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"Front-end developers must give up on rich, interactive,
and accessible features if they want to develop eco-
friendly websites."

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Abstract

Being in the Mid Digital phase of digital era, consumers of the internet have access to a varied host of services and products that would have previously been displayed or considered available only in the realms of science fiction. We have seen numerous factors add up to climate change and degrading environmental conditions. It is fascinating, rather astonishing to know that a simple webpage with a rich feature loaded interactions, garish animations or videos can add up to the cause for environmental degradation. All these issues have varying extents of direct impact on “Climate Change” and the environment. Often this is not immediately apparent, and frequently this impact is difficult to measure since it involves weighing up different priorities.

Much like any other reasons that affect nature, we need to stress the fact that a poorly designed website with unnecessary elements hogging on the load time, has a long lasting and unaccounted impact on the environment too. How can such an impact be tackled at an early stage and what standards need to be imposed to develop architecture, or validations that need to be performed to identify the environmental effects of the websites are briefed in this report.

The later part of the report confers on the measures that a front-end developer needs to take to reduce a website's carbon footprint.

Introduction

Motivation

Being a front-end developer for couple of years, I have rarely come across the fact that I have been a part contributor to the degradation that the environment is going through, because of the carbon emission from the websites that I have built. Knowing the causes and the ways to repair my actions in the future has been a great motivation towards researching and drafting this report.

Critical elements of websites and standards

Before diving into the effects of websites on the environment we shall understand what really a website is, what elements it must have on a general basis.

Any website hosted on the internet must serve information about the concerned organization, product or an individual. Websites serve as an organization's virtual front door and are responsible for drawing in most of the customer/ business at this current point of time in internet era. Still, despite its prominence, many businesses struggle to optimize it properly. Fancy looking websites might be an eye catcher for the user but keeping in mind the real necessity and purpose and the time it takes to load those animations or graphics along with the load it has on the client's machine and server on which the website is hosted, is a good food for thought while designing such websites.

Let us consider a website that promotes a business/brand and use this example to state all the necessary elements a page must have at a bare minimum [1]:

1. Purpose of the business

The main purpose of building a webpage must be to state the clear purpose of the business to an unfamiliar person. Two things must be clear on a site – what the business does and what the visitor can do with the information on the page.

2. A simple Web Address

With a simple address the end user can find the page easily without much hassle. This is important in the case of many webpages owning businesses, as this is what makes them stand out from their competitors.

3. Simple navigation

A simple intuitive navigation around the site without a complex folder structure is a sign of a good webpage. It is important for the end user to find what they want on a site. This indirectly links to a clean and simple Single Page Application which need not have multiple page rendering while navigating, thereby reducing the load on the server.

4. Contact Information

The contact information for a business is crucial for the end user as they are visiting the site for this information. Besides making the contact easy to find, it is also good to provide multiple ways of contacting the business. Phone, email, and website forms are good options.

5. Great Mobile Experience

Since the advent of smart phones, a major traffic to a site is via mobile phone. Therefore, a website must be able to supply a good user mobile experience for a website. Responsive websites are considered as norms when building a web application.

6. Valuable and compelling content

The contents of a page are what makes the user return to a page. They want to see valuable content that they can take away with them once they leave your site. Content is the way a website will get traffic, whether that is through search engines or social media sites.

Any other information not about the business/brand are considered as wastage and clutter the web site. A front-end designer needs to ensure that this information is captured, and the rest of the information can be refactored in case they do not add value to a business, thereby supplying a clean website.

When building a website, one must be aware of its supportability, which means that any new web technology that is introduced should be backwards compatible with what went before it (i.e., old web sites will continue to work), and forwards compatible (future technologies in turn will be compatible with what we currently have).

Building a separate website to cater to compatibility with older and newer technologies, accessibility and standards seems to be increasing the number of websites (same site but multiple versions) being hosted, which correlates to not being a sustainable option as it indirectly means a larger energy required to keep these sites up and running, thereby increasing the load on environment.

Let's talk Stats – Impact of modern webpages on planet

“The internet is essentially the largest coal-fired machine on the entire planet,” says Jack Amend [2], the co-founder of Web Neutral Project, an organization that helps tackle websites' carbon footprints.

Websites with animation and videos might provide a lot of information, but does a website really need all those when they can simplify and provide it with basic, but a little fancier text? Not only are those flashy messages on a website annoying to certain users, but also bad for the planet.

According to the online carbon calculator Website Carbon for the year 2022 [3], the average web page tested produces approximately 0.5 grams CO₂ per page view. For a website with 10,000 monthly page views, that's 60 kg CO₂ per year. According to another article on 'wired' published in the year 2021 [4], on an average website produces 1.76g of CO₂ for every page view, so a site with 100,000 page views per month emits 2,112kg of CO₂ every year. If we scale this up and consider complex websites, then there would be a large energy requirement to load the page – in a way a greater impact on climate.

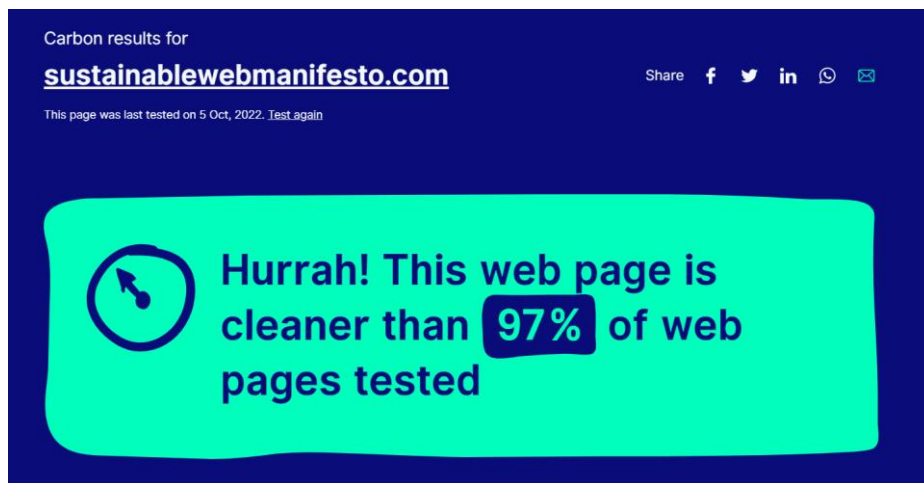
416.2TWh per year – this is the amount of electricity that the internet is said to be consuming. On comparison this is more than the energy consumption of the entire United Kingdom

Sustainable web development, what it means

Creating a sustainable web page should be a focus considering the long-lasting impact that it can have on the environment. Sustainable web design is an approach to designing digital products and services that puts people and planet first [14]. Getting an understanding of increments of digital footprint that grows as we produce content, host websites and virtual workshops, use cloud infrastructures, and design more apps to meet evolving needs is an important aspect in terms of sustainability. A Manifesto was defined to provide professionals in industry with a simple set of principles that they can follow to help create a web that is compatible with a sustainable planet and society.

The six core principles of Sustainable Web Manifesto are [11]:

- Clean: All products and services used or produced must be powered by renewable energy.
- Efficient: Least amount of energy and material usage by the products or services.
- Open: Products and services will be accessible, allow users to control their data, and enable the open exchange of information.
- Honest: No exploitation of the user.
- Regenerative: Products and services will support an economy that nourishes people and the planet.
- Resilient: Products and services will function in times and places where users need them most.



The image illustrates how the [sustainablewebmanifesto](https://sustainablewebmanifesto.com) webpage lives up to its own principles while being visually engaging and beautiful. Result is obtained from [Website carbon calculator](#).

Link between web accessibility and Sustainable Development

Web accessibility promotes justice and equal opportunity, which is crucial if we want to increase the chances for both professional and personal growth in terms of the web technology space. With better reach of websites to a large audience, leads to better growth of businesses and information online. Also, it supports social inclusion and citizen engagement in the information society.

Developing and promoting an accessible website with all web standards being followed leads to [13]:

- Encourage and foster innovation.
- Enhance, strengthen, and promote a brand.
- enlarge the market.
- lower the legal risk of non-compliance significantly.
- Leads to top the google ranking system (SEO), thereby increasing visibility when being searched for.

Search Engine Optimization - Because it fosters long-term, cost-effective business growth, SEO is economically sustainable. It is socially sustainable because it is about helping people find what they are looking for. Additionally, it is environmentally sustainable because it lessens the need for users to visit (many) other websites that might be less environmentally beneficial.

It will be simpler for business, institution, or organizations to provide services or business models that are inclusive and inventive if they adhere to the legal requirements imposed by the various web accessibility standards.

Rectification

In this section, we will discuss what measures the front-end developers can follow to design and build an ecofriendly green website. The carbon footprint of a website is decided on the amount of electricity that a website uses.

The question that we are trying to answer in this report is how a web professional can make a web page more energy efficient. Technically the energy being used by a device that renders the webpage is not only the concern, but also the server hosting the website [5].

Designing Sustainable websites – Front-end perspectives

Now the focus moves to the web developer to design a sustainable website. Imagine loading a webpage on phone only to know that it is image intensive or interaction-laden website and that the phone has drained a lot more energy to load it. The same applies to desktops too. This must be done when designing.


Ways to make a website more sustainable and ecofriendly [6]:

- Clean code – As the common saying Reinventing a wheel is unnecessary, same goes with web development too. There are numerous frameworks and libraries existing on the internet that can be utilized to perform the action that a developer would like to do by writing code from the ground up.

A professionally written simple code with no duplications and efficient queries is necessary when designing a front-end application. The code behind the scenes should be a well-oiled, lean machine.

- Good user Experience (UX) – A streamlined website catering to the end user's need and providing them with all the information needed without much navigation or hassle is considered a good user experience. Good user experience makes the process of surfing a site easier and enjoyable. With lesser navigation comes lesser energy consumption needed while loading information (images or videos) on multiple pages. This makes the next point.
- Reduced Images – Largest contributor to a websites weight are the high graphical image files. Flushing out the unnecessary, minimal impact images out of a page will lead to much faster loads and the effort taken by the clients and server machine to highlight these files. If the same impact that an image makes can be achieved with a CSS or vector graphic, then developers should consider this option.
- Reduced Video – Even though the videos on webpages are much lesser than images, the same questions and considerations arise when adding video to a page as an image. Rendering a video creates a much higher load on the CPU resulting in increased energy consumption.
- Server-side compression on all images, code, and content - Compressing content on-the-fly uses CPU time and saves bandwidth. This is a great tradeoff given the speed of compression. Static content can be pre-compressed to send the compressed versions. This has a reduced load time on webpages.
- Content Delivery Network (CDN) – CDN's provide a great solution to serving assets like image files from a network of data centers worldwide. This means that the largest files will be loaded from the CDN location in the user's own region, reducing the distance that data is moving each time a page is loaded. This improves energy efficiency and improves page load times.
- Using System fonts - The result of using the system fonts might not result in a great webpage and might cause a lower reach for a site. But this can be improved with an expertise CSS on the wording.

This is better than adding an additional custom font file and loading it along with page render, which can be an extra effort.

- Accelerated Mobile Pages  (AMP) – Most of the websites are built with a mobile first approach and are made to be responsive across multiple screen sizes. The websites are consumed on smart phones and hence they need to be optimized to load faster and better on mobile screens too. AMP can be a useful tool to deliver a more lightweight and energy efficient version to mobile users. By enabling you to design online pages and advertisements that are consistently quick, attractive, and high performing across devices and distribution channels, the AMP project seeks to "build the future web together." It does not help much if the website is already optimized and efficient to begin with.

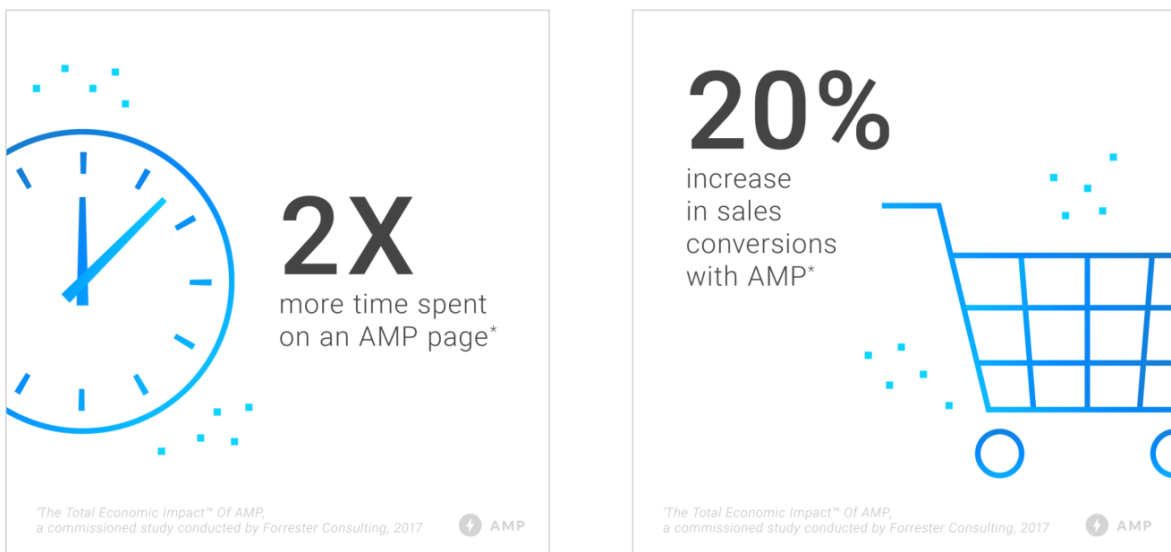


Image illustrates the impact created by AMP pages on e-commerce sites [7]

- Progressive Web Apps [8]: PWA are built and enhanced with modern APIs to deliver enhanced capabilities, reliability, and install ability while reaching anyone, anywhere, on any device with a single codebase. PWA allows websites to have native-like behavior with offline support and local file system access. PWA have proven to have user experience with improved loading times and lowered carbon footprint.

Using progressive enhancement, new capabilities are enabled in modern browsers. A web app manifest and service workers make a web application dependable and installable. The basic experience is still provided to users if the new features are not available.

- Caching – Websites are dynamic and tend to load every time someone visits a page. This requires server processing and tends to be inefficient. Caching is a workable solution to pre generate static version of pages and decrease the server overload and make a difference in loading of pages.
- Lazy Loading – Loading images only on demand, this lets the pages load faster and not pick up content before there occurs a need to serve it. From a socially sustainable point of view, it is recommended to input alt texts. Alt texts are image descriptions that appear when the user cannot see the image. For example, a visually impaired user may have a screen reader that reads out the alt text. Or the browser will display the alt text if the internet connection does not suffice to load the image.

Is Dark Mode a savior - Black vs White backgrounds?

One blog [9] that I came across spoke on the effects of using a Black background in comparison to White on a website to reduce the energy consumption on the end user device. Even though there are multiple factors that affect this statement like the type of display on which these sites are rendered, the brightness level of the machine, the statement still sounds like a reason most social media application and web applications resorted to dark mode as a secondary option. For example, blackle.com – the “energy efficient version of Google” – has a black background, rather than white and claims to have saved billions of watts in energy [5].

Dark mode clearly does save energy, but only on OLED devices, according to the Verdict. This is because, unlike LCD-LED displays, OLED displays are built in a way that does not require energy to manipulate crystals to block light during the dark mode. Instead, each pixel can be individually disabled, creating areas that are dark and lighting only the necessary pixels.

Back-end concerns when developing sustainable website

Front-end, often known as client-side languages, is primarily concerned with HTML, CSS, and JavaScript, or everything relating to the appearance and feel of the website being produced. Back-end (or server-side) languages belong to a different class of languages since they are executed on the server before the output is transmitted to the browser to be displayed. A server-side language is typically used to retrieve data from a database, create HTML to include the data, and then transmit the HTML to the user's browser for display.

Page load time being the main concern when it comes to sustainable websites, the factor underlying speed of delivery is dependent on the Back end built to serve the webpages. With a longer time taken to serve an API call, the time to load information on the front end is also increased. The speed with which the page loads is related to Search Engine Optimization.

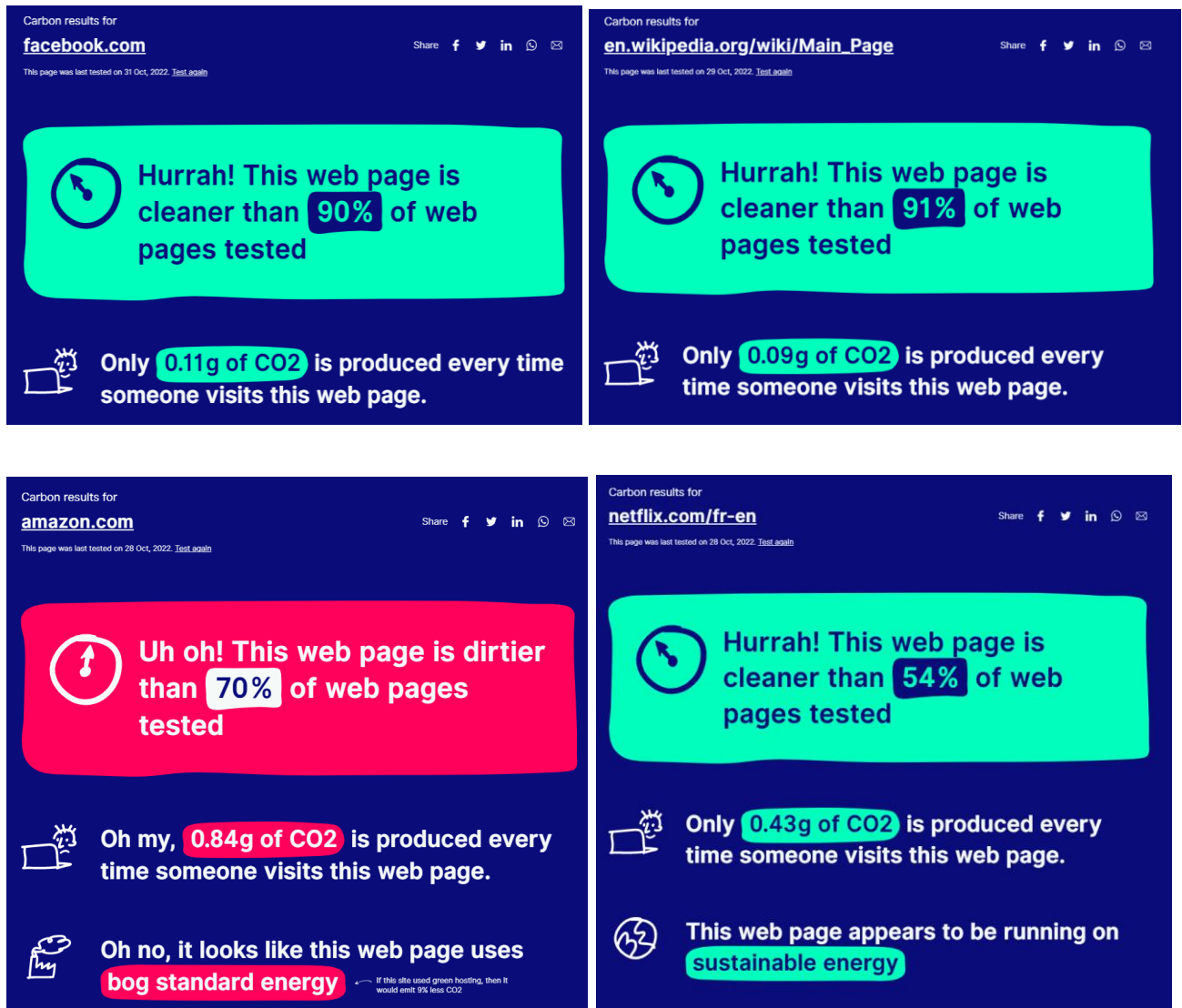
Time to First Byte (TTFB) measures the amount of time it takes for a user's browser to receive the first “byte” of data from your website's server [10]. TTFB has a pivotal role in website's User Experience (UX), as well as its Search Engine Optimization (SEO). Google determines the page ranking by considering TTFS along with First Contentful Paint (FCP), Largest Contentful Paint (LCP) and Cumulative Layout Shift (CLS). Using CDNs (Content Delivery Network) and ensuring maximum response times from your server is a vital part of overall page speed.

To tackle the server side of energy consumption, it is possible to get low carbon hosting, where the energy used to power the servers is generated by renewable means such as solar, wind or water powered generators that are generating the electricity to run the servers. Data centers require large amounts of power to run and are to be run 365 days on a 24-hour basis, so expecting a carbon neutral is unlikely.

Comparisons of the sustainability of websites that are widely used

For the purpose in this report four websites were chosen from different segments to check for their sustainability (as of August,2022). [12]. These include Facebook – Social media website, Wikipedia – an online encyclopedia, Amazon – e-commerce website and Netflix – Online streaming service. These are recorded to have some of the highest users daily.

The below images show the carbon emission from just using these websites. These sites were chosen based on the number of users they have daily. The number of users accessing these sites leads to more energy being consumed by the data centers to serve the edge devices that open these websites, leading to large carbon footprints.



Images illustrate the carbon emission from Facebook, Wikipedia, Amazon, and Netflix. Result is obtained from [Website carbon calculator](#).

These numbers have an enormous impact on the environment eventually, and hence steps need to be taken for a better future. One small step towards betterment is to make the websites follow all the necessary standards and rectification methods stated in this report, to reduce the load exerted by the web pages while being accessed.

Elevated levels of efficiency make the web more accessible to the least privileged users, who have slow connections and may only be able to afford a small amount of data, improving user experience by enabling faster load times for all users. Similarly, writing efficient, well-organized code makes it simpler to design web experiences that adhere to strict accessibility requirements. Better user experiences, job creation, and information access are all made possible by technological advances and sustainable development. Building websites with sustainability in mind contributes to a better future and environment.

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