

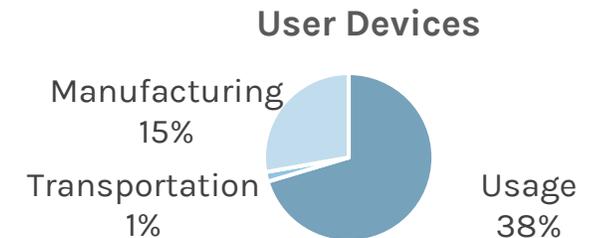
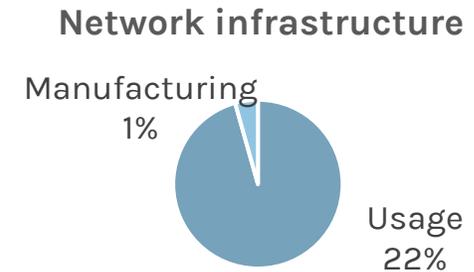
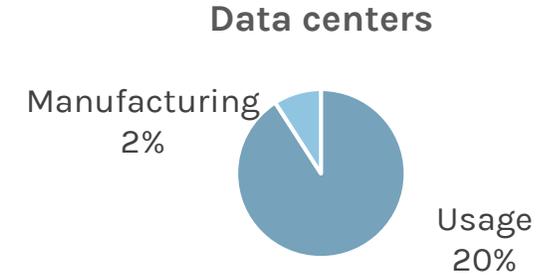
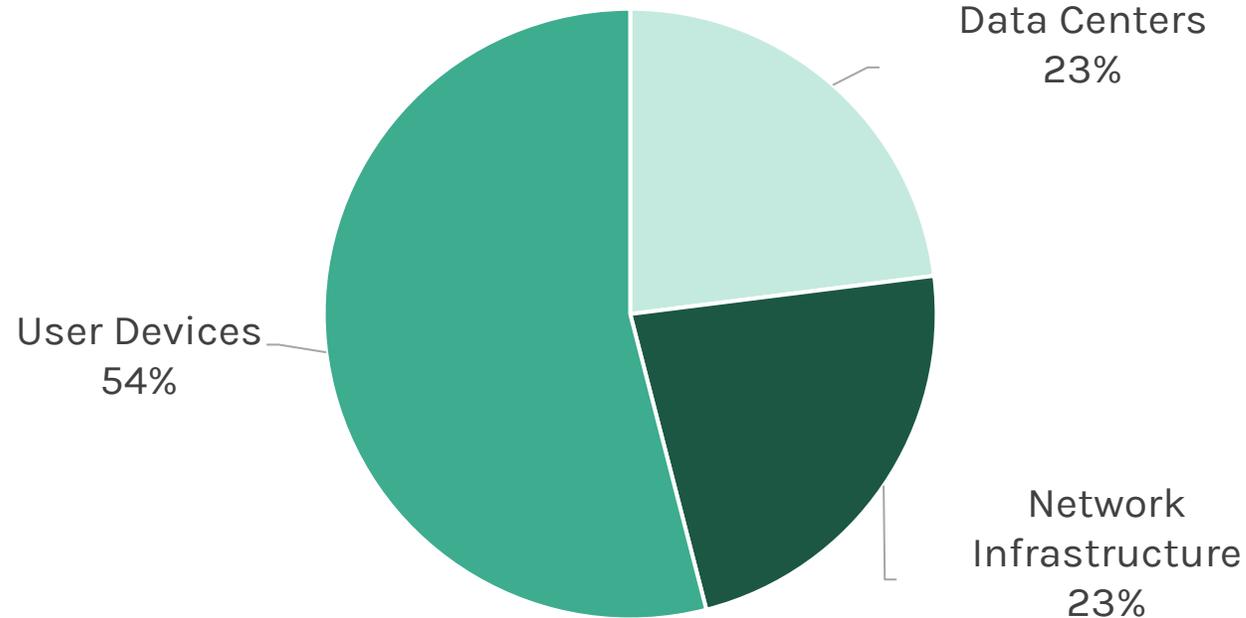
Green Frontend

Measuring and understanding the environmental impact of web applications

David Kopp, Jan Kirchner

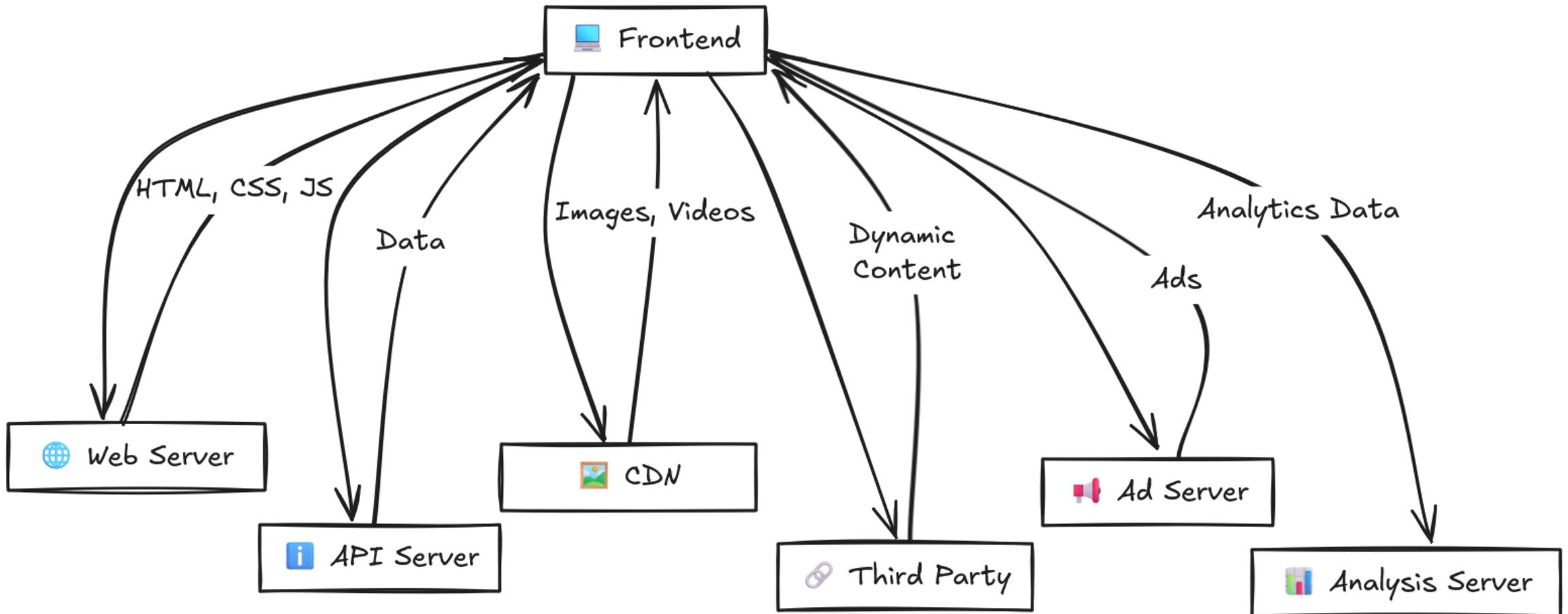
User devices: the biggest source of ICT's global CO₂ emissions

Relative carbon footprint per segment

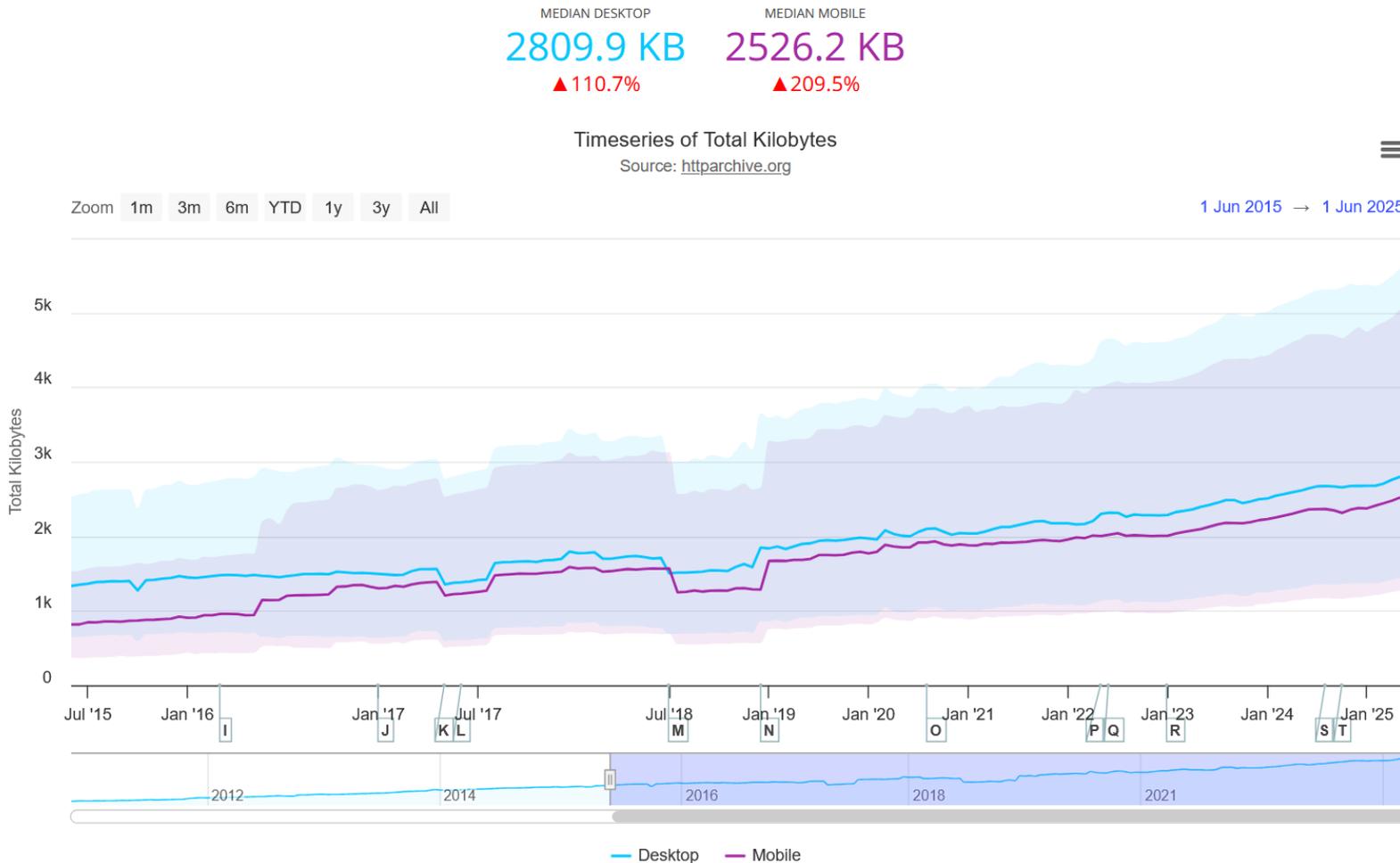


Environmental impacts of digital technology in the world, third edition, Green IT Association, 2025 (IENM 2025), <https://t.ly/greeniteco.IENM2025>

Frontends drive network and server load



Web pages become heavier



In the last 10 years, average web page size:

- has doubled (desktop)
- has tripled (mobile)

https://httparchive.org/reports/state-of-the-web?start=2015_06_01&end=latest&view=list

How to determine the environmental impact of a web application?

Measure!

Who are we?



- Founded in 2022
- IT Consulting focuses on Sustainability IN IT & Sustainability BY IT



- Jan Kirchner
- Green IT Consultant
- Focus: Frontend/Fullstack development



- David Kopp
- Green IT Consultant
- Focus: Backend development, DevOps, ecological assessment of IT systems

Agenda

✦ Introduction

Methodologies & Tools

User Interactions

Good & Bad Websites

Conclusion

Agenda

Introduction

✦ Methodologies & Tools

User Interactions

Good & Bad Websites

Conclusion

From energy to carbon

energy consumption [wh]

×

carbon intensity [g CO₂/wh]

+

embodied carbon [g CO₂]

=

carbon emissions [g CO₂]

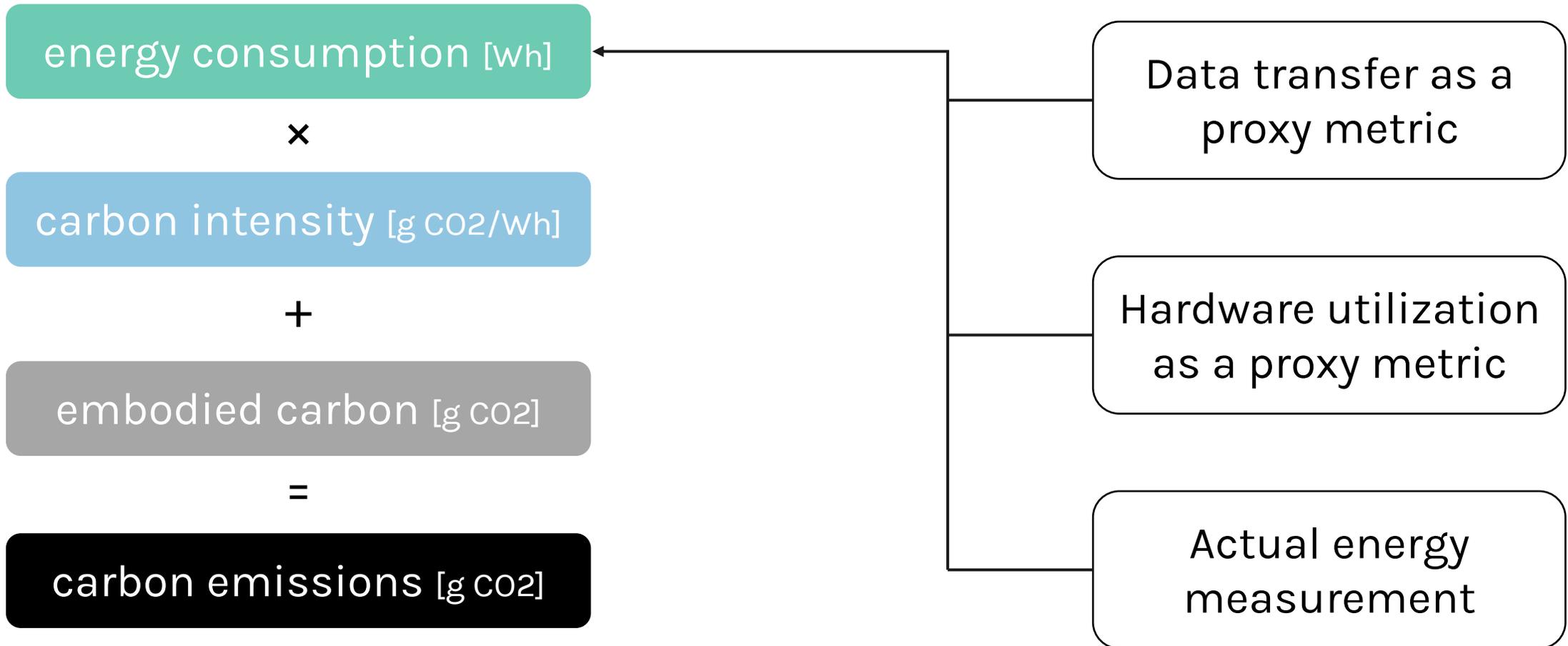
measured / estimated

static: global or regional average

dynamic: live, regional

LCA database

Capturing the energy consumption

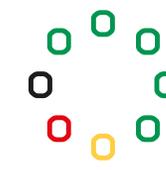


Server-side vs. client-side measurements

New challenges:

- Diverse hardware (from smartphones to desktops)
- No direct control over the runtime environment
- Devices' energy consumption depends on other factors
 - display brightness, network connection, background apps, energy-saving mode ...

Green Software Tool Landscape



Bundesverband
green.software

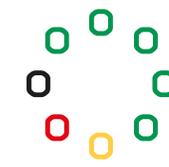
The screenshot displays the 'Green Software Tool Landscape' website. At the top, there is a navigation bar with 'EXPLORE', 'GUIDE', and 'STATS' tabs, and a search bar. Below the navigation, there are filters for 'GROUP' (Measurement, Optimization) and 'VIEW MODE' (Grid, Card). The main content area is a grid of tool cards, organized into several horizontal sections:

- Infrastructure & Cloud Level:** Includes tools like Li10, OVHcloud, Tallpipe, Cloud Asses, SPRUCE, greenpixie, txture, ecoinfra, Agent, Planning & Calculation (Data Vizta, EasyVirt, OxygenIT, Green Algorithms Calculator, Data Center Water Consumption Calculator, Hardware Replacement Calculator, Technology Carbon Estimator), and Kubernetes (KEPLER, KEIT, aether).
- Device & Process Level:** Includes CODE CARBON, TRACARBON, PERUN, PowerJeulor, powerstat, Perf, Turbostat, NVIDIA, intel, PowerTOP, EnergyBridge, CPU Energy Meter, Process Metrics Exporter, KEPLER, PROCPOWER, powerletrics, PowerRED, and EnergyAt.
- Data Aggregation:** Includes fruggr, sopht, tech., aguaro, Antartica, and Modeling (Carbon Footprint Modeling Tool, e-footprint model).
- Component:** Includes Containerized Application (cardamon, LIMO), Mobile App (PowDroid, Android Runner), and Desktop Application.
- Website:** Includes Website Carbon Estimation (CO2.js, Ecograder, Website Carbon Meter), Website Analysis (Ecograder, Ecoping, Cleaner Web, #G IT), and Website Energy Measurement (WebNRG).
- AI:** Includes AI Model Training and AI Inference.

<https://landscape.bundesverband-green-software.de>

Green Software Tool Landscape

Category "Website"



Bundesverband
green.software

Website

Website Carbon Estimation 🔍

CO2.js
IN ACTIVE USE BY BVGS MEMBERS

Ecograder
IN ACTIVE USE BY BVGS MEMBERS

Website Carbon Meter

cardamon

eco index

Ecoping

Cleaner Web

Website Analysis 🔍

Ecograder
IN ACTIVE USE BY BVGS MEMBERS

Ecoping

Cleaner Web

#G IT

Ecoping

Cleaner Web

Website Energy Measurement 🔍

WebNRG

IN ACTIVE USE BY BVGS MEMBERS

IN ACTIVE USE BY BVGS MEMBERS

<https://landscape.bundesverband-green-software.de>

Proxy Metric: Data Transfer

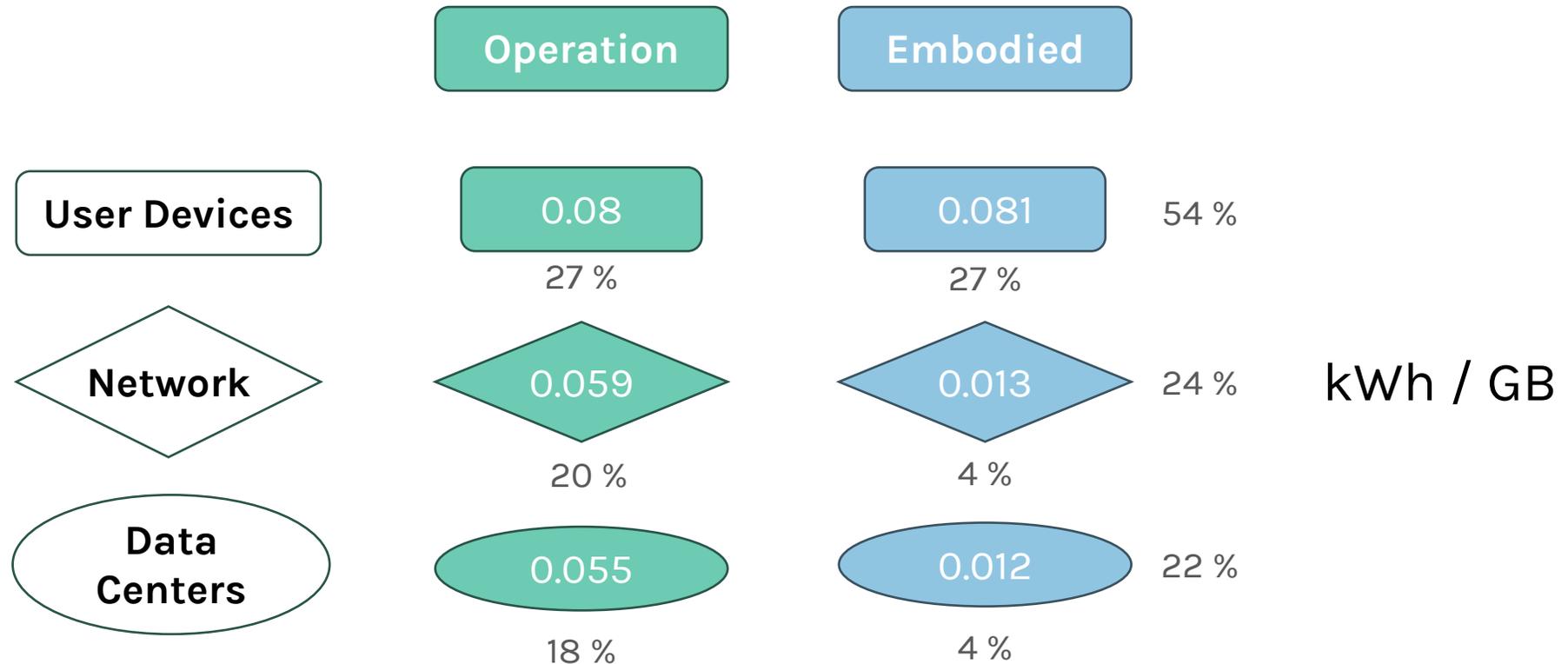
- Data transfer can be easily captured
- Used as proxy metric for energy consumption
- A conversion factor is needed (kWh / GB)
- Top-down approach based on global averages
 - Segments: user devices, network, data centers
 - Operational and embodied emissions
- Most widely used: Sustainable Web Design Model

Sustainable Web Design Model

- Input: amount of transferred data
- Additional variables:
 - carbon intensity of the grid (e. g. global: 494 g CO₂e / kWh)
 - Green hosting factor
 - Percentage of recurring visits + percentage of resources in cache
- Popular implementation: CO2.js
 - JavaScript library created by the Green Web Foundation

<https://sustainablewebdesign.org/estimating-digital-emissions/>

Sustainable Web Design Model – Coefficients

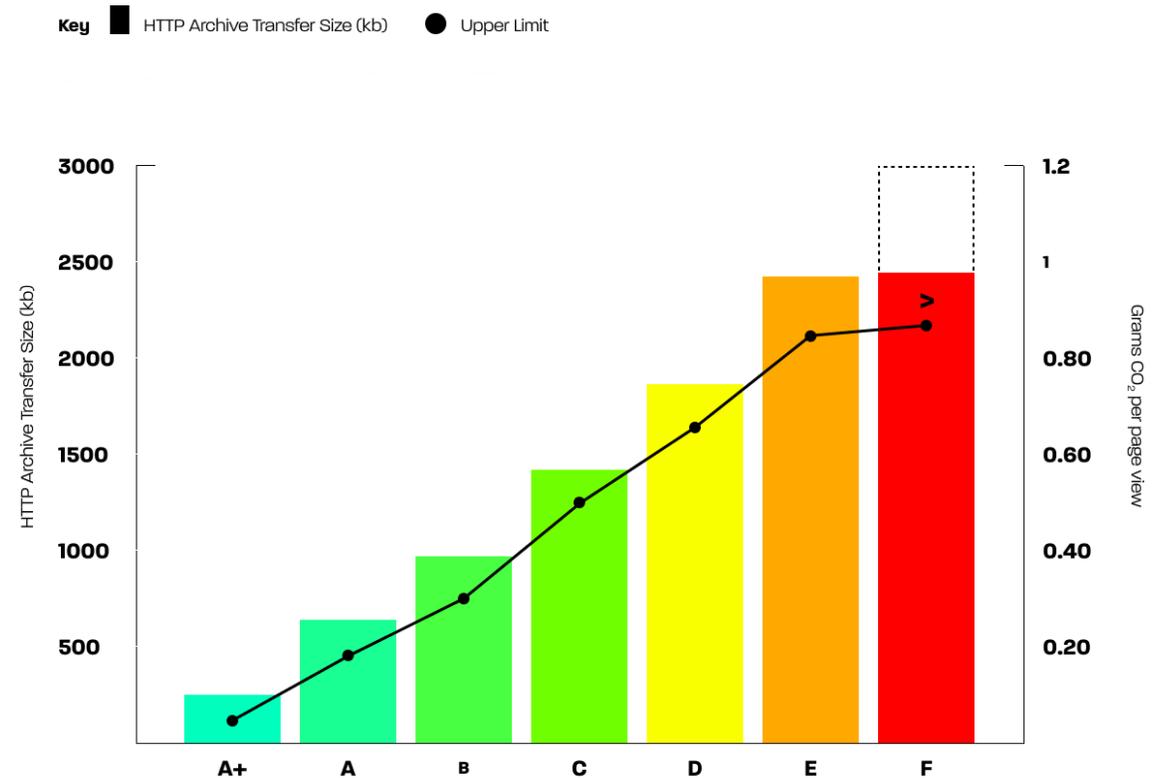


<https://sustainablewebdesign.org/estimating-digital-emissions/>

Digital Carbon Rating

Converts estimated carbon emissions into an intuitive rating from A+ to F

Rating	Data Transfer (kB)	g CO ₂ e per Page View
A+	272	0.040
A	531	0.079
B	975	0.145
C	1410	0.209
D	1875	0.278
E	2419	0.359
F	≥ 2419	≥ 0.360



<https://sustainablewebdesign.org/digital-carbon-ratings/>

WebsiteCarbon.com

Website Carbon Calculator

Website carbon results for: [eco-compute.io](https://www.eco-compute.io)

Hurrah! This web page achieves a carbon rating of B

This is cleaner than **76%** of all web pages globally

Learn about our [rating system](#)

This page was last tested on 7 Nov, 2025. [Test again](#)

[Copy URL](#)

Only **0.12g of CO2** is produced every time someone visits this web page.

Oh no, it looks like this web page uses **bog standard energy**

This result is an approximation

You can get a comprehensive view of a website's emissions and potential improvements by carrying out a [Website Carbon™ Audit](#).

Over a year, with

Ecograder

Ecograder

Scanned 11/7/2025, 7:27:51 PM GMT+1

[RESCAN PAGE](#) [TRY ANOTHER PAGE](#)

Your Impact Report

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

Performance Impact

Ecograder Score

58

Out of 100

Emissions per Pageload

0.46

grams of carbon dioxide

This page scores worse than 73% of all URLs crawled by Ecograder

Climate Impact

Digital Carbon Rating C	Page Emissions 0.46 g	Page Weight 1.18 MB
--	--	--------------------------------------

Ecograder scores pages based on a variety of performance, efficiency, and user experience factors as well as emissions estimates and green hosting powered by renewable energy.

- Page Weight**: 57
- UX Design**: 85
- Green Hosting**: 0

Assuming your page gets 1000 pageviews, you're emitting 460.00 grams of carbon dioxide.

This page is 60.39% smaller than the average web page.

Beacon

Beacon

<https://www.eco-compute.io/>

First visit

CO2	SIZE
0.444g	1.18 MB

Return visit

CO2	SIZE
0.412g	1.1 MB

Overall this web page has been graded C when it comes to its carbon

<https://www.websitecarbon.com/website/eco-compute-io/>

<https://ecograder.com/report/0D7go8uhRsXltVWwJx9PFfYR>

<https://digitalbeacon.co/report/eco-compute-io>

Optimization Recommendations



 **65** Ecodesign score [?](#)

Kastor advises you to prioritize



- ✘ Do not download images if they are not visible
- ✘ Avoids an excessive DOM size
- ✘ Prefer standard fonts

Frontend

- ✘ Reduce the impact of third-party code - Third-party code blocked the main thread for **1,200 ms**
0% of compliance
- ✘ Defer off-screen images - Potential savings of 494 KiB
0% of compliance
- ✘ Avoid serving legacy JavaScript to modern browsers
0% of compliance
- ✘ You should include specials print fonts in your print css
5% of compliance
- ✘ Do not download images if they are not visible - 11 images
6% of compliance



1 Page Weight 87 out of 100

By compressing image file size and removing unused items from a page you'll not only reduce emissions but faster-downloading pages make users happier as well. Below are some things you can do to reduce the size of this page.

 Optimize Media	97 OUT OF 100	
 Reduce Overall Page Weight	73 OUT OF 100	
 Remove Unused Code	75 OUT OF 100	
 Properly size images	94 OUT OF 100	

ecoIndex

Data Transfer + Complexity + Requests

eco Index Test a website How it works Ecodesign About Join us fr | en

← Back Retest Share

Calculated on Friday, November 7, 2025 at 7:34:14 PM

Analysis results

https://www.eco-compute.io/

D

The good news is that you can do much better!

max: 100 min: 0

A B C **D** E F G

Score: 42 / 100

Page rank: 326408 / 545658

- Too heavy 1.166 Mb
- Too complex 1904 elements
- Few requests 30 requests

ecoCompute conference

11 & 12 November 2025

The biggest engineering conference on

What does my score mean?

See score details

Environmental footprint

For 1000 monthly page views, this web page's footprint is:

- 32.4 l Blue water consumption
- 2.16 kgCO₂e Greenhouse gas emissions

What are the indicators?

Page weight

Too heavy

1.166 Mb

min median: 2.41 max

Target: 1.024 Unit: megabyte (Mb)

Complexity

Too complex

1904 elements

min median: 693 max

Target: 600 Unit: Number of DOM elements

Requests

Few requests

30 requests

min median: 78 max

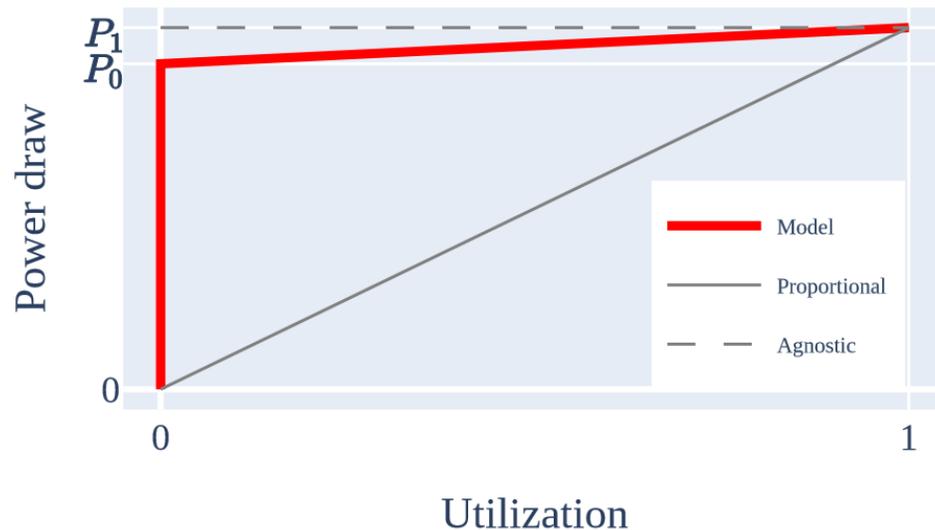
Target: 40 Unit: Number of server requests

<https://www.ecoindex.fr/en/result/?id=ec243ed4-737c-4754-9f3b-d811cc6cfe47#score-details>

Data transfer as proxy: problems

No proportionality

- Data \neq Network energy
- Data \neq User devices energy



Typical power profile of network hardware

Source: Jacob, R., & Vanbever, L. (2023). The internet of tomorrow must sleep more and grow old. <https://doi.org/10.1145/3630614.3630620>

Average values, concrete context is ignored

- Physical distance
 - between user device and server
- Transmission path
 - DSL, WiFi, mobile communications, satellite etc.

Access Network	kWh/GB (2020)
Wide (WAN)	0.007
Fixed (FAN)	0.07
Radio (RAN)	0.2

Energy intensity of network transfer in different access networks

Source: Coroama, V. (2021). Investigating the inconsistencies among energy and energy intensity estimates of the internet. Swiss Federal Office of Energy SFOE. https://vs.inf.ethz.ch/publ/papers/Coroama2021_InternetEnergy.pdf

Data transfer as proxy: what's it worth?

What it's NOT good for:

- ❌ Detailed carbon accounting → too imprecise
- ❌ Consequential claims → not credible
 - Example: "By reducing data volume by X MB, you saved Y kg CO₂"

What it IS good for: "Attributional Reasoning"

- ✅ Internal allocation: "Department X is responsible for Y% of our data footprint"
- ✅ Identifying hotspots and key drivers
- ✅ Creating incentives to optimize

Data transfer as proxy: positive effects

- **Direct:**

Less data = less processing, transmission, storage

- **Indirect:**

Leaner apps → longer device lifespans, less hardware waste

- **Cultural shift:**

Encourages efficiency mindset

Estimating carbon emissions of network impact

Use the **Energy Intensity Model** (kWh/GB) for

- optimization
- tracking relative improvements

But:

- ⚠ Estimates \neq actual savings (networks don't scale linearly)
- ⚠ Report separately — don't add the network impacts to client-side or SCl scores
- ⚠ Use as directional compass, not precise measurement

Bottom line: Guide optimization decisions, don't claim exact savings

Estimating CO₂ emissions of network impact

HOW TO MEASURE AND ACT ON NETWORK CARBON EMISSIONS IN GREEN SOFTWARE

Tue, Aug 5, 2025 - by Arne Tarara & David Kopp 

We have gotten pretty good at measuring the emissions from things like computing, storage and memory usage, because the hardware is right in front of us. But when it comes to network traffic, things get murky.

SO WHAT IS THE CARBON FOOTPRINT OF SENDING A CAT MEME?

The internet is a tangled web of cables, routers, and towers and your data might take a wildly unpredictable route from Berlin to Amsterdam (via Belgium, Poland or Denmark).

Basically, we often can't know the exact path or what networking hardware is used along the way, which makes it difficult to know how much energy is really being used. Academia has looked at this problem in the past through different approaches and this blog article shall analyse which of these models is most useful for Green Software Practitioners.

<https://www.green-coding.io/blog/network-carbon-emissions-in-green-software/>

Website Carbon Calculators – Conclusion

- **Benefits:**

- Estimation of the carbon footprint per website visit with little effort
- Easy comparison with other websites

- **Problems:**

- Data transfer as the main proxy metric
 - may lead to false conclusions
- Important factors are left out
 - User interactions: Accepting cookies, lazy loading, visiting multiple pages, etc.
 - Compute-intensive background activities: Animations, JavaScript calculations, etc.
 - Colors used, dark mode (affect the energy consumption of the screen)
- Lack of detailed analysis options

- **Positive:**

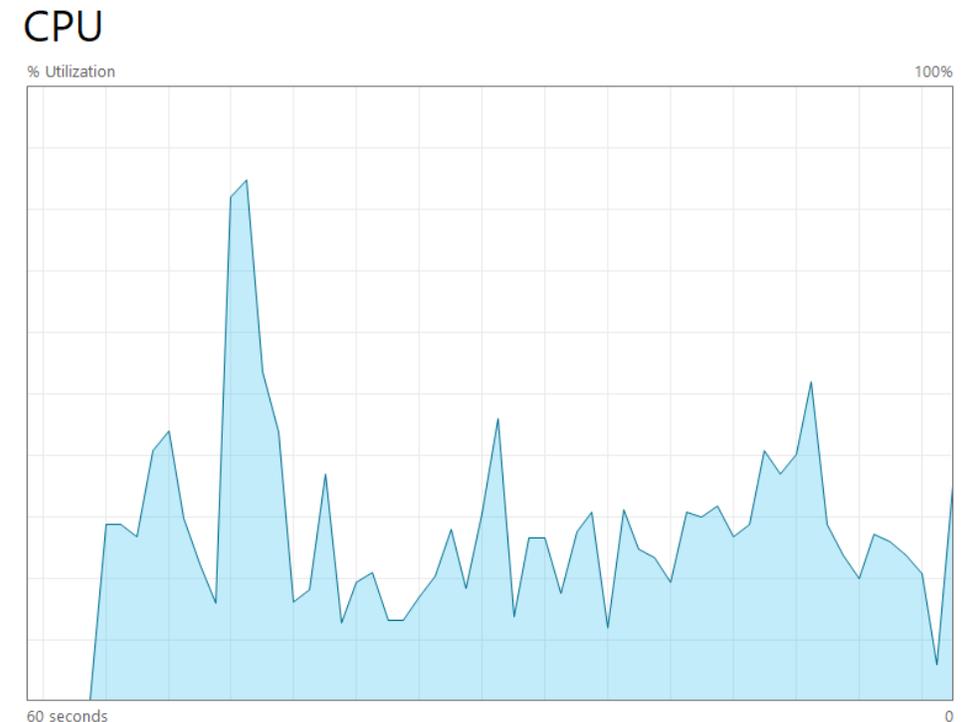
- Creates an incentive to reduce data volume

How can we better measure environmental impacts?

- **Direct measurement on the client side**
 - CPU/GPU/memory/energy monitoring
 - Make the costs of complex DOM and CSS structures and JS parsing visible
- **Recording of aspects other than “just” loading**
 - Real usage scenarios with interactions
 - Acceptance of cookies
 - Lazy loading of resources
 - Background activities
 - Animations, etc.
- **Profiling for detailed analysis**
 - Identification of bottlenecks
- However: Estimation of network impact is still necessary

Proxy Metric: Hardware Utilization

- Bottom-up approach
- Measure the **utilization** of hardware components on a **reference device** and convert it into energy values
- Big advantage:
 - It actually measures what happens on the client!
- Yet, energy consumption needs to be calculated



Digital Sustainability Report

Client: www.eco-compute.io

Date: November 7, 2025 - November 8, 2025

Overview

Coverage: views / 1 page ⓘ

 CO2e	 Energy	 Rating ⓘ
0.12 g	0.17 Wh	<p>Load Rating ⓘ</p> <p>A+ A B C D E F</p> <p>Scroll Rating ⓘ</p>

<https://web.cardamon.io/reports/ANvF7>

Frontend



CO2e

0.08 g



Energy

0.09 Wh

Network



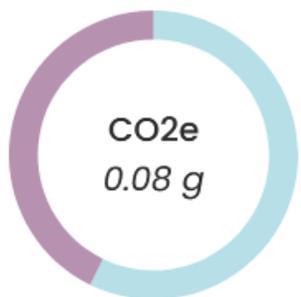
CO2e

0.04 g



Energy

0.08 Wh

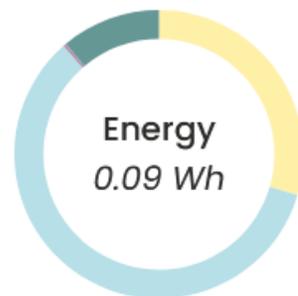


Operational

0.05 g

Embodied

0.03 g



CPU

0.03 Wh

Screen

0.05 Wh

Data

0.00 Wh

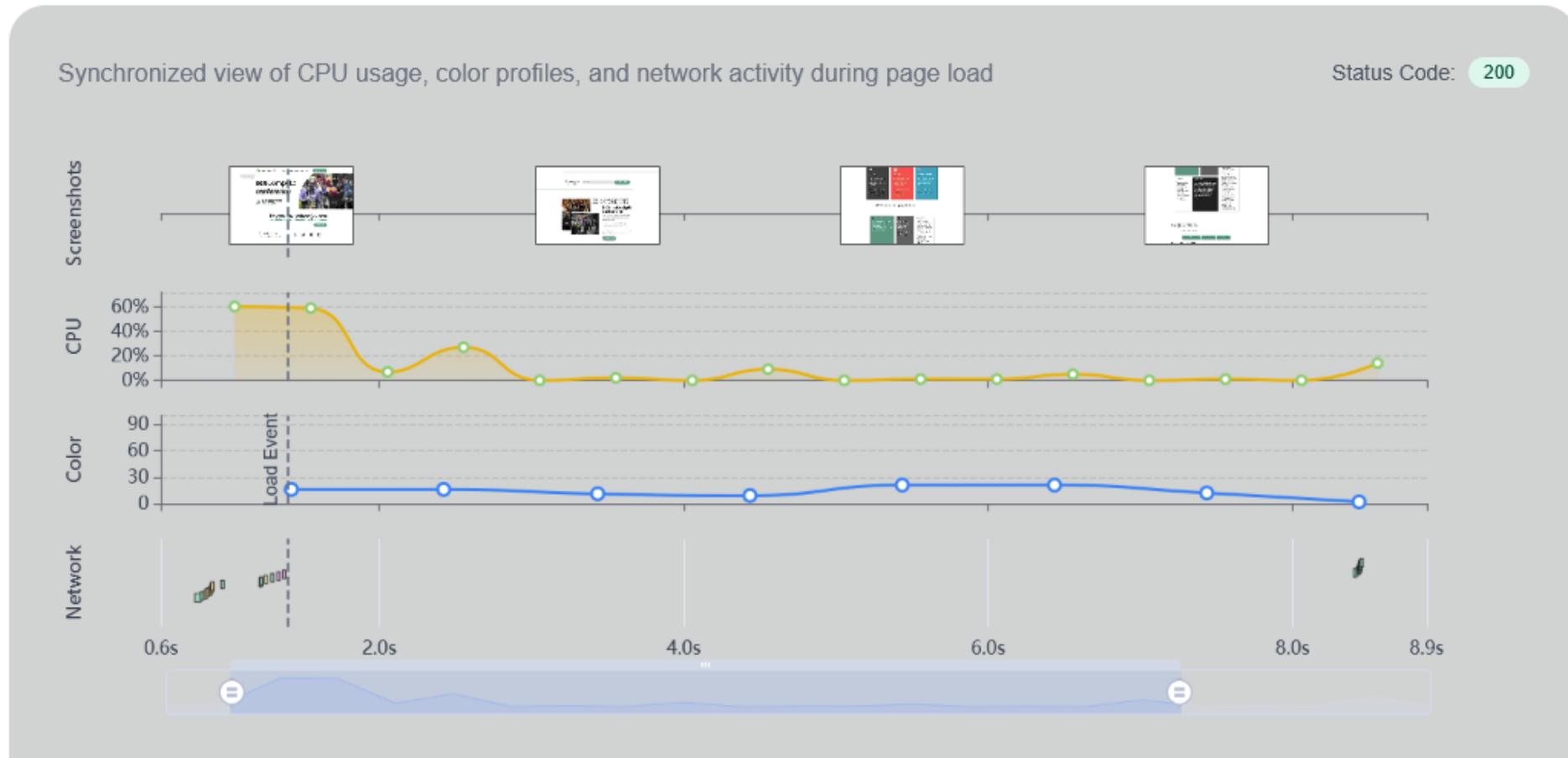
Idle

0.01 Wh

<https://web.cardamon.io/reports/ANvF7>

Cardamon Web – Analysis

Page Load Timeline



<https://web.cardamon.io/reports/ANvF7>

GreenFrame CLI



- Installation

```
$ curl https://assets.greenframe.io/install.sh | bash
```

- Measurement

```
$ greenframe analyze https://www.eco-compute.io/
```

```
✓ Check configuration file
✓ Retrieving Git information
✓ Analysis is in progress locally
  ✓ Docker version 27.2.0, build 3ab4256
  ✓ Running 1 scenario(s)...
```

```
Analysis complete !
```

```
Result summary:
```

```
✓ main scenario completed
The estimated footprint is 16.66 mg eq. co2 ± 2.6% (37.693 mWh).
```

<https://docs.greenframe.io/commands/>

Direct Energy Measurement

- on a generic device:

- Green Metrics Tool / webNRG

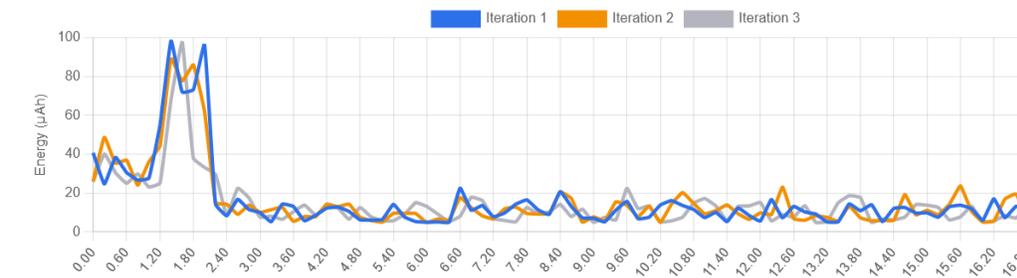
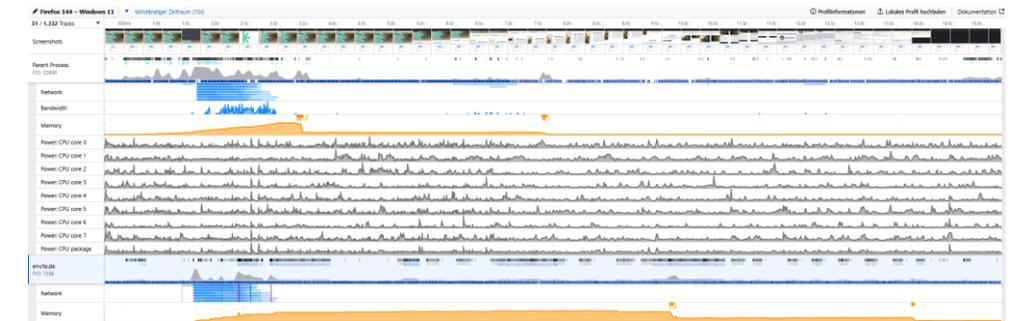
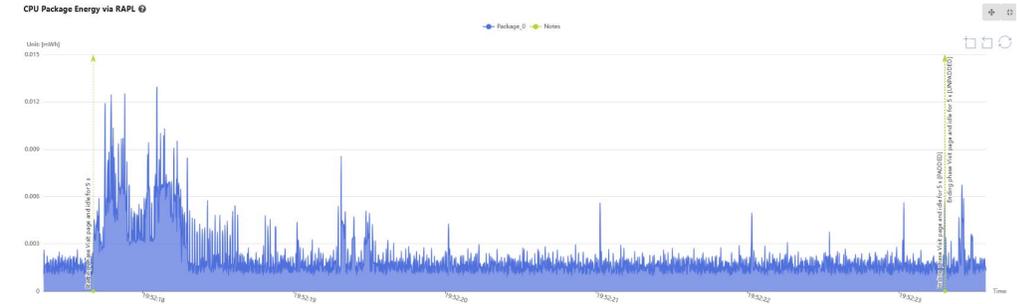


- Firefox Profiler



- on a real end user device:

- Greenspector Studio





What? websites produce carbon emissions? ×

Websites emit carbon through three factors: **Hosting**, **Network Traffic** and **User Viewing**

While [others look at green hosting](#) we created **webNRG** to measure **Network Traffic** and the power consumption while **Viewing** the page.

Check your site now and find out how emission your website creates for a **typical 10k users per month!**

 Website (e.g. [www.my-page.io](#))

 Your e-mail (optional. we ping you when measurement is done)

Send me results: One Time Every week

You can also leave e-mail empty and check back here in ~5-30 Minutes

Measure

- **Energy Measurement using the Green Metrics Tool**

- Loads the page using Playwright and waits for 5 seconds
- CPU + DRAM energy is captured via RAPL (2ms intervals)
- Cached reverse proxy: Isolation from browser startup and network latency
- Rendering Energy Label: A+ (best) to F (25% power increments per grade)



- **Network Traffic & Carbon**

- Captured at adapter level (actual transferred data)
- Network Data Label: Same grading system as the SWDM
- Carbon calculated using energy intensity model (constant: 41 Wh/GB)



<https://website-tester.green-coding.io/methodology.html>



<https://www.eco-compute.io>

Tested on Sat Nov 08 2025 18:53:58 GMT+0100 (Central European Standard Time)



Rendering Energy

The CPU power consumption for rendering was **3.40 W**

With a visit time of **5.63 s** this equates to **5.32 mWh**

If you have 10.000 people visiting your page per month this would consume **0.05 kWh** of energy



Network Data

The network data transfer the website was **2255.19 kB** for loading and staying on the page for **5.63 s**

Assuming you have 10,000 visitors per month this website would produce about **9.70 kg**

<https://website-tester.green-coding.io/details.html?page=https%3A%2F%2Fwww.eco-compute.io>

WebNRG – Measurement Details



 Phase Duration via Syscall

5.63 s 

 Network Traffic via cgroup

2.26 MB 

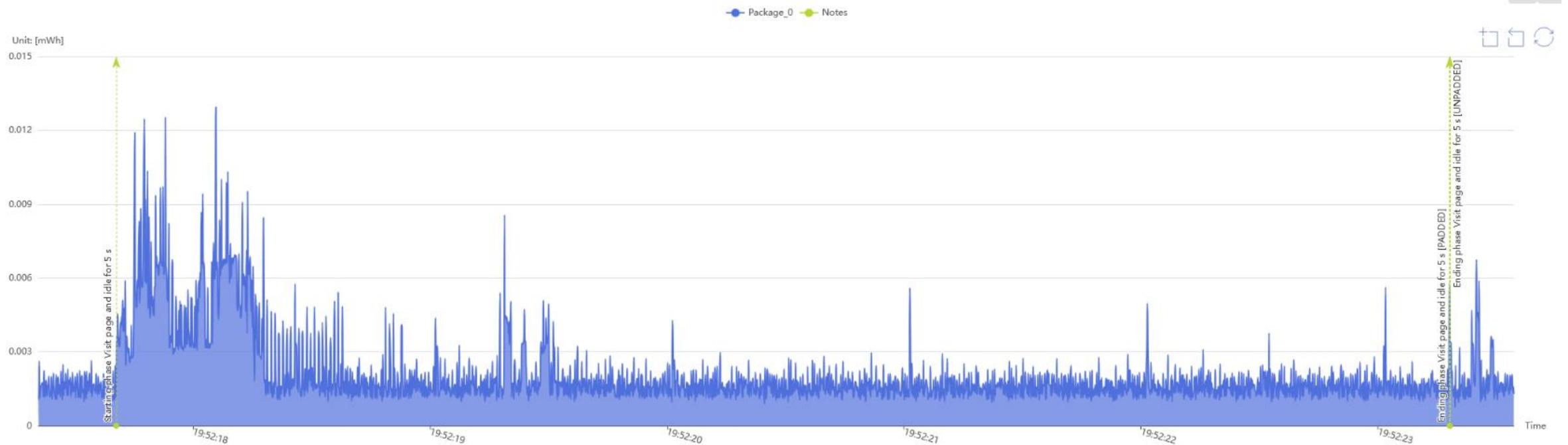
 CPU Package Energy via RAPL

5.32 mWh 

 DRAM Energy via RAPL

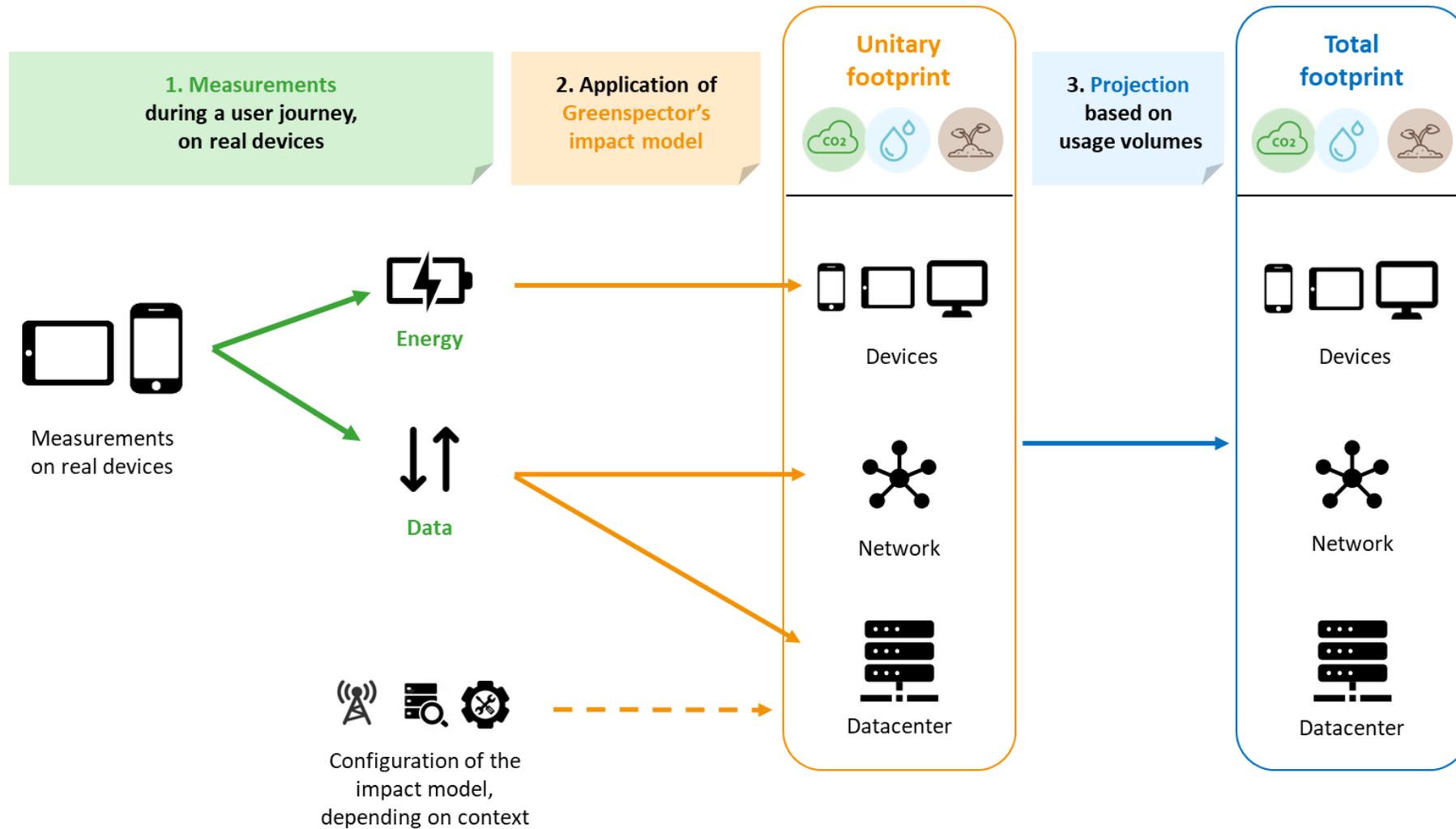
1.42 mWh 

CPU Package Energy via RAPL 



<https://metrics.green-coding.io/stats.html?id=dc49d51a-b89f-4c8a-943e-e4c001dad428>

Greenspector Studio – Methodology



Greenspector Studio – Benchmark



New analysis

App description

This information will allow us to configure the measurements.

What is the name of your application? _____

ecoCompute

What do you call this measurement? _____

7.11.2025

i This name will be used to compare other versions. It may be the same version code as your software, the current date...

On which smartphone do you want to measure?

Galaxy S7 Galaxy S9

Is your application web or mobile (Android)?

Web Android

i Your application is based on web technology that can be consulted in a browser (website, PWA, intranet, etc.) or is an Android mobile application (native, hybrid, etc.).

Next

Configuring the web application

In order to carry out the tests, we need the URL of your site.

What is the domain name or root URL of your application? _____

https://www.eco-compute.io

i The URL must use Hypertext Transfer Protocol Secure (HTTPS)

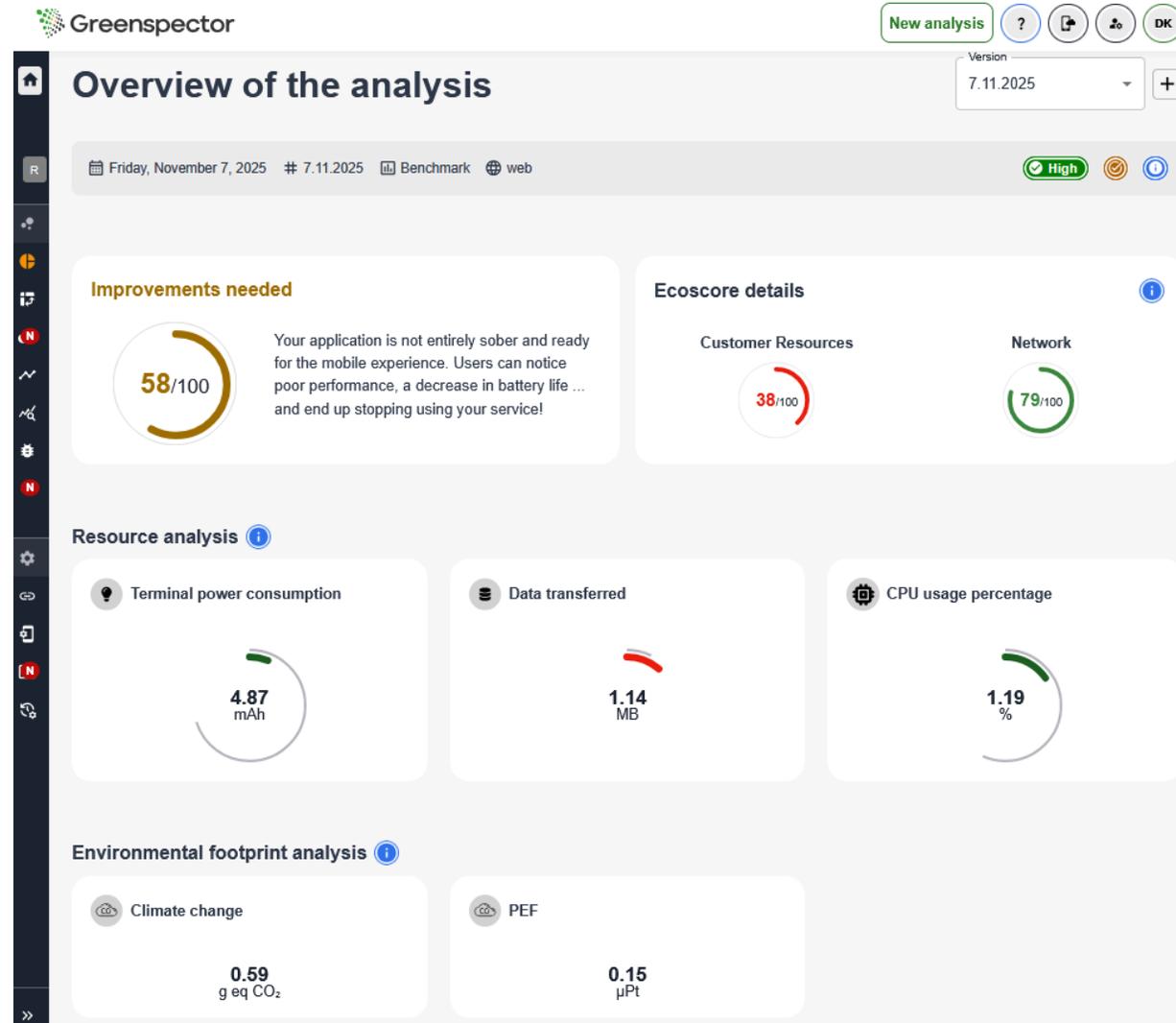
Is your URL public?

Yes No

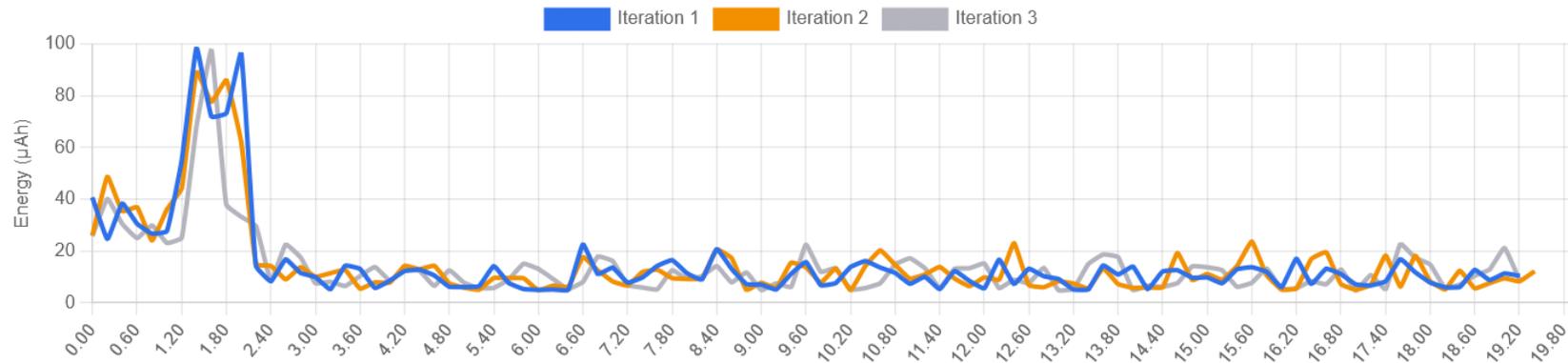
i To measure your site on our test cloud, the URL must be accessible on our device. Otherwise, you will be able to measure on your local device.

Save

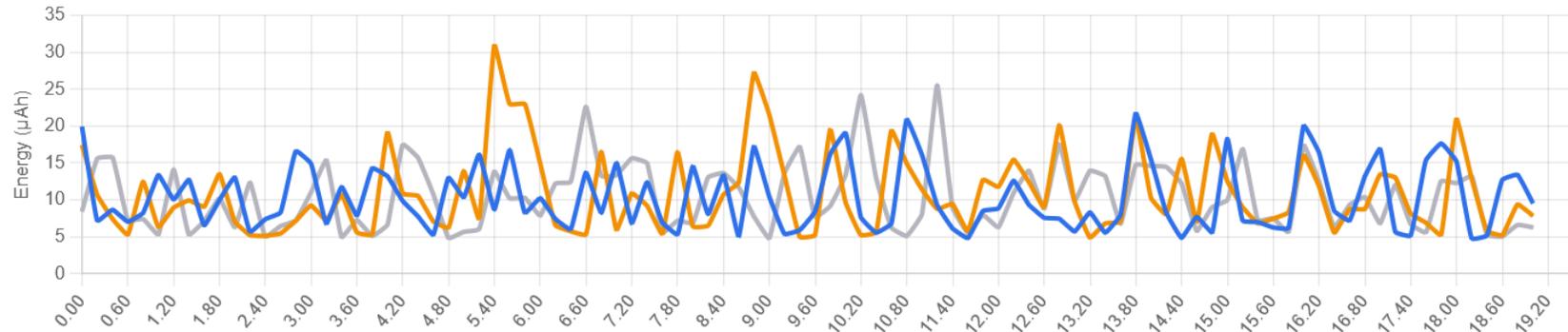
Greenspector Studio – Analysis



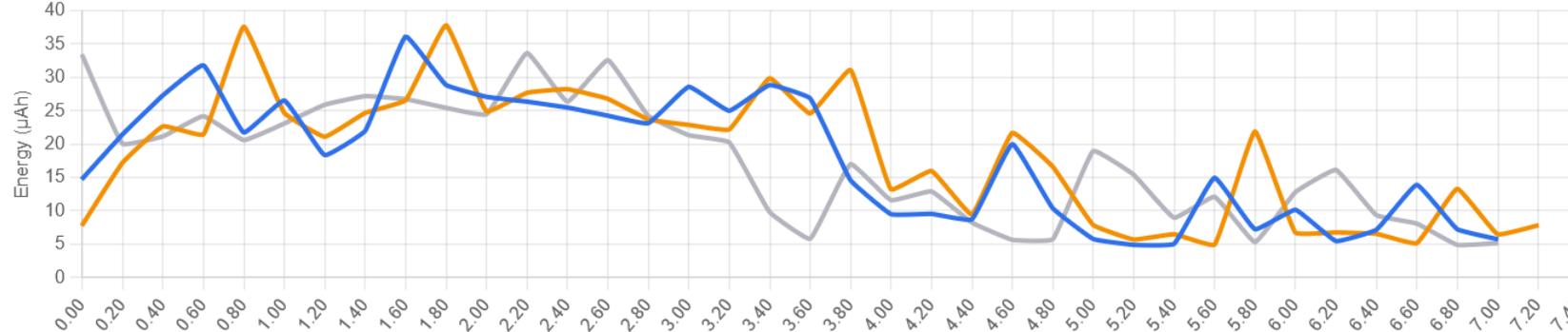
Greenspector Studio – Measurement Details



Loading



Idle



Scrolling

Overview of results for eco-compute.io

Methodology	Tool	Incl. server estimation	CO ₂ e (mg)	Energy (mWh)	Notes
Data transfer as main proxy metric	WebsiteCarbon.com	✓	120		
	Kastor	✓	353		
	Beacon	✓	444		
	Ecograder	✓	460		
	ecoIndex	✓	2160		own methodology, not SWDM
Hardware utilization as proxy metric	GreenFrame CLI	✗	17	37.7	
	Cardamon Web (client)	✗	80	92	only client
	Cardamon Web (network)	✗	40	82	only network (impacts are estimated)
Energy measurement	WebNRG (client)	✗	2.9	6.7	only CPU + DRAM
	WebNRG (network)	✗	81	285	only network (impacts are estimated)
	Greenspector Studio	✓	590	18	low carbon intensity of France is used

Agenda

Introduction

Methodologies & Tools

✦ User Interactions

Good & Bad Websites

Conclusion

From Page Loads to Real Interactions

- In reality, users interact with the website
 - Scrolling, clicking, navigating...

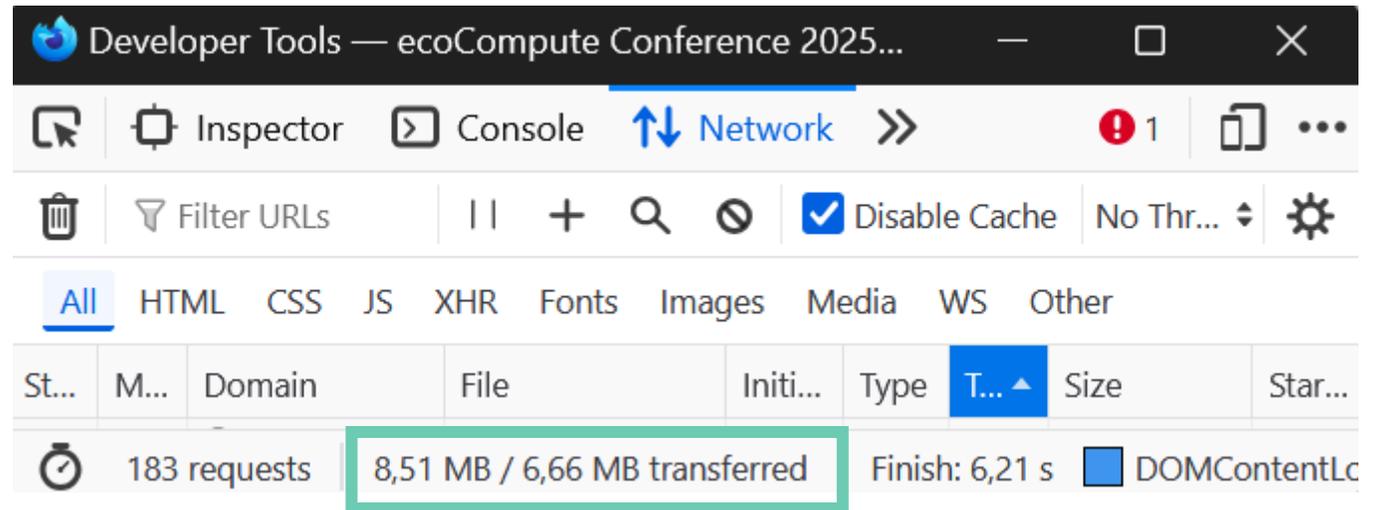


First step: Scrolling down

- The simplest and most common page interaction
- Only a few tools are including scrolling in their measurements by default
 - Greenspector Studio: scrolling for ~3s
 - Cardamon: scrolling for 10s
 - ecoIndex: scrolling to bottom

Scrolling on websites: eco-compute.io

Tool	Data (MB)
Greenspector Studio	1.14
ecoIndex	1.17
Cardamon Web	1.32



→ Automatic scrolling with the tools did not work as expected!

Scrolling on websites: eco-compute.io

- Tools are typically using `window.scrollTo()`
- This does not work on the eco-compute.io website, due to:

```
body, html {  
  height: 100%;  
}
```

- "`height: 100%`" makes the body the scroll container
- Possible workaround: `document.body.scrollTo()`

Scrolling on websites: developer-week.de

Tool	Data (MB)	Scrolling?	Notes
Ecograder	1.3	✗	
WebNRG	5.3	✗	
Greenspector Studio	8.2	✓	scrolling for 3 seconds
Cardamon Web	22.4	✓	scrolling for 10s
ecoIndex	31.5	✓	scrolling to bottom of the page

Big differences (web page contains a video that is lazy loaded during scrolling)

User Journeys

- Automated execution of a typical usage scenario in a (headless) browser
- Advantages:
 - Environmental impact of frequently used or resource-intensive use cases
 - Helpful for reporting
 - Good starting point for optimizations
 - Recording of potentially resource-intensive aspects:
 - Accepting cookies
 - Lazy loading of resources
 - Background activities
 - Animations
 - ...
 - Applying the Software Carbon Intensity (SCI) standard

SCI for Web

- root & branch (makers of Cardamon) are currently working on this topic: <https://cardamon.io/sci>



Oliver Winks @ Green IO London (2025)
Source: [LinkedIn](#)

- Green Metrics Tool supports SCI within a single usage scenario

Measuring the environmental impacts of automated user journeys – Tools

- **GreenFrame**

- Energy measurement: Conversion of utilization data into energy consumption
- Automation: Playwright with headless browser



- **Cardamon**

- Energy measurement: Conversion of utilization data into energy consumption
- Automation: Any tool (e.g., Playwright) with headless browser



- **Green Metrics Tool**

- Energy measurement: Energy measurement on reference device (server)
- Automation: Any tool (e.g., Playwright) with headless browser

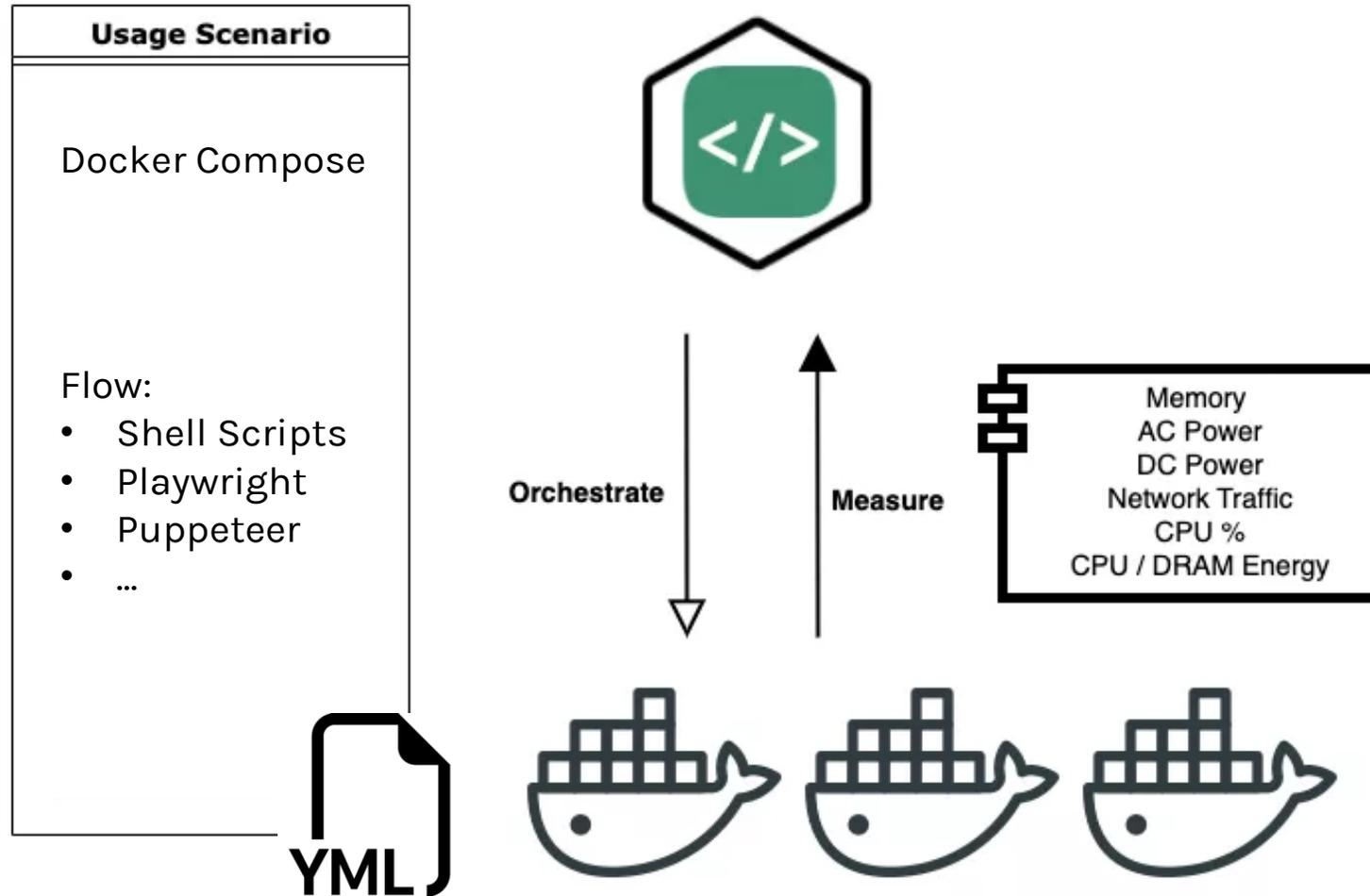


- **Greenspector Studio**

- Energy recording: Energy measurement on real end device (smartphone/tablet)
- Automation: Part of the tool; own DSL



Energy Measurement with the Green Metrics Tool



<https://docs.green-coding.io/docs/prologue/measurement-process/>

Energy Measurement with the Green Metrics Tool



usage_scenario.yml (excerpt):

```
name: "Website User Journey"

services:
  playwright:
    image: greencoding/gcb_playwright:v21

flow:
  - name: Execute user journey
    container: playwright
    commands:
      - type: console
        command: python3 /repo/playwright-flow.py
```

Energy Measurement with the Green Metrics Tool



playwright-flow.py:

```
browser = await playwright.chromium.launch(headless=False, args=["--headless=new"], slow_mo=2500)
context = await browser.new_context(viewport={"width": 1280, "height": 720})
page = await context.new_page()
# Load Home Page
await page.goto(website_url)
# Wait, until the cookie banner is visible
await page.locator('#uc-main-dialog').wait_for(state='visible')
# Accept cookies
await page.get_by_role('button', name='Accept all').click()
# Wait until the cookie banner disappears
await page.locator('#uc-main-dialog').wait_for(state='hidden')
# Go to page "Program"
await page.get_by_text('→Program').scroll_into_view_if_needed()
await page.get_by_role('link', name='→Program').click()
# ...
```


Greenspector Measurement Script



```
launchBrowser
browserGoToUrl,$WEBSITE_URL

# Load home page
assertNotExistsId,uc-main-dialog
measureStart,CHRG home_no_cookies
pressEnter
pause,{PAUSEAFTERACTION}
waitUntilId,uc-main-dialog
pause,{PAUSEAFTERLOAD}
measureStop

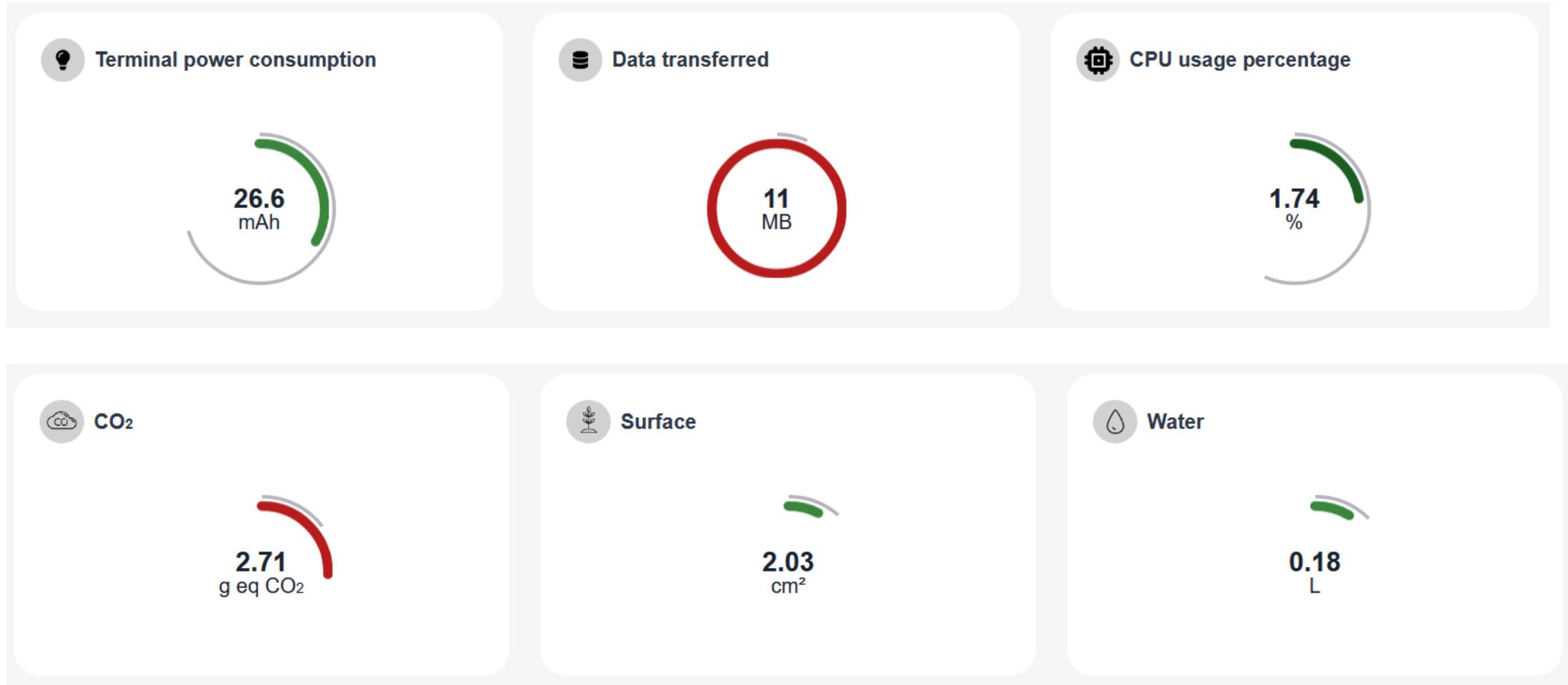
# Measure background activities
measureStart,PAUSE_home_no_cookies
pause,{PAUSEDURATION}
measureStop
```

```
# Accept cookies
measureStart,CHRG home_accept_cookies
clickById,accept
pause,{PAUSEAFTERLOAD}
measureStop

# Measure background activities
measureStart,PAUSE_home_accept_cookies
pause,{PAUSEDURATION}
measureStop

# Go to the button "→Program"
measureStart,SCROLL_to_button_to_pogramm
scrollToText,→Program
pause,{PAUSEAFTERACTION}
measureStop
```

Resource consumption & environmental impacts



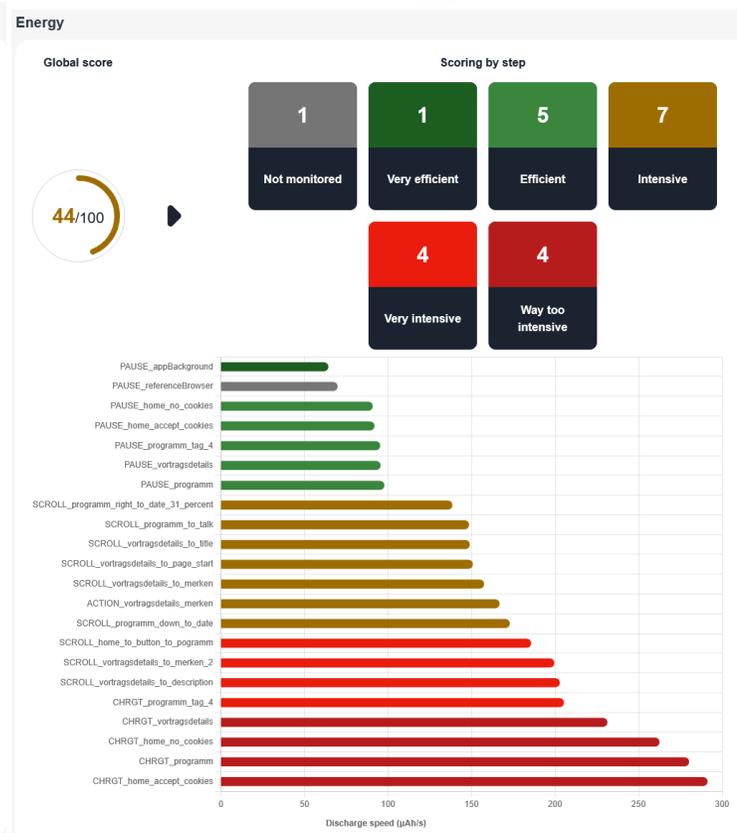
Results per Step



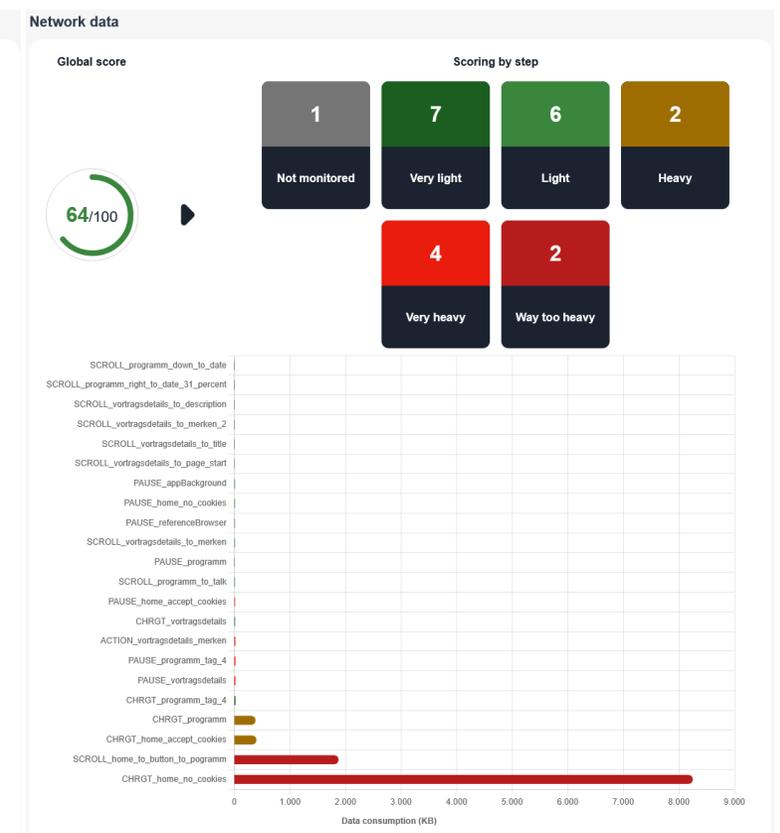
Time



Energy



Network



Tool Overview: Our Recommendations

	Measurement			Assessment	
Methodology	Data transfer as the main proxy metric	Hardware utilization as the main proxy metric	Energy measurement	Analysis of best practices	Manual profiling in the browser
Tools	<ul style="list-style-type: none"> • CO2.js • Website Carbon Calculator • Ecograder • Kastor • Ecolindex.fr • Klimatest • Beacon • ... 	<ul style="list-style-type: none"> • GreenFrame^(€) • Cardamon Web 	<ul style="list-style-type: none"> • WebNRG / Green Metrics Tool • Greenspector Studio^(€) 	<ul style="list-style-type: none"> • GreenIT-Analysis • Ecograder • Kastor 	<ul style="list-style-type: none"> • Firefox Profiler • Chrome DevTools • Safari Web Inspector

(€) Only really useful in the paid version

Agenda

Introduction

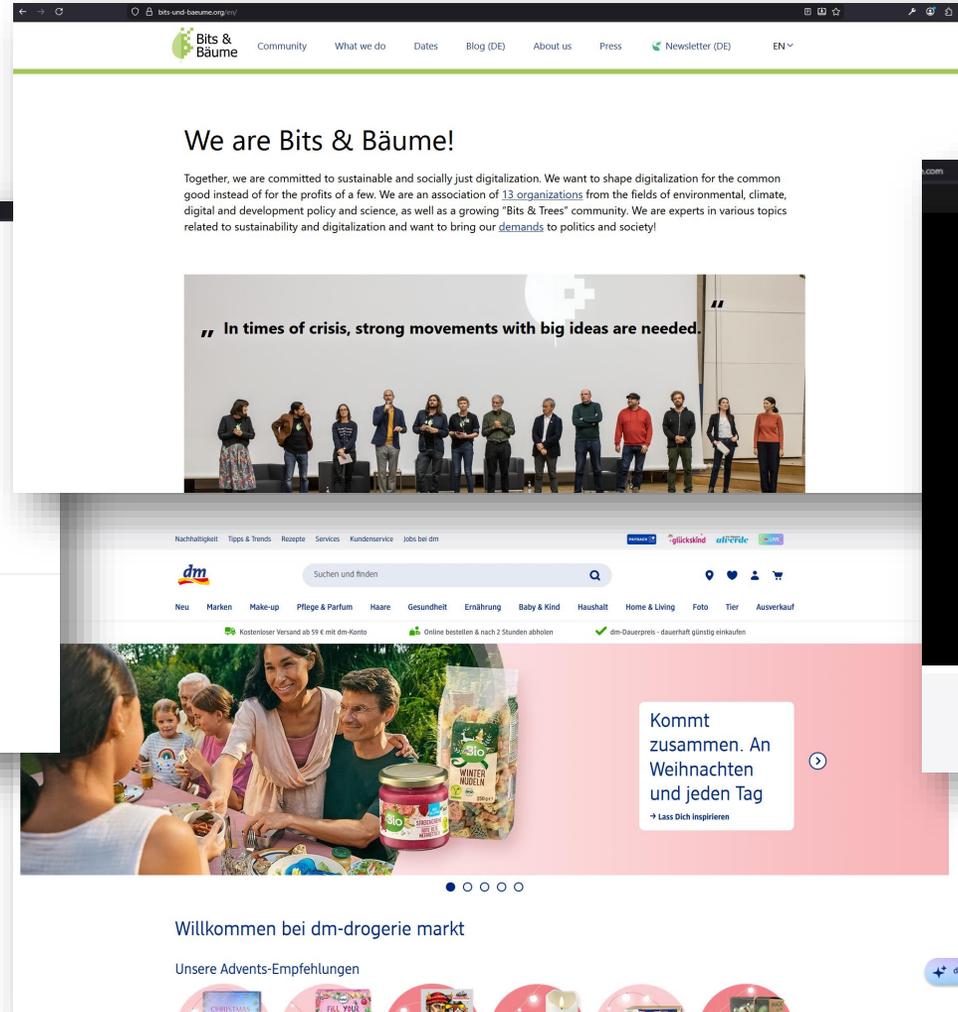
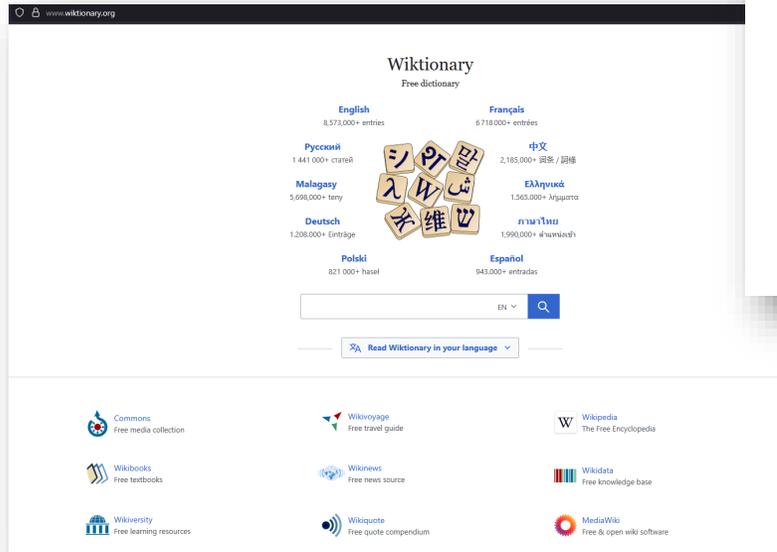
Methodologies & Tools

User Interactions

 Good & Bad Websites

Conclusion

What makes websites good or bad?



What makes websites good or bad?

	Rendering Energy Score	Network Data Score
wiktionary.org		
bits-und-baeume.org		
apple.com		
dm.de		

wiktionary.org

www.wiktionary.org

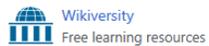
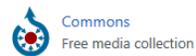
Wiktionary

Free dictionary

English 8,573,000+ entries	Français 6 718 000+ entrées
Русский 1 441 000+ статей	中文 2,185,000+ 词条 / 詞條
Malagasy 5,698,000+ teny	Ελληνικά 1,565,000+ λέξεις
Deutsch 1,208.000+ Einträge	ภาษาไทย 1,990,000+ คำพ้องศัพท์
Polski 821 000+ hasel	Español 943.000+ entradas

EN

 [Read Wiktionary in your language](#)





Rendering Energy

The CPU power consumption for rendering was **3.16 W**

With a visit time of **5.45 s** this equates to **4.79 mWh**

If you have 10.000 people visiting your page per month this would consume **0.05 kWh** of energy



Network Data

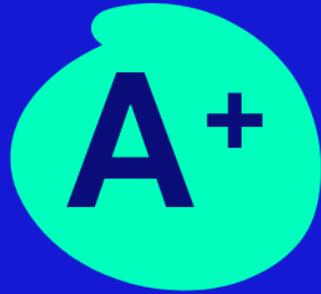
The network data transfer the website was **114.99 kB** for loading and staying on the page for **5.45 s**

Assuming you have 10,000 visitors per month this website would produce about **0.49 kg**

<https://website-tester.green-coding.io/details.html?page=https://www.wiktionary.org>



Website carbon results for: [wiktionary.org](https://www.wiktionary.org)



Hurrah! This web page achieves a carbon rating of A+

This is cleaner than **99%** of all web pages globally



Learn about our [rating system](#)

This page was last tested on 18 Aug, 2025. [Test again](#)

<https://www.websitecarbon.com/website/wiktionary-org/>

Overview

Coverage: views / 1 page 

 CO2e

0.08 g

 Energy

0.09 Wh

 Rating 

Load Rating 



Scroll Rating 

<https://web.cardamon.io/reports/H6KcS>

wiktionary.org



Developer Tools — Wiktionary — https://www.wiktionary.org/

Inspector Console Debugger Network Style Editor Performance

Filter URLs | Disable Cache | No Throttling

All HTML CSS JS XHR Fonts Images Media WS Other

Status	Method	Domain	File	Type	Transferr...	Size
200	GET	www.wiktionary.org	/	html	18,56 kB	75,20 kB
200	GET	www.wiktionary.org	index-a282805166.js	js	7,14 kB	16,31 kB
200	GET	www.wiktionary.org	gt-ie9-38c8b5f74a.js	js	1,55 kB	586 B
200	GET	www.wiktionary.org	Wiktionary-logo-tiles_1x.png	png	35,17 kB	34,21 kB
200	GET	www.wiktionary.org	wiktionary.png	png	7,61 kB	6,66 kB
200	GET	www.wiktionary.org	piece.ico	vnd.micr...	7,60 kB	6,62 kB

6 requests | 139,59 kB / 77,62 kB transferred | Finish: 642 ms | DOMContentLoaded: 459 ms | load: 483 ms

- Only 6 requests
- Only 139 kB

bits-und-baeume.org



We are Bits & Bäume!

Together, we are committed to sustainable and socially just digitalization. We want to shape digitalization for the common good instead of for the profits of a few. We are an association of [13 organizations](#) from the fields of environmental, climate, digital and development policy and science, as well as a growing “Bits & Trees” community. We are experts in various topics related to sustainability and digitalization and want to bring our [demands](#) to politics and society!





Rendering Energy

The CPU power consumption for rendering was **3.29 W**

With a visit time of **5.52 s** this equates to **5.03 mWh**

If you have 10.000 people visiting your page per month this would consume **0.05 kWh** of energy



Network Data

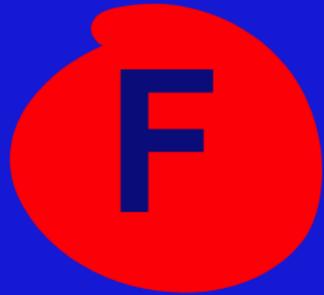
The network data transfer the website was **5512.85 kB** for loading and staying on the page for **5.52 s**

Assuming you have 10,000 visitors per month this website would produce about **23.69 kg**

<https://website-tester.green-coding.io/details.html?page=https://bits-und-baeume.org>



Website carbon results for: [bits-und-baeume.org](https://www.websitecarbon.com/website/bits-und-baeume.org/)



Oh no! This web page achieves a carbon rating of F

This is dirtier than **71%** of all web pages globally



Learn about our [rating system](#)

This page was last tested on 11 Nov, 2025.

<https://www.websitecarbon.com/website/bits-und-baeume.org/>

Overview

Coverage: 1 views / 1 page

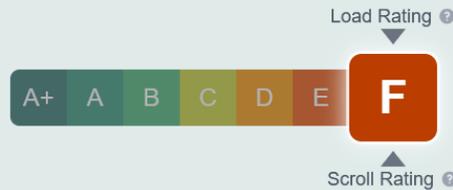
 CO2e

0.21 g

 Energy

0.35 Wh

 Rating



Frontend



CO2e

0.08 g



Energy

0.09 Wh

Network



CO2e

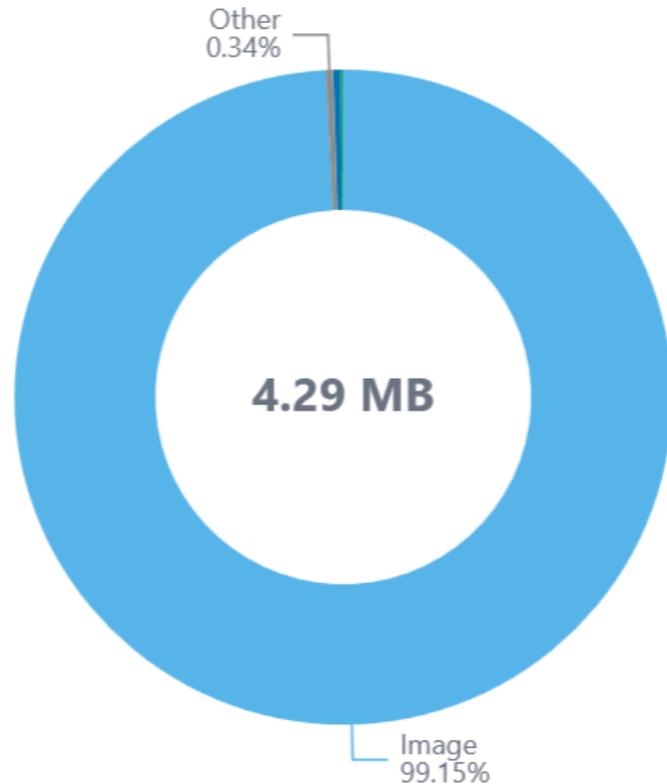
0.13 g



Energy

0.27 Wh

<https://web.cardamon.io/reports/vqHrK>



All Resources

Resource	Size
Image	4.25 MB
Document	15.78 KB
Other	15.04 KB
Stylesheet	5.56 KB
Manifest	707 B

<https://web.cardamon.io/reports/vqHrK>

bits-und-baeume.org

- Bad: a lot of data transferred over the network
 - 4.25 MB unoptimized images
- But: Rendering is highly efficient
 - WebNRG: Rendering Energy Score of A

→ Using data transfer only is here a bad proxy for the environmental impacts of the web page

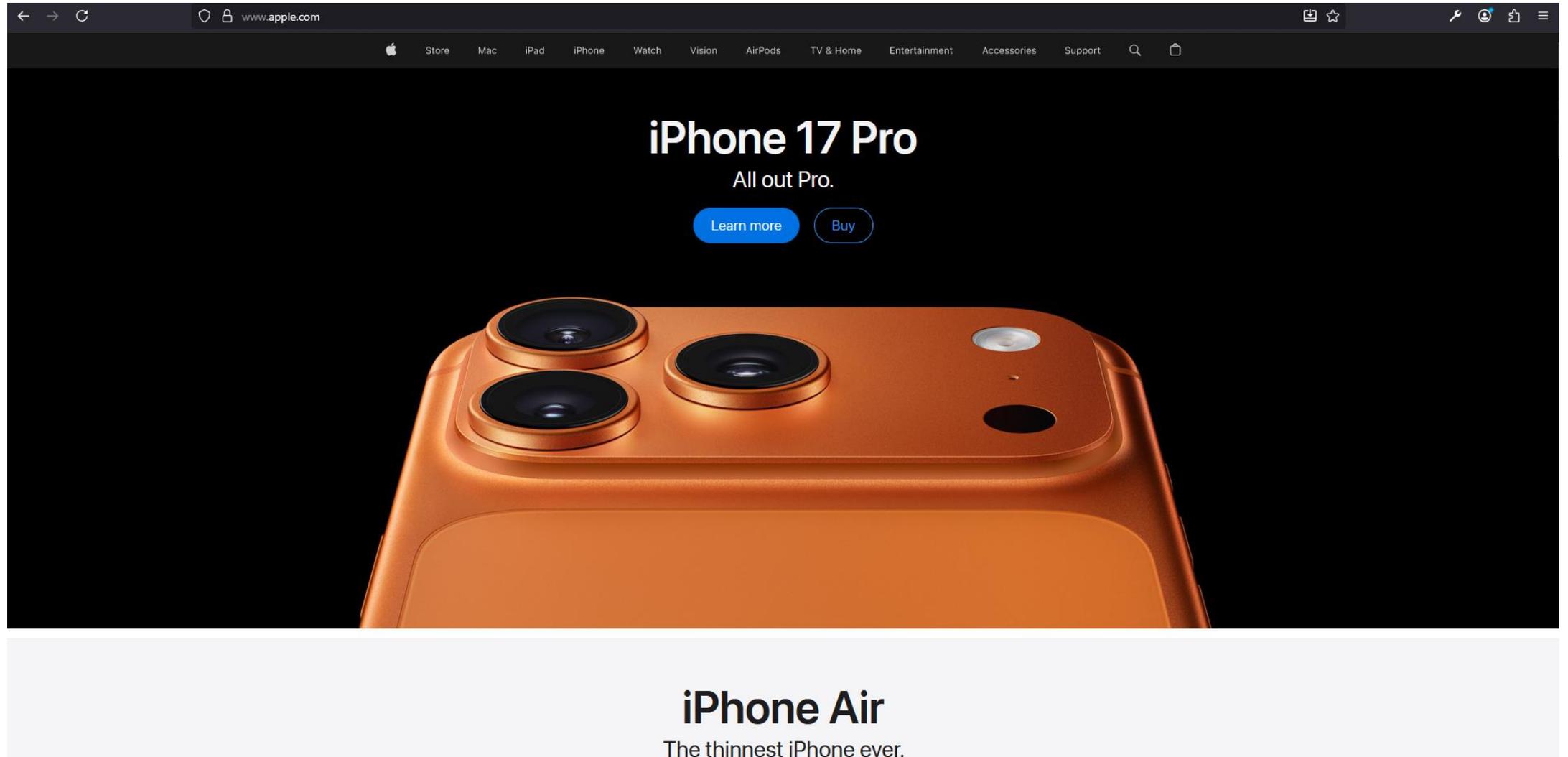
→ Why is the rendering so efficient?



HTML & CSS & no JavaScript:

File	Type	Transferred	Size
/	html	16,29 kB	95,01 kB
main.4d4bef4d8fcc5f0db816.css	css	5,82 kB	17,48 kB

- Server-side rendering is used
- No JavaScript at all!



The screenshot shows the Apple website homepage for the iPhone 17 Pro. The browser address bar displays "www.apple.com". The navigation menu includes links for Store, Mac, iPad, iPhone, Watch, Vision, AirPods, TV & Home, Entertainment, Accessories, and Support. The main content area features a large image of the back of an orange iPhone 17 Pro, highlighting its triple-camera system. The text "iPhone 17 Pro" is prominently displayed in white, followed by the tagline "All out Pro." Below this, there are two blue buttons: "Learn more" and "Buy". At the bottom of the page, a light gray banner introduces the "iPhone Air" with the tagline "The thinnest iPhone ever."



Rendering Energy

The CPU power consumption for rendering was **3.67 W**

With a visit time of **5.73 s** this equates to **5.85 mWh**

If you have 10.000 people visiting your page per month this would consume **0.06 kWh** of energy

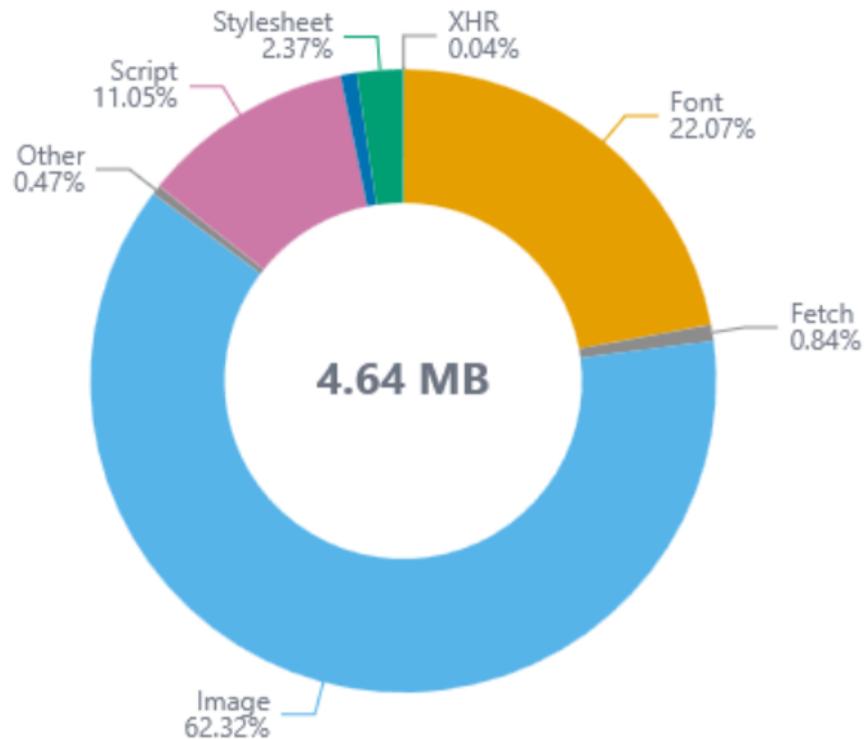


Network Data

The network data transfer the website was **3510.41 kB** for loading and staying on the page for **5.73 s**

Assuming you have 10,000 visitors per month this website would produce about **15.09 kg**

<https://website-tester.green-coding.io/details.html?page=https://www.apple.com>



All Resources

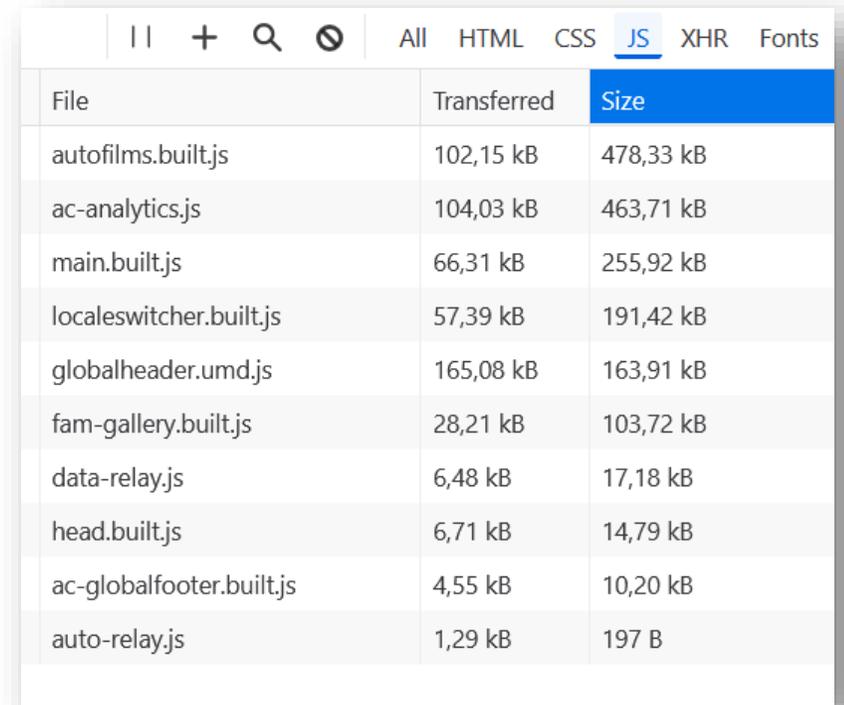
Resource	Size
Image	2.89 MB
Font	1.02 MB
Script	525.42 KB
Stylesheet	112.45 KB
Fetch	39.95 KB
Document	39.76 KB
Other	22.6 KB

<https://web.cardamon.io/reports/wLCu9>

apple.com

- Bad: a lot of data transferred over the network (4.6 MB)
 - 1 MB of custom fonts!
 - Unoptimized Images (JPEG, 2.8 MB)
- Good:
 - Server-side rendering is used
 - Only a few “nice-to-have” JS scripts (web page works with JS disabled)

JavaScript:



File	Transferred	Size
autofilms.built.js	102,15 kB	478,33 kB
ac-analytics.js	104,03 kB	463,71 kB
main.built.js	66,31 kB	255,92 kB
localeswitcher.built.js	57,39 kB	191,42 kB
globalheader.umd.js	165,08 kB	163,91 kB
fam-gallery.built.js	28,21 kB	103,72 kB
data-relay.js	6,48 kB	17,18 kB
head.built.js	6,71 kB	14,79 kB
ac-globalfooter.built.js	4,55 kB	10,20 kB
auto-relay.js	1,29 kB	197 B

The screenshot shows the dm.de website interface. At the top, there is a navigation bar with links for 'Nachhaltigkeit', 'Tipps & Trends', 'Rezepte', 'Services', 'Kundenservice', and 'Jobs bei dm'. Below this is the dm logo and a search bar with the text 'Suchen und finden'. A secondary navigation bar lists various product categories: 'Neu', 'Marken', 'Make-up', 'Pflege & Parfum', 'Haare', 'Gesundheit', 'Ernährung', 'Baby & Kind', 'Haushalt', 'Home & Living', 'Foto', 'Tier', and 'Ausverkauf'. Below the navigation bar, there are three promotional banners: 'Kostenloser Versand ab 59 € mit dm-Konto', 'Online bestellen & nach 2 Stunden abholen', and 'dm-Dauerpreis - dauerhaft günstig einkaufen'. The main content area is dominated by a white cookie consent dialog box. The dialog box features the dm logo and the heading 'Ein Moment für Deine Privatsphäre'. It contains the following text: 'Für eine optimale Nutzung unserer Services setzen wir und unsere Partner Cookies und ähnliche Technologien ein. Mit „Alles akzeptieren“ hilfst Du uns, Dir personalisierte Inhalte, Angebote und Kommunikation bereitzustellen. Dafür können Cookies auf Deinem Gerät gespeichert und Nutzungsdaten an unsere Partner übermittelt werden.' Below this, it states: 'Deine Einstellungen kannst Du jederzeit in der [Einwilligungsverwaltung](#) mit Wirkung für die Zukunft anpassen.' At the bottom of the dialog box, there are two buttons: 'Einwilligung ablehnen' and 'Alles akzeptieren'. Below the dialog box, the website content is partially visible, showing the text 'Willkommen bei dm-drogerie markt' and 'Unsere Advents-Empfehlungen' with a row of product images.



Willkommen bei dm-drogerie markt

Unsere Advents-Empfehlungen





Rendering Energy

The CPU power consumption for rendering was **7.89 W**

With a visit time of **5.72 s** this equates to **12.58 mWh**

If you have 10.000 people visiting your page per month this would consume **0.13 kWh** of energy



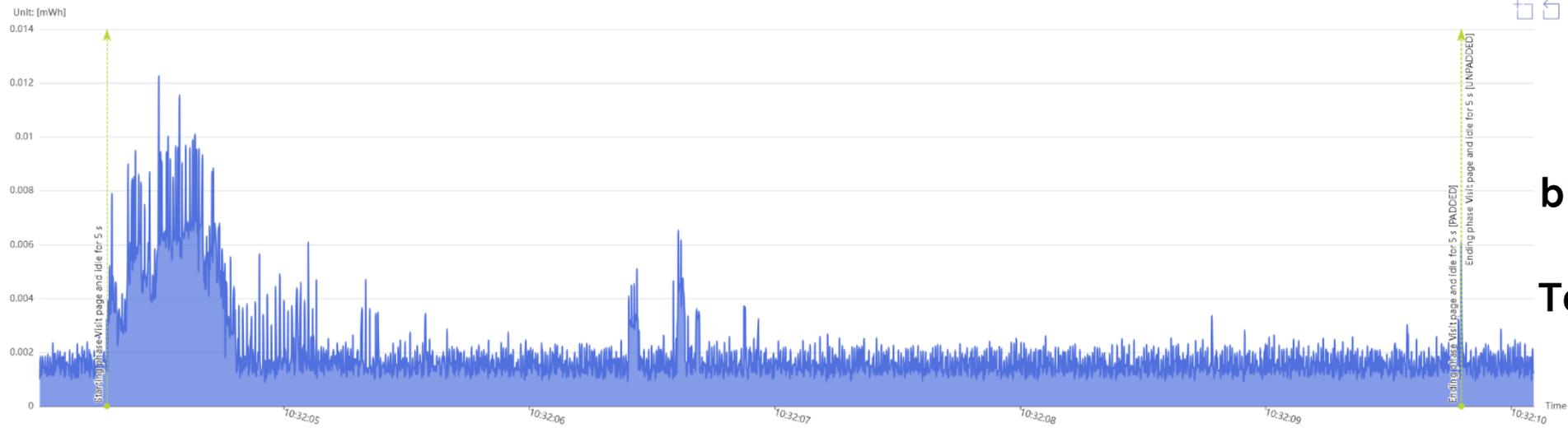
Network Data

The network data transfer the website was **3177.30 kB** for loading and staying on the page for **5.72 s**

Assuming you have 10,000 visitors per month this website would produce about **14.27 kg**

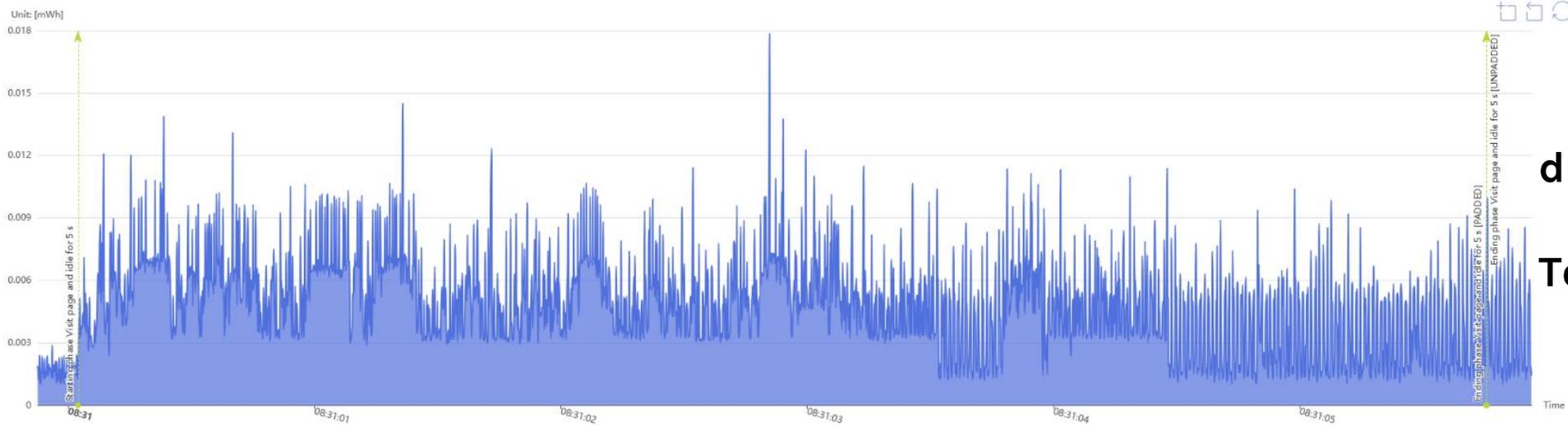
<https://website-tester.green-coding.io/details.html?page=https://www.dm.de>

dm.de - Comparison Energy Consumption



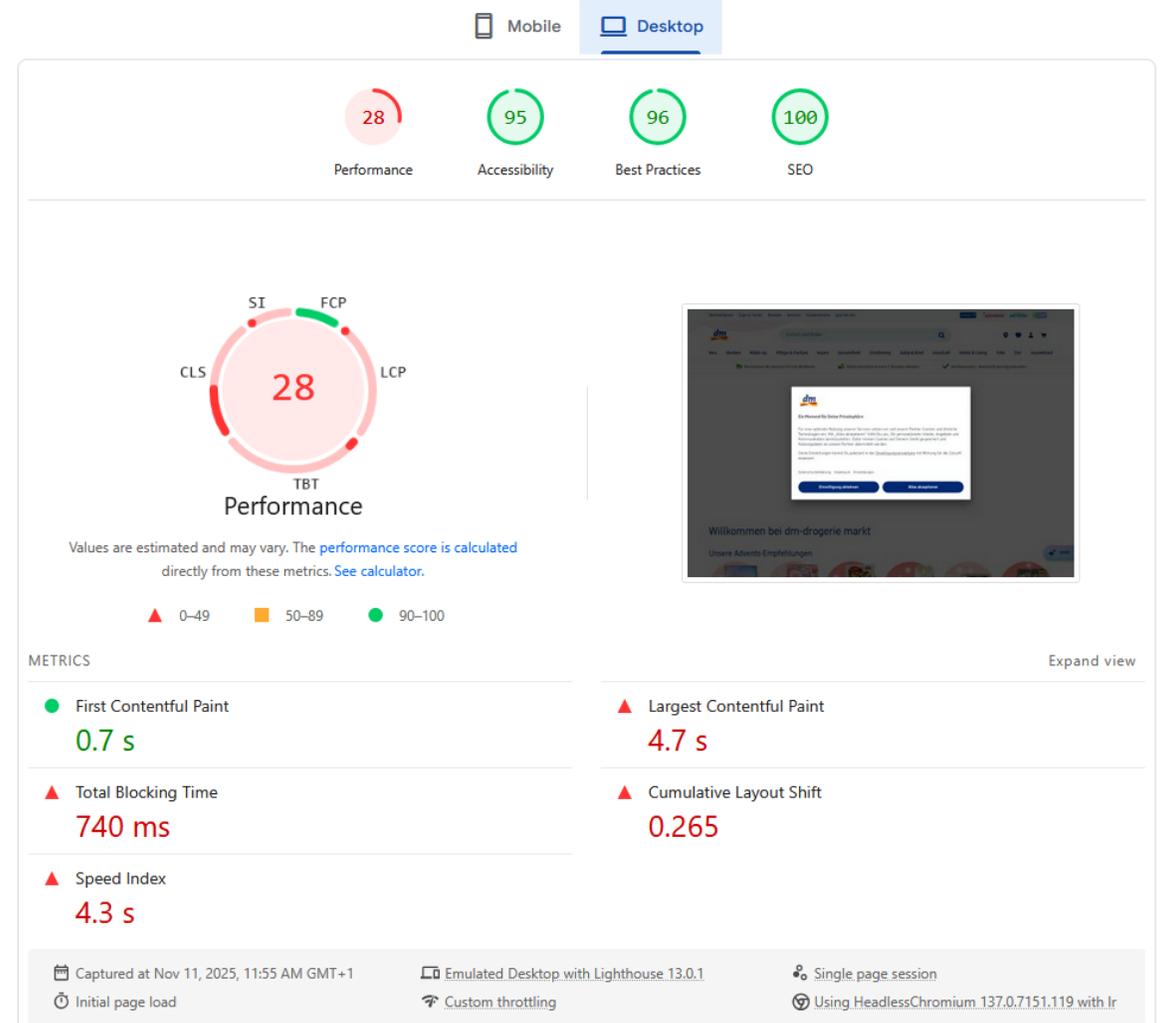
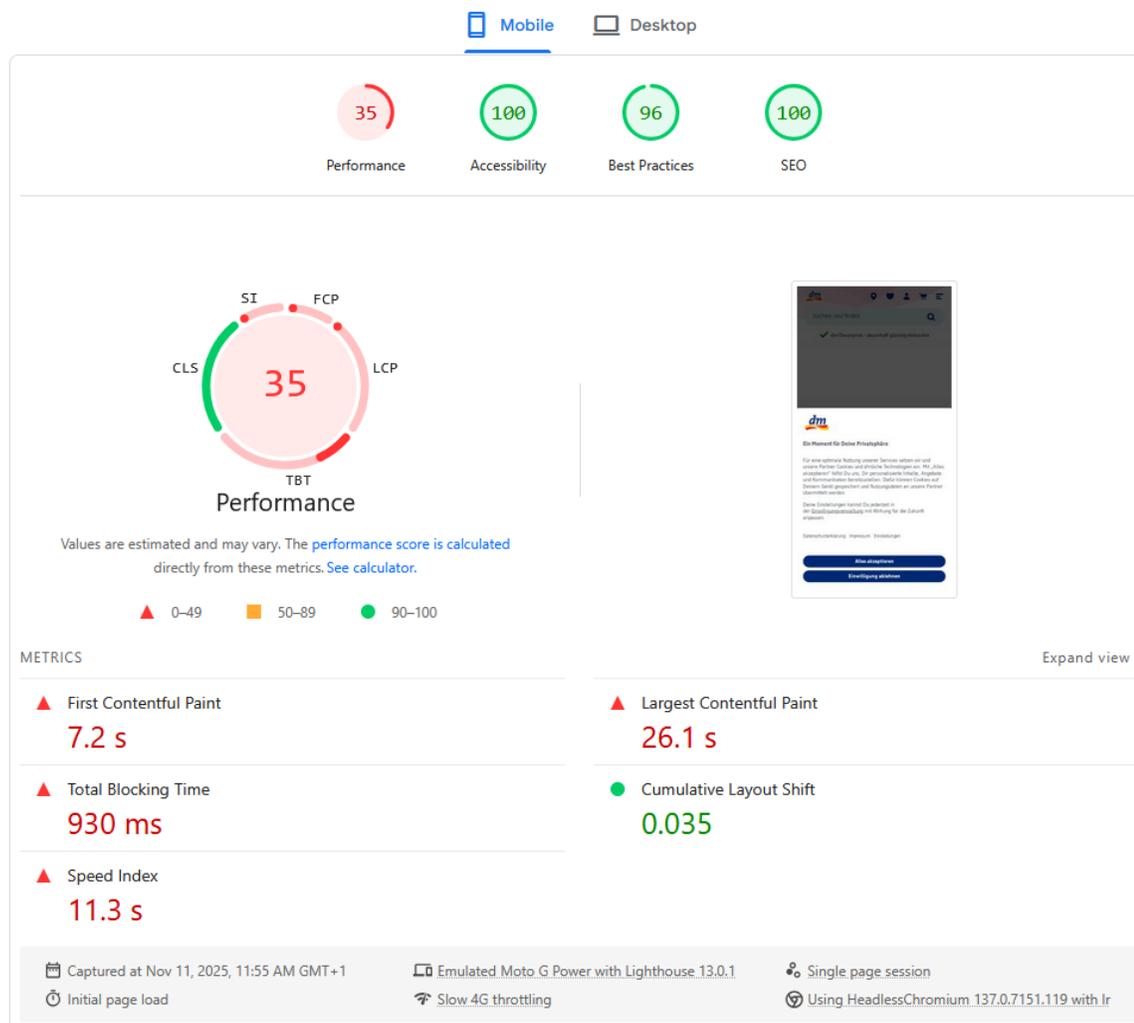
bits-und-baeume.org

Total: 5.03 mWh



dm.de

Total: 12.58 mWh



<https://pagespeed.web.dev/analysis/https-www-dm-de/mt8gqozxeo>

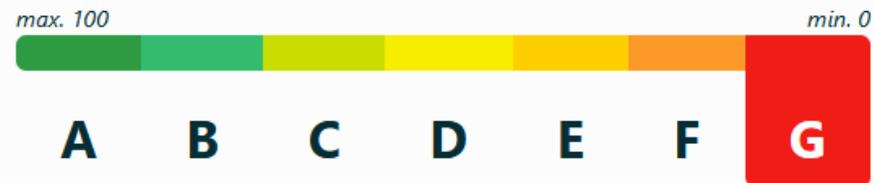


Ouch.

Score: 8 / 100



Let's not hide it: it hurts. Time to act!



Page rank: 534083 / 546563

- Too heavy 3.529 Mb
- Too complex 3324 elements
- Too many requests 239 requests

Too heavy

Page weight

3.529 Mb

min median: 2.41 max

● Target: 1.024 Unit: megabyte (Mb)

Too complex

Complexity

3324 elements

min median: 693 max

● Target: 600 Unit: Number of DOM elements

Too many requests

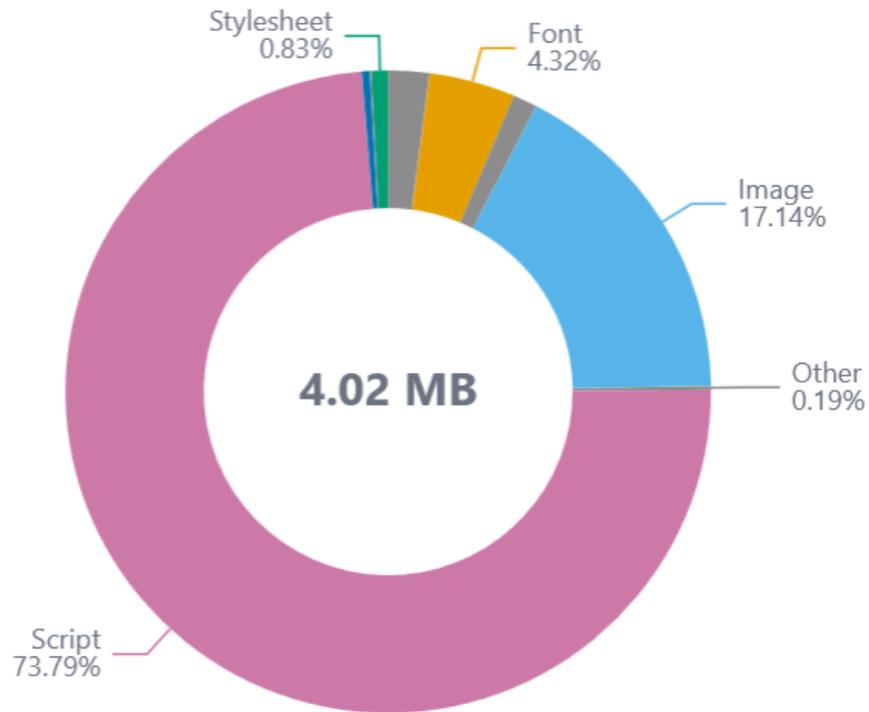
Requests

239 requests

min median: 78 max

● Target: 40 Unit: Number of server requests

<https://www.ecoindex.fr/en/result/?id=844ac0b4-3382-4b67-8f67-09a9e409c470>



All Resources

Resource	Size
Script	2.96 MB
Image	704.8 KB
Font	177.58 KB
XHR	84.13 KB
Fetch	49.94 KB
Stylesheet	34.1 KB
Document	16.16 KB

<https://web.cardamon.io/reports/sTVww>

dm.de

- Good:
 - images are optimized! (webp, biggest image has only 80 kB)
 - no videos!
 - caching is used!
 - ...
- Bad:
 - >200 requests!
 - ~3 MB of JavaScript!
 - a lot of duplicated and unused scripts
 - login.js >300 kB transferred size

Agenda

Introduction

Methodologies & Tools

User Interactions

Good & Bad Websites

 Conclusion

Conclusion

- **Tools & Methodologies**

- Understand the scope and limitations of each tool
- Results may vary significantly between different approaches
- Measure beyond just data transfer
- Select the right methodology & tool for your goals

- **User Interactions**

- The more your tests reflect actual user behavior, the more valuable your insights

- **Act on Results**

- Leverage recommendations as a starting point
- Transform insights into concrete actions

Questions?



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