Firefox power profiling

A powerful visualization of web sustainability

Link to slides:
https://share.firefox.dev/power-profiling-fosdem2024

Florian Quèze

February 4, 2024 - Brussels
Web sustainability

The carbon footprint of browsing the web comes from:

- the user device
- remote equipment (network, servers, ...)
- power used by the browser on the device
The user device

Embodied emissions of the device (laptop, smartphone, ...)

- We don’t pick the user’s device...
- ... but can reduce incentives to replace it
  - Performance
  - Compatibility with old devices
    Firefox ESR 115 is the only browser receiving security updates that still supports Windows 7
Infrastructure emissions

Caused by the resources fetched by the web page.

- The financial cost (mostly) scales with emissions
- Good incentive to reduce it.
- Already a lot of tools to look at web page optimization from this perspective
Browser power use

Often neglected because hard to measure:

● There’s no good tooling available
● ... except now there is!

Focus for the rest of this talk
Table of contents

- Motivation
- Measuring local power use
- Power profiling
  - The Firefox Profiler
  - Power profiling
  - Examples
- Demo
  - External power profiling
  - More examples
Why?
For sustainability

Mozilla made climate commitments:

- being carbon-neutral.
- reducing its GHG footprint year over year
- leading openly by sharing materials, tools, and methodologies.
- exploring approaches to develop, design, and improve products from a sustainability perspective
Emissions Distribution 2022

Business Services 2.8%
Product Use 97.2%
For our users

Excessive power use = poor user experience

- Noisy fans
- Hot laptops
- Short battery life
For a better web

Mozilla’s mission:

“We’re building a better Internet”

Tools created to make Firefox more energy efficient are directly re-usable to make web pages more efficient.
Measuring local power use
(cheap) Wattmeter

- Affordable
- Reasonably accurate
- Can’t track evolution over time
Better wattmeter

- Connects over bluetooth
- Data readable from another computer
- Still difficult to match with what was done
How did Microsoft do it?

Browser efficiency comparison - Webdriver
Windows 10 Anniversary Update

Methodology summary

The Microsoft Windows team measured the average power consumption of the CPU, GPU, and Wifi antenna while Microsoft Edge, Chrome, Firefox, and Opera ran a complex yet representative set of user activities.

Measuring power

Power was measured on the Surface Book because it has integrated hardware instrumentation that's able to measure the real power consumption of the CPU, GPU and Wifi antenna while the automation is being executed. This is done using the Maxim 34407 Power Accumulator chip. The results of the Maxim chips were read using the built-in Windows tool "Performance Monitor". Performance Monitor was opened and configured to measure each component independently:

- \Energy Meter (CPU_CORES)\Power
- \Energy Meter (GPU_TOP)\Power
- \Energy Meter (WLAN_BT)\Power
Devices with MAXIM power meters

- Surface Book 1, Surface 3
- Many other devices expose it in their ACPI table, but don’t actually have the chip
- Energy meters in perfmon.exe:
A good surprise...

- Some machines report energy meter channels with familiar names.
- Windows 11 with Intel CPUs.
Energy Meter Interface API

- The perfmon.exe UI is horrible, but...
- There's a [documented API](#)!
  - unit is picowatt-hour
  - can be queried many times per second
  - accessible in user land
    (no requirement to install a specific driver)
- Usable for profiler counters:

  Bug 1774844 - Use the Windows Energy Meter Interface to record power use data in profiles
Introducing the Firefox Profiler

https://profiler.firefox.com
What’s the Firefox Profiler

● Built-into Firefox
● Initially for performance work. Helps:
  ○ users to make useful bug reports
  ○ developers to make sense of them
● One of the best profilers!
What’s the Firefox Profiler

Main sources of data:

● Sampling
  ○ Stacks
  ○ Counters
● Markers
Firefox Profiler — Web app for Firefox performance analysis

Capture a performance profile. Analyze it. Share it. Make the web faster.

Enable Firefox Profiler Menu Button

Enable the profiler menu button to start recording a performance profile in Firefox, then analyze it and share it with profiler.firefox.com.

You can also profile Firefox for Android. For more information, please consult this documentation: Profiling Firefox for Android directly on device.

Load existing profiles

You can drag and drop a profile file here to load it, or:

- Load a profile from file
- Load a profile from a URL

The Firefox Profiler can also import profiles from other profilers, such as Linux perf, Android SimplePerf, the Chrome performance panel, Android Studio, or any file using the dait format. Learn how to write your own importer.

Your recent uploaded recordings

No profile has been uploaded yet!
Firefox Profiler — Web app for Firefox performance analysis

Capture a performance profile. Analyze it. Share it. Make the web faster.

To start profiling, click on the profile icon and use keyboard shortcuts. The icon is blue with an "M". To stop recording, hit Ctrl+Shift+1. To capture and load profile, hit Ctrl+Shift+2.

You can also profile Firefox for Android. For more information, please consult this documentation: Profiling Firefox for Android directly on device.
Loading the wikipedia home page - https://share.firefox.dev/3I5H1aF
Loading the wikipedia home page - https://share.firefox.dev/3I5H1aF
Loading the wikipedia home page - https://share.firefox.dev/3l5H1aF
Firefox power profiling
Firefox Power profiling

- Built-in, no extra tool required
- Supports all 3 major desktop platforms
- Shipped in Firefox 104 (June 2022)
- Not copied yet!
Power profiling - Windows support

- Windows 10 - devices with hardware power meters (Surface Book 1, Surface 3, ?)
  CPU, GPU, Wifi power use
- Windows 11 - Intel CPUs
  CPU, GPU, DRAM power use
- Windows 11 22H2 - AMD Ryzen CPUs
  CPU, with 1 track per core!
Power profiling - Mac support

- **Apple Silicon**
  - Undocumented API, returning a per-process value!
    ```c
    task_info(mach_task_self(), TASK_POWER_INFO_V2,
              (task_info_t)&task_power_info, &count);
    task_power_info.task_energy // ← nanojoules
    ```

- **Intel x64-64 CPUs**
  - `diagCall64(dgPowerStat, ... called from asm gives us the RAPL MSR.
  - (copied from an [9 years old implementation](#))`
Power profiling - Linux support

- Use RAPL perf events
- `sudo sysctl kernel.perf_event_paranoid=0`
  Access to power data is restricted since October 2020 due to a side channel attack.
- AMD CPUs supported since Linux Kernel 5.8
- Doesn’t work with Ubuntu’s Firefox snap package
Power profiling - configuration

There is a ‘Power’ preset for easy configuration.
Reducing overhead

- Longer interval
- No periodic stack sampling
Examples

Link to slides:
https://share.firefox.dev/power-profiling-fosdem2024
Firefox startup power use

Starting Firefox - https://share.firefox.dev/3X0PHMP
Measure tiny things

What’s the smallest thing we can power profile?

Power: 358 mW

Energy used in the current selection: 1.5 μWh

Energy used in the visible range: 13 μWh
Demo

Zooming on openstreetmap - https://share.firefox.dev/3UjDlfy
Recap
Android?
External power profiling
AC power measure

Max 50Hz sampling

CPU power data

Not profiling the entire computer

Babylonfive David W. Smith, CC BY 3.0, via Wikimedia Commons
Charger testers

- Affordable (<100€) devices made to verify how good chargers are.
- Up to 1kHz sampling
- Some can export data to a computer through USB or Bluetooth.
- When the battery is full, they measure how much power is used by the phone.
Charger testers also work for laptops

- Supports up to 240W
- Modern laptops support charging through USB PD (Power Delivery)
- Support for “external power profiling” landed in Firefox 121.
Testing and reverse engineering

- Software only for Windows
- Mix of Chinese and English
- Poorly documented APIs (if documented at all)
- Tested with a USB light
Compatible USB power meters
Plug & play!

- The models on the picture “just work”
- [https://github.com/fqueze/usb-power-profiling](https://github.com/fqueze/usb-power-profiling)
- Example profiles for each supported device:
  - Good example:
  - Bad example:

- Data source for the “USB power” track in examples for the next slides.
The power used by the idle phone is around 2W. Goes up to 7W during page load.

Android wikipedia page load - https://share.firefox.dev/3QTmhii
More examples

Link to slides:
https://share.firefox.dev/power-profiling-fosdem2024
Using efficiency mode on Windows 11

The power used by using 100% of a core drops from 10W to 2W.

Win11 “Efficiency mode” (EcoQos) - https://share.firefox.dev/3FJoAkc (bug 1796525 Firefox 108)
Using ‘background’ QoS on Mac

1 s of CPU time

The power used by cores drops from 18W to 1.6W.
Entire MacBook from 30W to 10W.
Using ‘background’ QoS on Mac
Running the same task

<table>
<thead>
<tr>
<th></th>
<th>Foreground</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>500ms</td>
<td>1.6s</td>
</tr>
<tr>
<td>CPU energy</td>
<td>3mWh</td>
<td>1.2mWh</td>
</tr>
<tr>
<td>Laptop energy</td>
<td>4.1mWh</td>
<td>5mWh</td>
</tr>
</tbody>
</table>

Mac ‘background’ QoS - https://share.firefox.dev/3STHhsa
## Raising the CPU clock frequency

<table>
<thead>
<tr>
<th>USB power</th>
<th>CPU 0</th>
<th>CPU 1</th>
<th>CPU 2</th>
<th>CPU 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Power and CPU frequency profiling on Android - [https://share.firefox.dev/3Uqh45j](https://share.firefox.dev/3Uqh45j)
Animated background

Burning your lap, millions of pixels at a time

The GPU power is as high as the CPU core power.

DRAM power is significant too.

Animated background - https://share.firefox.dev/3GbKA6o
Animated background

In different window sizes

GPU power:
- 0.3W for 0.45Mpixels
- 1.3W for 2.4Mpixels
- 6W for 6.3Mpixels

CPU power dominates while resizing

Animated background at different sizes - https://share.firefox.dev/3uB0sws
Animated background
At different refresh rates

Average GPU power:

- 4.5W for 60Hz
- 1.3W for 30Hz
- 0.4W for 10Hz
- 0.05W for 1Hz

<30Hz, a spike per frame

Animated background at different fps - https://share.firefox.dev/3RbY1t6
Playing a video

In a frame or fullscreen

CPU and GPU power use comparable to the animated background.

Note: 30fps on the video.

Video playback - https://share.firefox.dev/3R9EzgD
### Waking up... too often

```javascript
setTimeout(0)
```

<table>
<thead>
<tr>
<th>Marker Chart</th>
<th>Marker Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOM</td>
<td></td>
</tr>
<tr>
<td>DOMEvent</td>
<td></td>
</tr>
<tr>
<td>setTimeout callback</td>
<td></td>
</tr>
</tbody>
</table>

First half: tab is visible, timer wake-ups every 4ms.

Second half: tab in the background, timers throttled to 1Hz.

Timers - [https://share.firefox.dev/499xUcB](https://share.firefox.dev/499xUcB)
Bonus

A few more things
Firefox task manager

With one click profiling (the ‘power’ feature is enabled)

- Nightly (82362)
  - 16 active threads out of 86: MainThread 0.7%, (41382907) 0.4%, (4

- https://mozilla.org (82410)

- Tab: MDN Web Docs
  - 31 inactive threads

- About page (82364)
CO₂ equivalent using `co2.js`

Power: 2.68 W
Energy used in the current selection: 63 μWh (0.028 mg CO₂e)
Energy used in the visible range: 168 μWh (0.074 mg CO₂e)

Thanks to **Chris Adams** and **Fershad** from **The Green Web Foundation**.
Network bandwidth

Loading the wikipedia home page twice - [https://share.firefox.dev/3SfHijL](https://share.firefox.dev/3SfHijL) (Bandwidth track in Firefox 123)
# Network bandwidth (cached)

<table>
<thead>
<tr>
<th>Screenshots</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Parent Process</th>
<th>PID: 2782</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Network</th>
<th>Bandwidth</th>
<th>Process Power</th>
<th>Renderer</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>wikipedia.org</th>
<th>PID: 3898</th>
</tr>
</thead>
</table>

- **Transfer speed for this sample:** 0.000B per second
- **read/write operations since the previous sample:** 0

- **Data transferred up to this time:** 7,439B (0.001 g CO₂e)
- **Data transferred in the visible range:** 7,439B (0.001 g CO₂e)

---

Loading the wikipedia home page twice - [https://share.firefox.dev/3SfHljL](https://share.firefox.dev/3SfHljL) (Bandwidth track in Firefox 123)
When power profiling is not supported on your machine...
Conclusion

- **Power profiling is:**
  - Possible
  - Easy
  - Fun

- **But start with**
  - Web compat
  - Good performance
Thanks! Questions?

- Share ideas, #profiler:mozilla.org
- Questions: florian@mozilla.com

Link to slides: https://share.firefox.dev/power-profiling-fosdem2024