

Firefox power profiling A powerful visualization of web sustainability

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

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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
 Eirofox ESP 115 is the only browser receiving
 - 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

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- Measuring local power use
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Why?

For sustainability

Mozilla made climate commitments:

- being carbon-neutral.
- reducing its <u>GHG footprint</u> year over year
- leading openly by sharing materials, tools, and methodologies.
- exploring approaches to develop, design, and **improve products**

from a sustainability perspective







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

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Better wattmeter



- Connects over bluetooth
- Data readable from another computer



Still difficult to match with what was done



How did <u>Microsoft do it</u>?

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.

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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 <u>Maxim 34407</u> <u>Power Accumulator chip</u>. 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:

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- Some machines report energy meter channels with familiar names.
- Windows 11 with Intel CPUs.

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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



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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
 - o developers to make sense of them
- One of the best profilers!

What's the Firefox Profiler

Main sources of data:

- Sampling
 - \circ Stacks
 - \circ Counters
- Markers







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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!

task_info(mach_task_self(), TASK_POWER_INFO_V2,

(task_info_t)&task_power_info, &count);

- Intel x64-64 CPUs
 - diagCall64 (dgPowerStat, ... called from asm gives us the RAPL MSR.
 - (copied from an <u>9 years old implementation</u>)



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.



Windows 11 & Apple Silicon since Firefox 104 — Linux & Intel Macs since 107

Reducing overhead

- Longer interval
- No periodic stack sampling

		 Profile Info 	ú
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Profile Informa	ition		4
Main process			
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Buffer duration:	Unlimited		
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Examples



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

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

Measure tiny things

What's the smallest thing we can power profile?





Demo

Zooming on openstreetmap - https://share.firefox.dev/3UjDIfy

Demo



Demo

Android?

External power profiling

AC power measure CPU power data



Max 50Hz sampling



via Wikimedia Commons

Not profiling the entire computer



Charger testers

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- 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.

47

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"
- <u>https://github.com/fqueze/usb-power-profiling</u>
- Example profiles for each supported device:
 - Good example:

• Bad example:

 Data source for the "USB power" track in examples for the next slides.

Android remote + ext. power



More examples



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

Using efficiency mode on Windows 11

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Using 'background' QoS on Mac 1s of CPU time





Using 'background' QoS on Mac Running the same task

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Raising the CPU clock frequency

USB power	المريالية معالم الملاحد وينايا الألية فالثال معر والدار
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CPU 1	
CPU 2	
CPU 3	



Animated background Burning your lap, millions of pixels at a time



Animated background In different window sizes

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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 refresh rates

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Average GPU power:

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

<30Hz, a spike per frame

Playing a video In a frame or fullscreen

CPU and GPU power use comparable to the animated background.



Note: 30fps on the video.

Waking up... too often setTimeout(0)



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

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



Bonus

A few more things

Firefox task manager

With one click profiling (the 'power' feature is enabled)

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Name					
Nightly (82362)					
> 16 active thread	s out of 86: N	MainThread 0.	7%, (41382907) 0.4%,	(4	
M https://mozilla.o	rg (82410)	<u> </u>			
M Tab: MDN Web Do	ocs	Profile all threads of this process for 5 seconds			
> 31 inactive threa	ads				
About pages (92)	261)				

CO₂ equivalent using <u>co2.js</u>

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



Network bandwidth (cached)



Process CPU

Screenshots			Image: Control (Control (Contro (Control (Control (Control (Control (Control (Control (Control (C	
Parent Process PID: 94635				When power
Renderer				profiling is not
Process Power	A summer all dealers have been a summer of the second second second second second second second second second s	with the start for the start with	Internet the state of the second second	
Process CPU	an your destroy and a second a second and a second second and a second second second second second second second		Angermanne when	supported on
Drivile and Content				
Privileged Content PID: 94637				your machine
Process Power	Note in the second s	LIMA INLA		
Process CPU	Alm.		July Mar Mar	
Call Tree Flam All stacks JavaScrip	e Graph Stack Chart Marker Chart Marker Table Network Image: Native Invert call stack Filter stacks: Image: Classical stack Filter stacks: Image: Classical stack Image: Classical		mozilla::detail::Runnab /Users/florian/buildhg/mozill	e a/
Complete "Privileged Conte	ant"		~ .	
Inspector	Console D Debugger ↑↓ Network {} Style Editor (2) Performance 3 Memory	🗄 Storage 🚿	🔕 ČJ ••	• >
🗊 🛛 🗑 Filter Output	Errors Warnings (412) Log	gs Info Debug	CSS XHR Requests	*
>> experimental.enable	eProcessCPUTracks()			
☑ The process CPU ← Note that this i	tracks are now enabled and should be displayed in the timeline. is an experimental feature that might still have bugs.		window-console.js:9	04:1

 $\,\,$ As an experimental feature their presence isn't persisted as a URL parameter like the other things.

← undefined

Ē

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