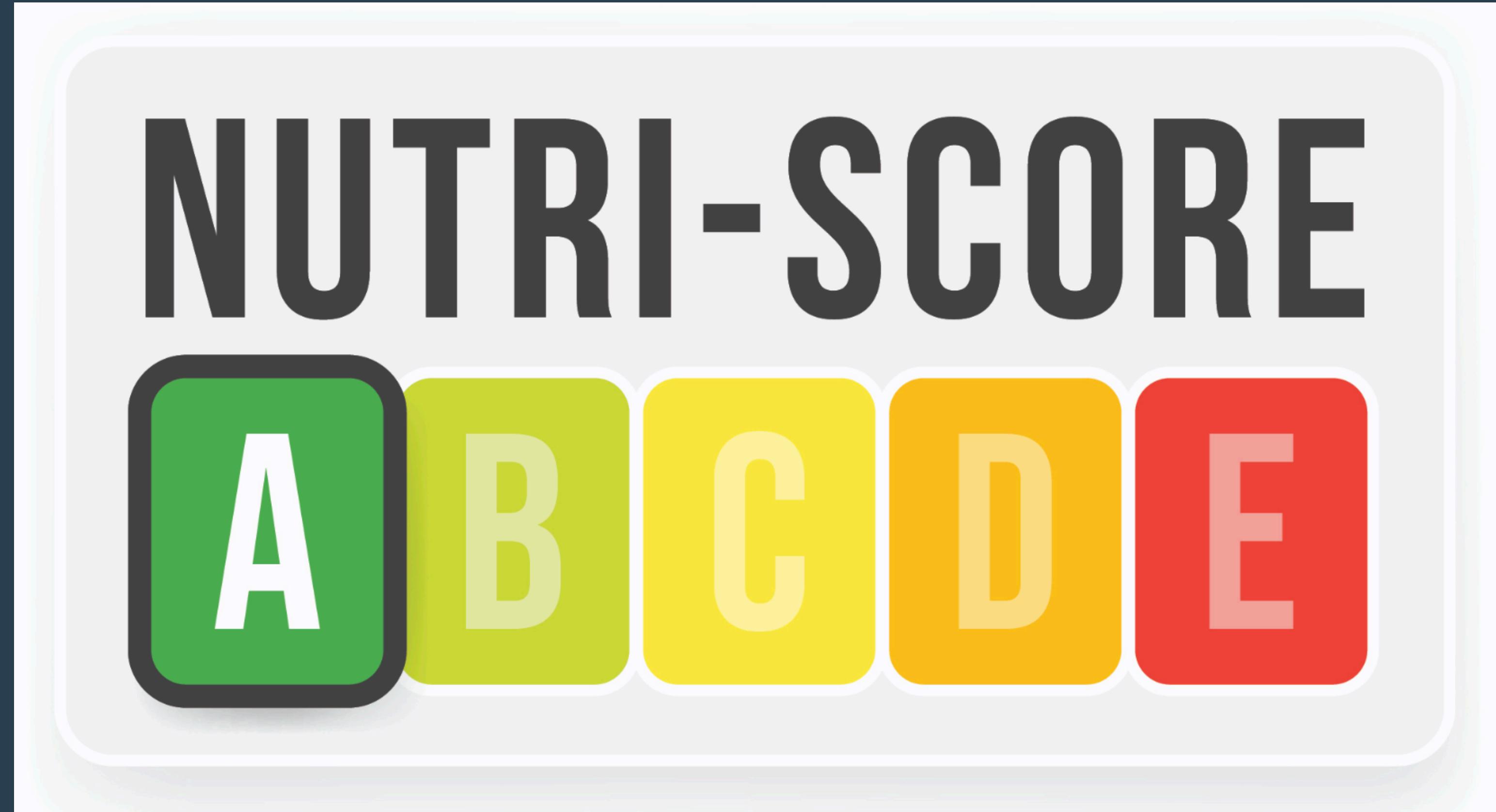
Energy Cost 112.62 J via RAPL

SCI 25.08 mgCO<sub>2</sub>e/page request

Show measurements

# Energy-ID project

Using standardized functional benchmarks for software



# Future works of Energy ID

## Implementation into the GMT

- Use best practices as we have for running code
  - Use resource planning
  - Check how software reacts to carbon signals
  - Check with AI models for energy hotspots.
  - Identify LoC in different software iterations - Flamegraph
  - Apply AI test-optimizations and see if software gets better
- Monitor software over time if feature-addition impacts energy
- Goal: Identify what is the current most efficient code and create a **gold standard**

# Thank you

## Want to know more

- Website / Blog / Newsletter: <https://www.green-coding.io>
- Demo Open Data Repository: <https://metrics.green-coding.io>
- Our projects: <https://www.green-coding.io/#projects>
- Our case-studies: <https://www.green-coding.io/case-studies>
- Meetup Group (Berlin): <https://www.meetup.com/green-coding>
- <https://www.linkedin.com/in/arne-tarara> / arne@green-coding.io

# Eco-Compute conference

The first engineering conference on sustainability in hardware & software

- We are looking for talks!
- Case studies with clients that save carbon / energy
- New tools and practices in Green Coding
- Hardware / Software interaction for efficiency
- ... <https://www.eco-compute.io/call-for-speakers/>

**EcoCompute Conference 2024**

**The first engineering conference on sustainability in hardware & software**

**April 25 – 26**

**Munich, Germany**



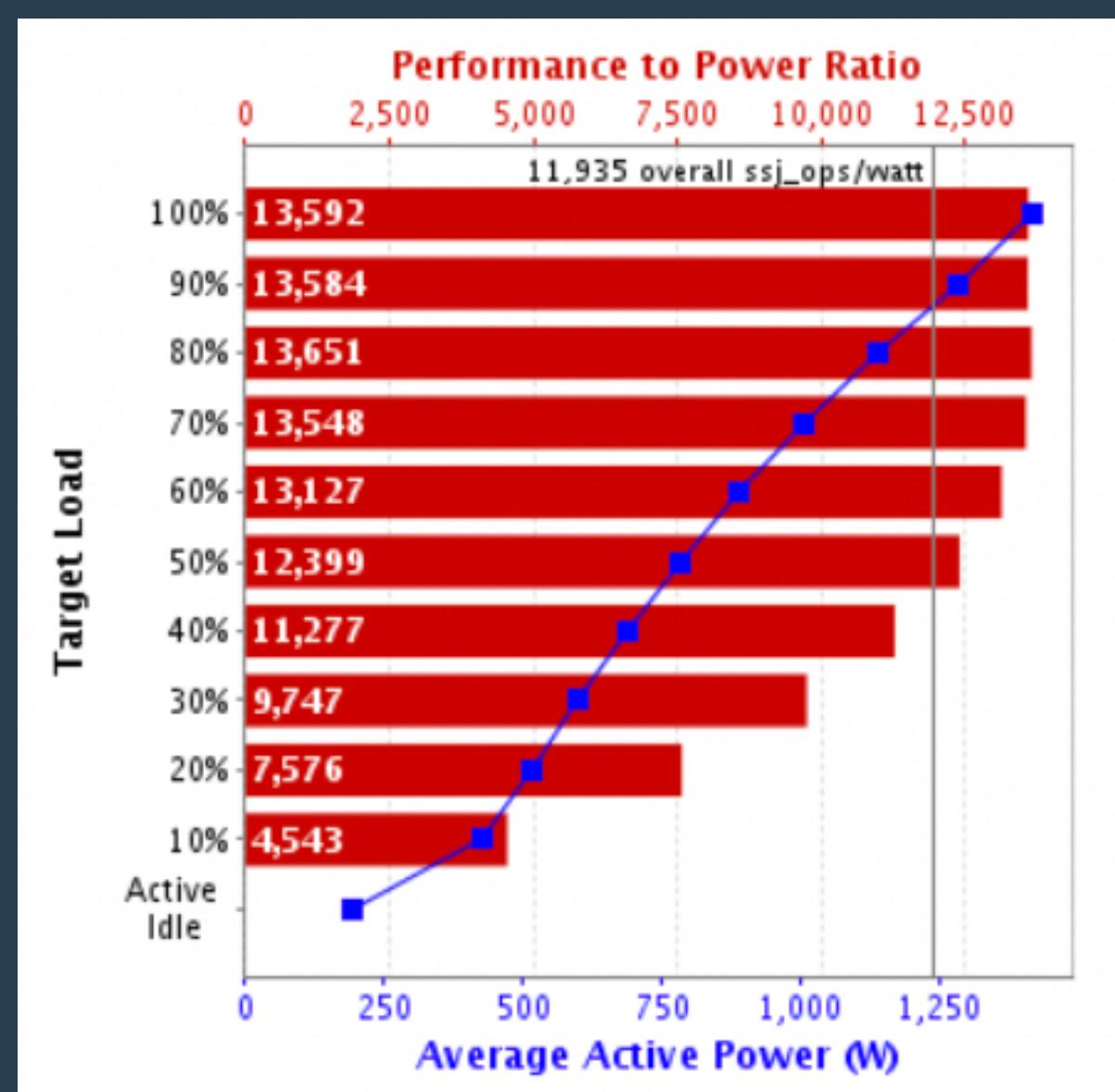
<https://www.eco-compute.io/call-for-speakers/>

# Backup Slides

# Zusammenspiel von Hardware und Software

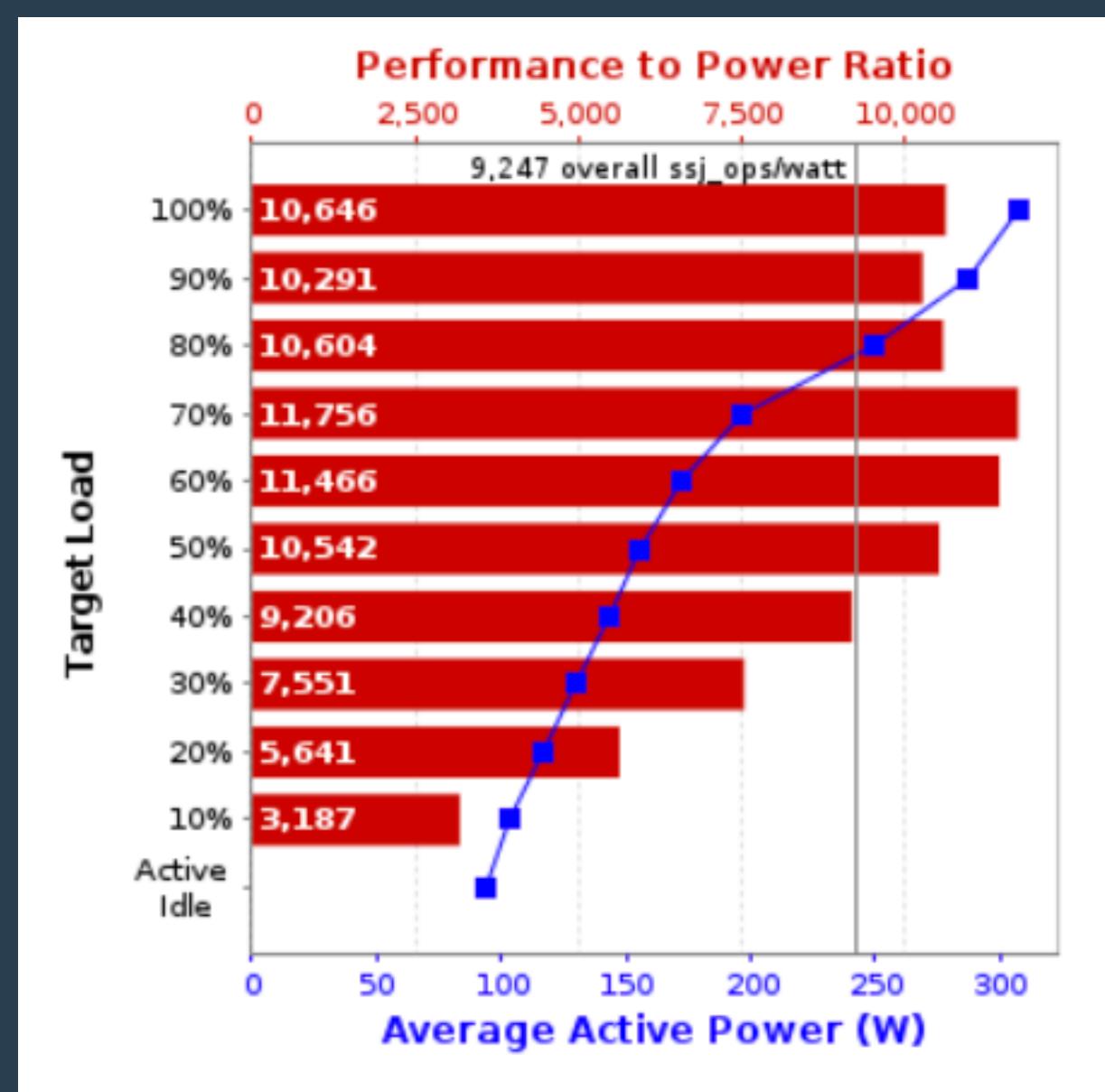
## Datenbanken für Energiekennlinien durch Hardware und Konfiguration

High Idle, but almost linear



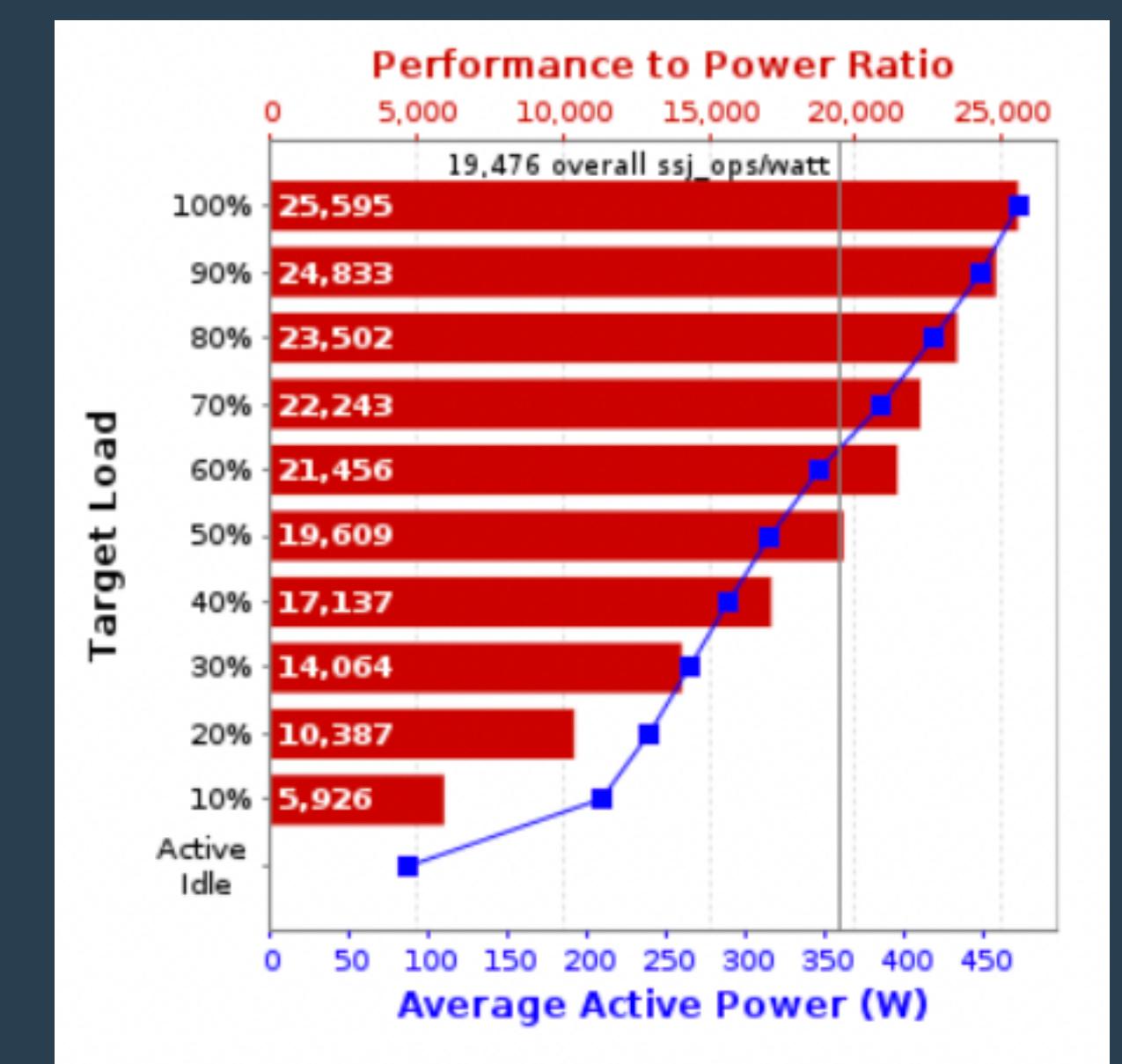
ASUSTeK Computer Inc. RS720Q-E9-RS8 (2019)

50% Power increase at 70% utilization



Hewlett Packard Enterprise ProLiant DL110 Gen10 Plus

Idle optimized

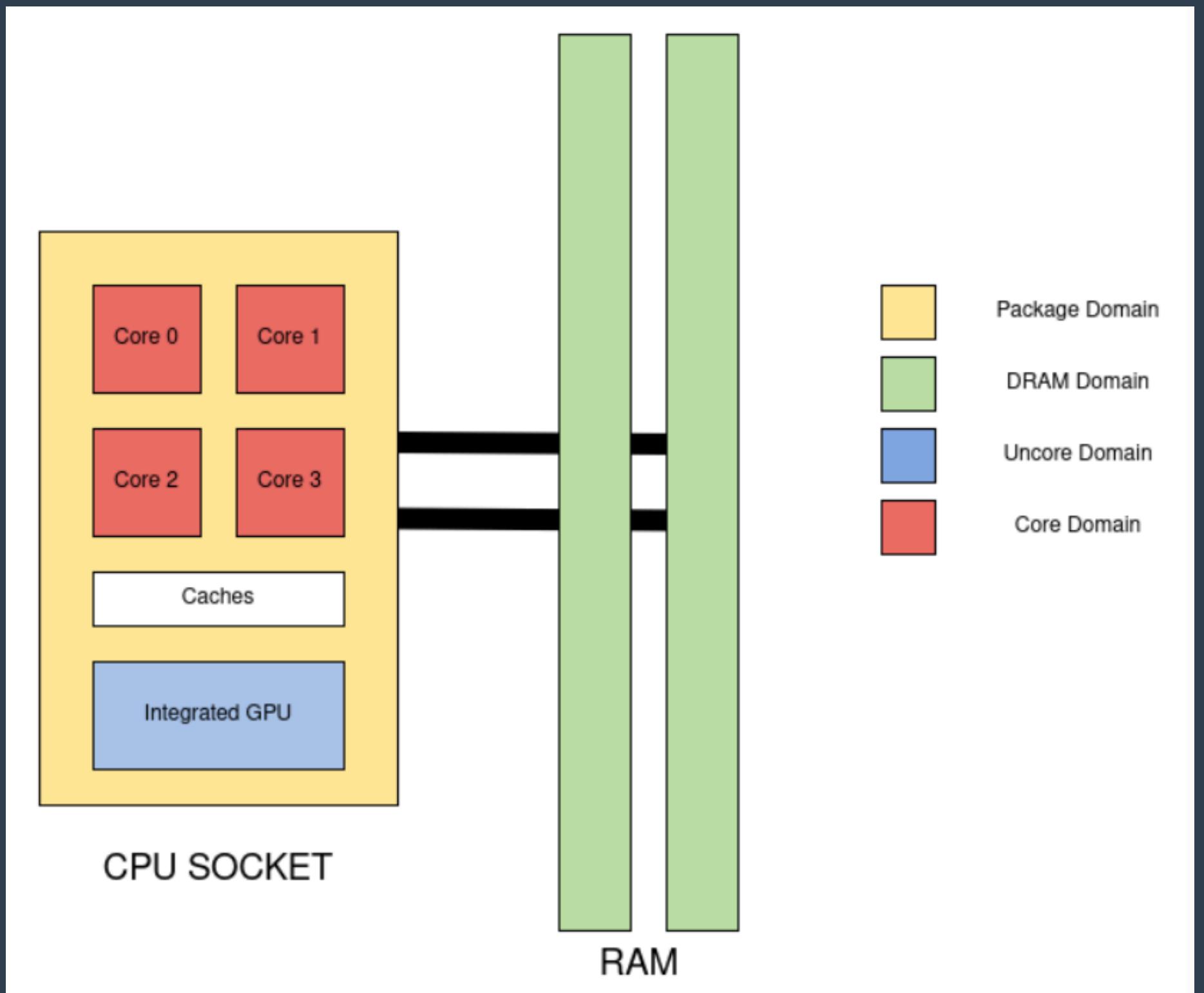


QuantaGrid D43K-1U (2022)

# Details on RAPL

## The most used technology atm

- Energy measurement capabilities on most modern Intel/AMD processors
- Measure:
  - CPU Energy per Core / Package
  - RAM
  - Integrated GPU
- Software model of capacitor readings on mainboard
  - Resolution 1ms / 15.3 microJoules
- Exposed in Linux kernel through device



Source: [https://pjoules.readthedocs.io/en/stable/devices/intel\\_cpu.html](https://pjoules.readthedocs.io/en/stable/devices/intel_cpu.html)

**GREEN CODING;**