Fast & Fair: Design & Development Decisions to Accelerate Inclusive, Equal, and Sustainable Web Access

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Building a sustainable web for an equitable energy future

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Introduction

The internet is arguably one of the most valuable tools humankind has created. The early web was founded on principles of:

- to be open/free with ability to publish anything
- to be non-discriminatory
- universally available to anyone (who had access)
- encouragement of maximum participation from everyone.[1]

The spirit of these principles lives on today in many ways, but there is much to do to ensure it remains this way.

Today, a large percentage of the population has access to the internet - but that access is not equal – hardware, infrastructure, socioeconomic trends, governments, organizations, moderators, web developers and designers play a role – behaviors play a role.

Each passing year yields technology gains in hardware and software development; web tech companies and developers tout advancements such as JavaScript frameworks and cloud and edge resources – designers claim users want more video, and web pages need more images. Don't worry – they say – 5G mobile and increasing broadband speeds solve user-end issues. What many of them don't realize is there is a growing gap between who benefits from those gains and who can easily access what on the internet. It is easy for those who build the web to lose sight of this when they have access to blazing-fast speeds and the latest/greatest hardware.

A brief history on web page evolution

Using transportation/vehicles as an analogy for web pages:

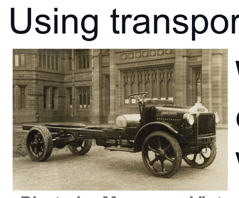


Photo by Museums Victoria on Unsplash

Where we started. Pages contained just the bare essentials, speeds were steady and slow. But people were curious in adopting new technology.

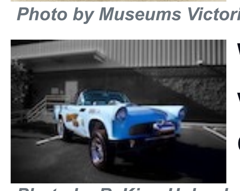


Photo by RyKing Uploads on Unsplash

Where we went. Pages were quirky and weird. Speed was deceivingly slow, while some were performant, others took minutes to load.

Photo by Idzard Schiphof on Unsplash

Where we *think* we are. Pages are refined, light and performant (*but are they?*) Speeds are fast and we can go just about anywhere! (mobile & desktop)

Photo by Sibylle Dreyer on Wikipedia

Where we *actually* are. Pages are fast in specific/preferred conditions, but most are heavy & shipping more than necessary. On a long straight road, this truck can go fast – but will be slow or blocked from going into busy city centers, narrow streets, or on roads that cannot support the weight.

Web page weight

Web page weight is generally considered as the transferred byte size of data request(s) from the source/server to the end-user device to render the web page. Data requests include HTML, text, multimedia (images, video, etc.), CSS, JavaScript, and Third-Party resources.[2]

When a web page is first visited, **all** the resources that page needs to render transfer in the data request from the server to the end-user device. The transfer speeds are affected by the number of requests, the transferred data size, the bandwidth of the service, the location of the user and server, and the hardware capabilities.

As bandwidth speeds allow for more data transfer and as hardware rendering improves, the amount of data included on a web page increases. Developer choices, such as depending on JavaScript based frameworks, for building web pages and apps add to increased page weight.

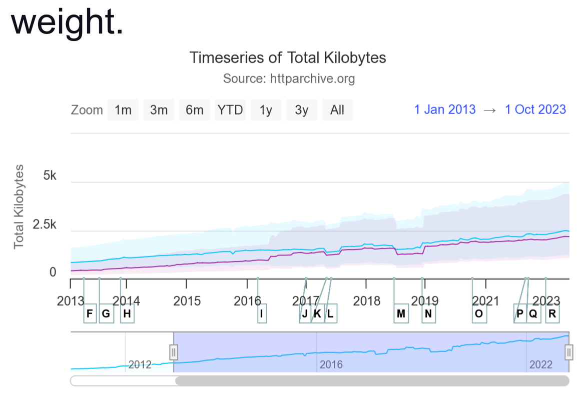
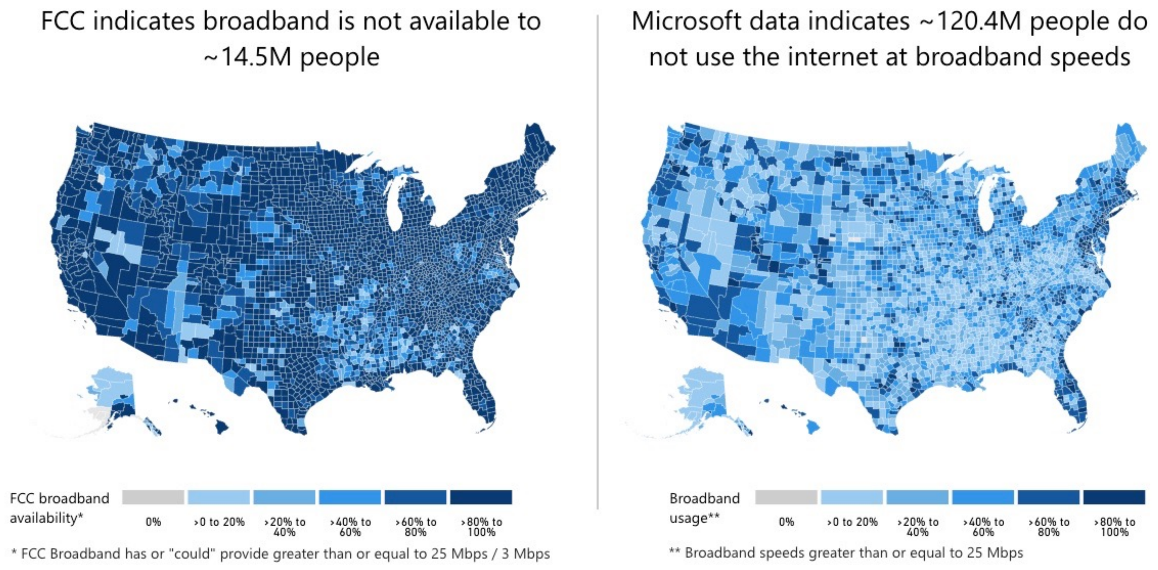


Chart obtained frem HTTP Archive

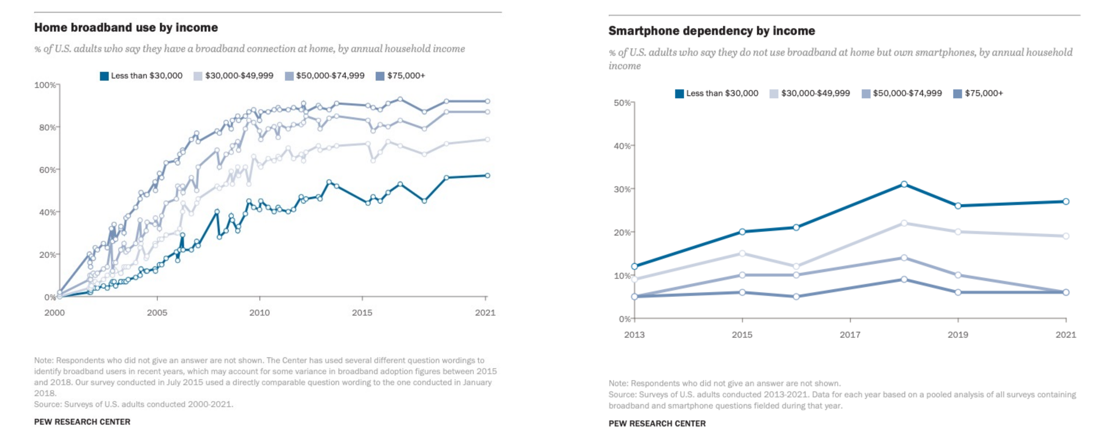
- The median desktop page weight on Jan. 1, 2013, was 834 KB [3]
- The median desktop page weight on Oct. 1, 2023, was 2445 KB [3] **(+193%)**
- The median mobile page weight on Jan. 1, 2013, was 404 KB [3]
- The median mobile page weight on Oct. 1, 2023, was 2174 KB [3] **(+438%)**

User Access

Not all users use the same devices or broadband internet service provider (ISP) to access the internet.[4]



Income is one of the largest influences on access.[5]



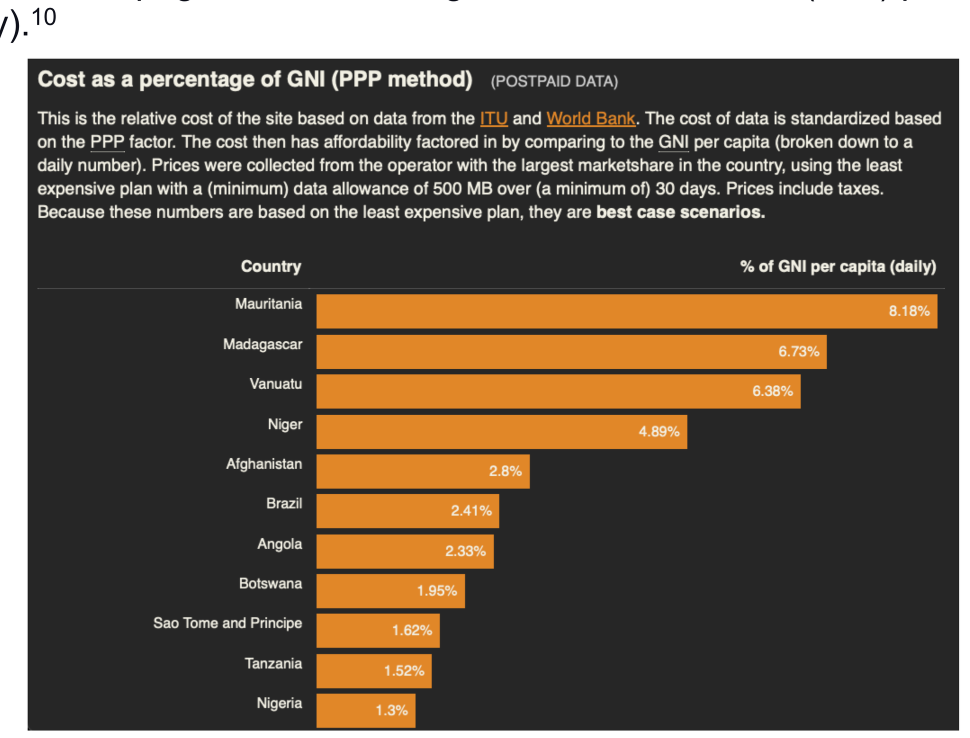
Data indicates that approximately 57% of all online activity is done on a mobile device, and 95% of all internet users go online with a mobile device for at least some of their online experience.[6]

In 2022, research reported that 56% of affluent Americans reported owning an Apple smartphone.[7] As such, we'll use an iPhone as the baseline for an affluent mobile device in comparison to budget models.

It seems safe to assume many low-to-moderate (LMI) income users might access the internet on a budget smartphone, as a product of hardware costs and smartphone dependency for internet access. As of Oct. 2023, according to one tech website, the Samsung Galaxy A13 is considered the best budget phone under $300[8] – this will be the budget phone for comparison.

The Galaxy A13 was released in March 2022, and has hardware performance and data transmission specifications comparable to that of an iPhone 7, released in 2016.[9] As web pages increase in weight and rely on more JavaScript, we do not see budget hardware increase in performance at the same rate. Less performant hardware can struggle to render the same performance and experience on weight-heavy or JavaScript-intensive pages as the latest flagship devices, widening the gap between users.

Socioeconomic factors in smaller or lesser developing nations can exacerbate this accessibility gap. Internet data plans are often less affordable to users in these countries. Consider the web page for this conference – using an online tool that standardizes data costs and factors affordability in different countries, we can see that visiting this conference's page can be 5% of gross national income (GNI) per capita (daily).[10]



Internet Electricity Consumption

In 2022 internet traffic resulted in over 4.4 zettabytes of data transfer.[11] One zettabyte is 1 x 10^{21} bytes, which are enormous amounts of data. In 2022, there were an estimated 5.3 billion internet users.[11]

Global trends in digital and energy indicators, 2015-2022

	2015	2022	Change
Internet users	3 billion	5.3 billion	+78%
Internet traffic	0.6 ZB	4.4 ZB	+600%
Data centre workloads	180 million	800 million	+340%
Data centre energy use (excluding crypto)	200 TWh	240-340 TWh	+20-70%
Crypto mining energy use	4 TWh	100-150 TWh	+2300-3500%
Data transmission network energy use	220 TWh	260-360 TWh	+18-64%

Some research models predict that the total electricity demand for the internet may be as much as 20% of the total global electricity demand by 2030.[12] Additionally, models predict that global communications technologies could be responsible for more carbon emissions than any country other than China, India, and the U.S.[13]

The constellation of devices connected to the web makes it difficult to agree on what is part of internet electricity consumption or demand. A 2017 analysis concluded that an accurate estimation of electricity needed to transfer data on the web was 0.06-kilowatt hours per gigabyte (0.06 kWh/GB)[14]. This estimate is for a system with boundaries that only consider hardware to transfer web data within the U.S. network. It does not consider international data transmission, data centers, or end-user devices. The energy required for those considerations would increase the kWh/GB. However, this analysis was for 2015, and hardware gains have likely improved, so the 0.06 figure within the system boundaries is likely lower today. For simplicity, we'll consider 0.06 kWh/GB as the standard in this poster.

One less kilobyte (-1 KB)

What if we set a goal for web designers and developers to reduce the transfer size of their web pages by just 1 KB? 1 KB may seem insignificant, but at scale, there could be a measurable impact. Another transportation analogy, reducing web page transfer size is similar to keeping a vehicle's tires inflated to the recommended pressure settings – proper tire pressures improve miles per gallon efficiency. Reducing data transfer size results in more efficient web page loading.

Time for some back-of-the-napkin math! Let's make a reasonable assumption that every one of the 5.3 billion web users were to visit one new webpage every day for a year. And, let's assume that each of those visits was 1 KB smaller in data transfer size, using a system boundary as 0.06 kWh required to transfer 1 GB of data.[14]

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5.3 B users * 1 KB = 5.3 B KB or 5,300 GB reduced per day
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And, if just 1KB could be saved per visit per day over 1 year…

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5,300 GB * 365 = 1,934,500 GB reduced per year
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If 1GB of data uses 0.06kWh of energy for transmission and storage...

`1,934,500 GB * 0.06 kWh =` **`116,070 kWh annual reduction.`** Or,

`5,300 GB * 0.06 kWh =` **`318 kWh daily reduction.`**

The average U.S. home uses about 889 kWh of electricity per month.[15] Given the above contrived result, reducing a web page visit by -1 KB per day for every global user in one year might be the same as saving approximately the same electricity as 186 U.S. households in that same time period!

Performance Budgets

Google defines a performance budget as:

> *A performance budget is a set of limits imposed on metrics that affect site performance. This could be the total size of a page, the time it takes to load on a mobile network, or even the number of HTTP requests that are sent. Defining a budget helps get the web performance conversation started. It serves as a point of reference for making decisions about design, technology, and adding features. Having a budget enables designers to think about the effects of high-resolution images and the number of web fonts they pick. It also helps developers compare different approaches to a problem and evaluate frameworks and libraries based on their size and parsing cost.*[16]

This means that performance budgets can be used in the early planning stages for a website or application, and then used to inform design and development decisions. Consider the targeted audience for the application, as their access to the web may influence performance budget decisions.

Discussion

We know that web pages are growing in KB, requiring more data transmission for each page rendered. Web access and the fastest speeds are not distributed evenly across user populations. Many LMI users access the internet solely through a mobile device, running hardware specs years behind those of wealthier users. The web consumes enormous amounts of energy, and it will continue to grow. Global web users are still growing – more users = more bytes. We are not building the web as efficiently as we could. Where can we go from here?

Web designer and developer behaviors can be a contributing factor, being an advocate for a performant and efficient web. Design and developer teams can be an active force for improving overall web experience and access, helping to level the playing field for more equitable access.

All web products would benefit from a practical performance budget. I'll argue that most don't have one, and many teams don't even know what one is. Builders of the web should challenge status quo decisions, like frivolous use of images and video or building a new site with a JavaScript framework – because many projects can achieve the same or better results without these if thoughtfully planned and implemented.

Designers can limit font library imports, consider the use of images and video in content, use proper image formats for media types and compress those when handing off to developers, strive to meet accessibility standards, carefully think through the necessity of JavaScript interactivity, and consider reducing or improving advertisement integration.

Developers should challenge decisions as well, compress/minify everything, question the use of JS frameworks and dependencies, adhere to the performance budget, enforce accessibility and don't take shortcuts, write performant code, use modern techniques like lazy loading and image size control, and set cache controls.

This list is hardly exhaustive, and there are many excellent resources online that can benefit design and development teams to improve education in these areas and execute these practices in their projects.

Resources to start learning more

- W3C Web Sustainability Guidelines (https://w3c.github.io/sustyweb/)
- W3C Ethical Web Principles (https://www.w3.org/TR/ethical-web-principles/)
- W3C Content Accessibility Guidelines (https://www.w3.org/TR/WCAG22/)
- Sustainable Web Design (https://sustainablewebdesign.org)
- Google Lighthouse (https://developer.chrome.com/docs/lighthouse/overview/)
- Performance Budgets 101 (https://web.dev/articles/performance-budgets-101)
- Mozilla Web Docs (https://developer.mozilla.org/en-US/docs/Web/Performance/Performance_budgets)
- Can I use…? (https://caniuse.com)
- What Does My Site Cost? (https://whatdoesmysitecost.com)
- Website Carbon (https://www.websitecarbon.com)

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