Bachelor's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Design

Truls Teige Pettersen, Sivan Sabir Mahmud

Embracing Digital Sustainability

Guideline Development and Implementation for TV2

Bachelor's thesis in Web development
Supervisor: Yavuz Inai
Co-supervisor: Carlos Vicient-Monllaò
May 2023

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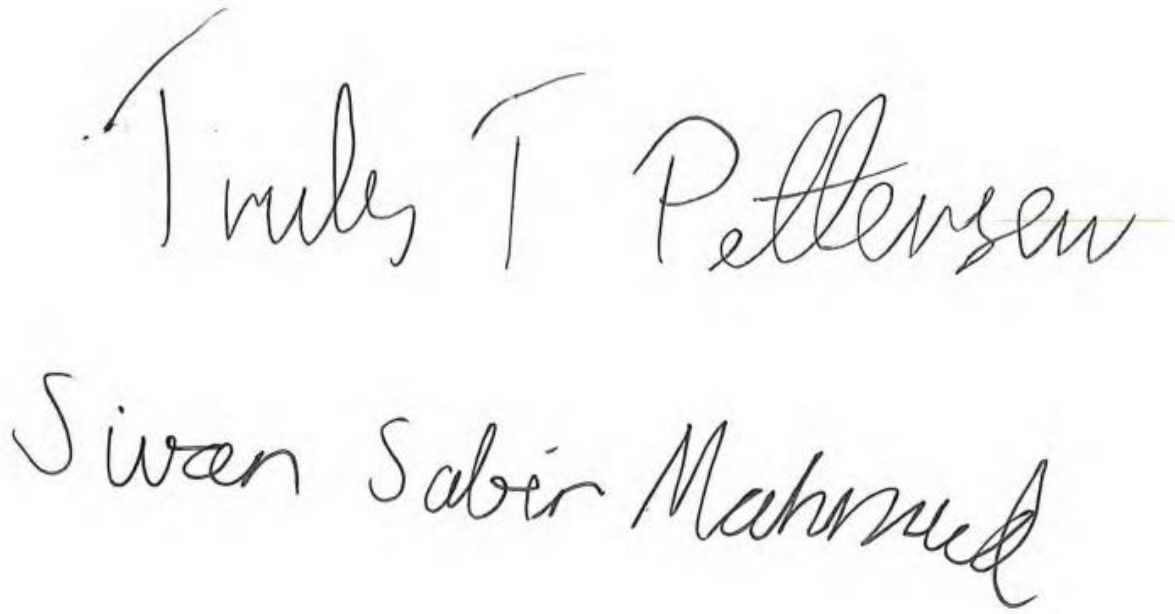
Foreword

This bachelor thesis in web development at NTNU (Norwegian University of Science and Technology) in Gjøvik explores the potential for improving the sustainability of web platforms for a major media company like TV2. By enhancing sustainability, we aim to positively impact the user experience for their audience.

Throughout the project, we have collaborated closely with TV2 and would like to extend our gratitude to Arild Rugsveen, our product owner at TV2, who has been invaluable in providing data and access to TV2's codebase. We also want to express our appreciation to our tutors Yavuz Inal and Carlos Vicient-Monllaò, who have guided us through our selected project.

February 28th, 2023, Gjøvik, Norway.



Abstract

Title: Embracing Digital Sustainability: Guideline Development and Implementation for TV2

Date: 15.05.2023

Participants: Truls Teige Pettersen, Sivan Sabir Mahmud

Supervisor: Yavuz Inal

Co-supervisor: Carlos Vicient-Monllaò

Employer: TV2 AS

Project owner: Arild Rugsveen

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This thesis scrutinizes the potential of sustainable web design guidelines to enhance the efficiency of TV2's websites, specifically targeting its page weight reduction, load times, and energy costs. As a practical application of these guidelines, we developed a website displaying these sustainable guidelines as well as a data carbon calculator to serve as a companion tool. Following this, we put into action selected strategies from the guidelines on a couple of TV2's websites, with a primary focus on their food recipe website. The results match that of existing research in that implementing sustainable web design will reduce a website's page weight. This not only affirms the positive implications of incorporating sustainable web design practices but also indicates their potential for optimizing TV2's web services by enhancing speed, energy efficiency, and overall performance.

Abstract (Norwegian)

Tittel: Embracing Digital Sustainability: Guideline Development and Implementation for TV2

Dato: 15.05.2023

Deltakere: Truls Teige Pettersen, Sivan Sabir Mahmud

Veiledere: Yavuz Inal

Medveileder: Carlos Vicient-Monllaò

Oppdragsgiver: TV2 AS

Prosjekteier: Arild Rugsveen

Emne: Webutvikling

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Denne oppgaven undersøker potensialet for retningslinjer for bærekraftig webdesign for å forbedre effektiviteten til TV2 sine nettsider, spesielt med mål om å redusere sidens vekt, lastetider og energikostnader. Som en praktisk anvendelse av disse retningslinjene, utviklet vi en nettside hvor vi viser disse bærekraftige retningslinjene sammen med en datakarbonkalkulator som et tilleggsverktøy. Deretter satte vi i verk utvalgte strategier fra disse retningslinjene på et par av TV2 sine nettsider, med mest fokus på TV2 sin mat oppskrift nettside.. Resultatene fra vårt arbeid bekreftet at våre revisjoner betydelig reduserte sidens vekt. Dette bekrefter ikke bare de positive implikasjonene ved å innarbeide praksis for bærekraftig webdesign, men indikerer også deres potensial for å optimalisere TV2s webtjenester ved å forbedre hastighet, energieffektivitet og generell ytelse.

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1 Introduction

This bachelor's thesis aims to provide TV2 with a comprehensive set of guidelines for sustainable web design. These guidelines, accessible on a dedicated Svelte-based website, offer practical recommendations for developing environmentally friendly websites. As part of this project, we have conducted testing to validate the accuracy and effectiveness of select guidelines. The overarching goal of the thesis is to address the United Nations' Sustainable Development Goal 13: Climate Action by promoting the development of more sustainable websites.

As the world's population continues to grow, so does the demand for access to the Internet, currently 62% of world's population has access to the internet, and there are 500,000 new internet users every single day (Flynn, 2023). While this has the potential to bring many benefits, such as greater connectivity and access to information, it also comes with a significant environmental cost. The internet currently accounts for a large and rapidly growing share of global greenhouse gas emissions it is estimated that by 2025 the internet if counted as a country would be the 4th most polluting country in the world behind China, The United States, and India (S. Larsen, 2018). This is due to a combination of factors, including the energy required to power data centres and the devices used to access the internet, as well as the carbon emissions associated with manufacturing and shipping these devices. To solve these problems, a more sustainable design philosophy is needed, and there comes Sustainable Web Design.

Sustainable web design is essential for minimizing the environmental impact of the internet. By adopting practices such as optimizing website code, using renewable energy sources for web hosting, and promoting accessibility, web designers can reduce the energy and resource consumption of their websites, and minimize the carbon emissions associated with their creation and use. This not only helps to mitigate the negative impact of the internet on the environment but also ensures that access to the internet can continue to expand in a sustainable way, benefiting people around the world for generations to come.

Sustainable web design combines principles of environmental conservation with performance-based web and usability standards. By integrating these practices into the life

cycle of websites, apps, and online media, efficiency, utility, and performance can be maximized. Moreover, sustainable web design can significantly reduce the environmental impact of digital products and services by employing strategies such as green hosting, carbon measurement and reduction, and minimizing electricity consumption.

The practices of sustainable web design according to Wholegrain Digital (Frick, 2023) a pioneer in the field, can be categorized as follows:

1. Web Performance Optimization: How efficiently do assets download on users' devices?
2. Content Findability: How quickly and effectively can users locate relevant content?
3. Usability: How easily can users across various devices and platforms accomplish tasks, considering different bandwidth speeds?
4. Green Web Hosting: Does the hosting infrastructure utilize renewable energy sources to power digital products and services?

While TV2 currently incorporates some sustainable web design practices, the company lacks official guidelines to implement them consistently. Since spring 2022, TV2 has become increasingly aware of the environmental impact of its digital services and has expressed a commitment to enhancing sustainability within its web services.

This thesis examines the process of designing and developing guidelines for implementing sustainable web design practices. Additionally, we present the results of testing some of these guidelines on selected TV2 websites. The study aims to provide insights into the effective implementation of sustainable web design practices, contributing to TV2's efforts to create more environmentally friendly web services.

1.1 Who is TV2 and what is their impact?

TV2, one of Norway's prominent media companies, holds the 5th position for web traffic among Norwegian websites (similarweb, 2023). In January alone, they garnered a staggering 44 million monthly visitors. To assess the environmental impact of TV2's website, we can

estimate their carbon dioxide (CO2) emissions for a given month by multiplying the total monthly visitors with the average number of pages visited per user and the average CO2 output per page visit. Based on this calculation, it is estimated that TV2's website emitted 212 metric tons of CO2 in January 2023.

Company	Visits in the month of January	Average pages visited per user	Average Co2 per page	Co2 for the month of January
TV2	44,412,776	3.73	1.28g	212 tons of Co2

The team responsible for managing tv2.no and its sub-websites is determined to make it the most visited media website in Norway. Since spring 2022, they have shifted their focus towards web sustainability after some members of their IT staff attended the Booster Conference 2022 and viewed a presentation titled "Green Code". Inspired by this event, TV2 has implemented sustainability upgrades across its services, such as replacing JPEG files with WEBP format and prioritizing data caching. However, they still lack a comprehensive set of guidelines on sustainability that can be utilized when developing new services or updating existing ones.

1.2 How sustainable web design would benefit TV2.

TV2 has a crucial role to play in providing information and entertainment to its audiences while minimizing the environmental impact of their online content. The internet, as previously mentioned, is a significant contributor to global greenhouse gas emissions, and media companies like TV2 that have a large digital presence in Norway can have a particularly large carbon footprint.

By adopting sustainable web design practices, TV2 can reduce their environmental impact while also benefiting their bottom line. For example, optimizing website code and reducing page load times can improve website performance and user experience, which can in turn increase engagement and reduce bounce rates. Similarly, using renewable energy sources for web hosting can not only reduce energy costs over the long term, but also demonstrate TV2's commitment to sustainability to their audience and stakeholders.

Overall, sustainable web design is both a moral and business imperative for TV2, and adopting these practices can help them achieve their goal of becoming the most visited news website in Norway while also aligning with their values and contributing to a more sustainable future.

1.3 Problem statement

The problem statement is defined as follows:

Is it possible to develop and tailor a set of web sustainability guidelines specifically for TV2 by testing and refining them on their food recipe website?

1.3.1 Definition of concepts in problem statement

- **Web sustainability guidelines:** A set of practices that are aimed at reducing the environmental impact of a website.
- **Tailor:** In this context, tailoring means to adjust the guidelines to fit the specific needs, characteristics, and constraints of TV2. It does not mean that the guidelines are only relevant for TV2's websites, however it does mean that every aspect of them holds relevance for TV2, ensuring their comprehensive applicability.
- **Testing:** This refers to the process of applying parts of the sustainability guidelines to TV2's food recipe website and monitoring the outcomes. This is done to determine the effectiveness of these guidelines.
- **Food Recipe Website:** This is a specific website run by TV2 where they share various food recipes. In this context, it is being used as the testbed for the sustainability guidelines. The URL to the website is https://www.tv2.no/mat/oppskrifter and it will from here on be referred to by its URL.

1.4 Report structure

Our bachelor thesis is structured as follows:

- **Background:** Here we aim to promote a comprehensive understanding of web sustainability, starting with an exploration of how to measure web services' carbon footprint and the factors impacting it, followed by a review of relevant literature.
- **Methods:** In this part, we share the research methods employed, including interviews, the research used for creating the web sustainability guidelines, and the tools used in the process.
- **Results:** This section presents the findings from our research and the development process. It includes results from interviews, iterations of the guidelines and the guidelines website, and the effects of changes made to specific areas of the TV2 site.
- **Discussion:** Here, we discuss the implications of our findings, the challenges we faced, and potential areas for future research and improvements to the guidelines.
- **Conclusion:** We wrap up the report with a summary of our findings.

The report also includes an appendix with relevant links and a complete list of references for further reading.

2. Background

In the following section, we are going to lay the groundwork for our project. We will first tackle how to measure the carbon footprint of web services. We will talk about several factors that affect a website's sustainability. Next, we will dive into a review of relevant literature on sustainable web design. Tom Greenwood's "Sustainable Web Design," will gain extra attention, as it is a book which offers some great insights into making websites that are efficient, resilient, and sustainable. By exploring these areas, we hope to give ourselves and you a solid understanding of web sustainability.

2.1 Measuring the Carbon Footprint of Web Services

Determining the exact carbon footprint of a website can be a challenging task, we cannot measure the fumes coming out of our laptops like we can with exhaust pipes for cars. However, the most reliable methods we currently have at our disposal involve analysing two main components: data transfer and the carbon intensity of electricity (Greenwood, 2021).

2.1.1 Data Transfer

A common metric used to gauge energy efficiency in this context is kilowatt-hours per gigabyte (kWh/GB), which measures the energy required to transfer data across the internet when a website or application is accessed. The total data transfer for a single visit to a web page is often calculated using the page weight, which is the transfer size of the page in kilobytes upon an initial. As of 2020, the median page weight for desktop websites was 1.97 MB, a 36% increase from 2016. Notably, images account for about half of this weight, making them the largest contributor to carbon emissions on an average website.

While faster performance can sometimes reduce emissions, it may only decrease the subjective perceived load times of pages. Using page weight and transfer size as benchmarks provides a more objective and reliable measure of emissions. A page weight

budget which we suggest later can be established as a limit for data size, which can be set relative to industry averages or the previous version of a website. To further optimize efficiency, transfer size for repeat visitors can be considered, helping to establish page weight budgets beyond the initial visit.

2.1.2 Carbon intensity of electricity

Carbon intensity refers to the grams of CO2 emitted per kilowatt-hour of electricity (gCO2/kWh). Renewable energy and nuclear energy sources have low carbon intensities (less than 10 - 30 gCO2/kWh, including construction), while energy made by fossil fuels range from 200 to 800 gCO2/kWh. Norway for example is mostly powered by waterpower (88%) and wind power (9%) and the estimate is 11 gCO2/kWh for all power produced in Norway in total (Tuset, 2023).

Most electricity is sourced from national or state grids, where energy from various sources is combined. As end-users, web servers, and telecom networks may all utilize power from different grids, the selection of the appropriate data centre to host a website becomes a crucial factor in controlling the carbon footprint. Each data centre relies on different grids with varying electricity sources, and by choosing the right data centre, the carbon emissions associated with web services can be significantly influenced.

This concept of “megabyte miles” refers to the distance between the data centre and the website’s core user base. By analysing website analytics, the core user base location can be identified, and the distance to the data centre can be calculated. If this distance is too great, it may be advantageous to select a closer data centre, which would reduce both emissions and latency for users. By focusing on the strategic selection of data centres, web designers can have greater control over the carbon footprint of their web services.

2.2 Literature review

What are the key principles and practices of sustainable web design?

A sustainable web design approach aims to minimize the environmental impact of websites and web applications while maximizing their accessibility and usability for users. This literature review critically examines published research literature relevant to sustainable web design, with the objective of establishing familiarity with current thinking and research in this area. The purpose of this review is to identify key issues, trends, and best practices for designing sustainable web applications and sites.

The scope of this literature review encompasses published and unpublished works on sustainable web design, in English, from various locations. The focus will be on works that address practices that are relevant and up to date with current design trends and technologies. We will exclude works related to non-web-based digital design, non-English works. Due to the nature of how quickly the design practices and technologies surrounding web development change, older writings will be excluded from this thesis. That is unless they relate to technologies and design practices that are still in use today.

2.2.2 Sustainable Web Design by Tom Greenwood

In "Sustainable Web Design," Tom Greenwood explores the concept and practice of sustainable web design for addressing the increasing demand for data worldwide while simultaneously reducing pollution and moving towards a zero-carbon economy. Greenwood identifies several fundamental principles for a sustainable web, including clean, efficient, open, honest, regenerative, and resilient design practices.

Clean web services require hosts that utilize 100% renewable energy. Efficient websites need to adapt to increasing traffic by resizing images properly, using only necessary code, and removing redundant lines of code. Such practices not only make the website more energy-efficient but also increase its speed. Openness and honesty are crucial for fostering collaboration and raising awareness about sustainability. Regenerative and resilient design involves mitigating harm and ensuring the web can reliably serve information during crises.

Measuring the carbon footprint of web services requires assessing data transfer and the carbon intensity of electricity. Data transfer can be estimated with the page weight, which is the transfer size of the page in kilobytes when a user first visits the page. Researchers use kilowatt-hours per gigabyte (kWh/GB) as a metric to measure energy efficiency when examining data transferred over the internet. Carbon intensity refers to the grams of CO2

emitted for every kilowatt hour of electricity (gCO2/kWh). Renewable and nuclear energy sources have low carbon intensity, while fossil fuels have significantly higher carbon intensity.

To set a sustainability budget for a website, it is crucial to benchmark relevant metrics, estimate what is theoretically possible, set achievable budget goals, and establish stretch goals for further improvement. Additionally, considering the embodied carbon of digital projects, which refers to the carbon emitted during the production, manufacturing, and delivery of a physical product, is essential for understanding the overall environmental impact of a website.

Greenwood emphasizes the importance of minimalist web design, streamlined content, lightweight imagery, efficient typography, and careful use of motion in creating low-carbon websites. Furthermore, sustainable web development involves well-written, efficient code that reduces server load and energy consumption. Utilizing technologies such as Progressive Web Apps and Jamstack can improve a website's speed, security, reliability, and energy efficiency. Compressing code and blocking unwanted bots also contribute to energy-efficient web hosting.

In conclusion, Tom Greenwood's "Sustainable Web Design" offers valuable insights and techniques for designing and developing sustainable websites that meet the increasing demand for data while minimizing environmental impacts. By adopting these principles and practices, web developers can contribute to a more sustainable and eco-friendly digital landscape.

3 Methods

This section outlines the strategies and methodologies we employed to gather data, develop our web sustainability guidelines, and validate their effectiveness. Our approach incorporated a blend of qualitative interviews, creation of tailored sustainability guidelines, use of various assessment tools, and making plans on how to practically implement guidelines in order to verify their effectiveness. Through this multi-faceted methodology, we sought to ensure a comprehensive understanding of web sustainability, develop practical and relevant guidelines, and test their effectiveness in a real-world setting. The process involved working closely with TV2 and making decisions based on their specific needs and operational framework.

3.1 Interviews

Interviews were a pivotal component of our research methodology, providing first-hand, nuanced information from professionals in the field of sustainable web design. Our rationale for choosing interviews over other research methods such as surveys or secondary data analysis was driven by several factors. Firstly, interviews allowed us to delve into the practical aspects of web sustainability, learning about specific practices, tools, and strategies employed by organizations. Secondly, they enabled us to understand the mechanisms employed by organizations to monitor their sustainability performance. Lastly, through the interviews, we aimed to stay informed about the latest trends, challenges, and opportunities in sustainable web design.

With this objective, two professionals from a competing Norwegian media company, were identified and interviewed for this study. The subjects were chosen based on their positions within the company: a Chief Engineer specializing in DevOps and a Senior-Engineer.

3.2 Web sustainability guidelines

This section of the thesis goes through the process of creating the web sustainability guidelines.

3.2.1 Requirements

A lot of insight was gathered from talking to Arild Rugsveen from TV2, and from looking at TV2's websites. The guidelines must give a short, concise, and accurate overview of web sustainability. It should be quick and easy to implement into your work, and not require too much time to set up. The guidelines also must be relevant to TV2, and how they currently operate their websites. It should not include solutions to problems that TV2 does not have.

The guidelines will follow a chronological order. It will follow this path:

- Researching and figuring out your goals for sustainability.
- Vital things to keep in mind while designing the website.
- Programming the website in a sustainable manner.
- Hosting the website.

There will be multiple steps within each of these points. Going from top to bottom will give you the best order for working on sustainability on your website, however it might be the case that some people will want to focus on, for example how to host the website first. For that reason, each step of the guideline will be stand alone. They can be read and understood by themselves, and you will not be expected to have read and worked on previous steps.

3.2.2 Guidelines content

This section covers every topic that is to be included in the guidelines, and why they are important.

The guideline starts off with telling you about how to plan a course of action to make your website more sustainable. This includes measuring the sustainability of your current website as well as your competitors, finding out what are theoretically best metrics for your website, and how you should set your goals after having all those metrics written down (Greenwood, 2021).

Yoyo user journey

The guideline mentions certain design choices that are detrimental to the sustainability of websites. One of these is referred to as the yoyo user journey. Some websites are designed in such a way where it pushes the user to go back to the homepage, to navigate to a

different page. A common example of this is websites making you go to the shopping cart page to see what items are in the shopping cart. A solution to this would be to have the functions of the shopping cart display on whichever page you are on. Then the user can quickly check the contents, before continuing to browse for other items (Greenwood, 2021).

TV2 Live's current website design forces users to return to the homepage to navigate between different sports sections. For instance, while on the football page, a user must click "Other sports," leading them back to the homepage to access a list of different sports. This design choice compromises sustainability, as it necessitates loading two pages instead of one to switch sports, thus increasing data transfer and energy usage.

When designing a website, it is vital to bear in mind that adopting a "less is more" approach contributes significantly to creating a sustainable online presence. By embracing a minimalist philosophy, designers can ensure that the website's design, content, and functionality are streamlined and focused, leading to decreased energy consumption, reduced data transfer, and minimized carbon emissions. Careful consideration of each design element, optimization of images and code, and prioritization of user experience enable the creation of a website that not only caters to users' needs but also promotes a sustainable and eco-friendly digital environment.

Images

The images that a website decides to host are a huge factor in sustainability. On average, they are the single biggest source of carbon emissions on a given website (Lahan, 2020). For optimal web sustainability, you should consider how many websites your website needs. Additionally, it is important to learn about the diverse ways you can optimize images so that they get a significantly reduced file size.

The most used image format for websites is JPEG. Almost 80% of all websites use JPEG in some way (W3Techs, 2023). However, JPEG is far from being the best choice of image file formats when it comes to sustainability. WebP is an image file format developed by Google (Calore, 2010). It has the features and the quality of any well-known image file format, but what is great about this one is that its images are around 30% smaller in file size compared to JPEG images (Google, 2023).

AVIF (AV1 Image File) is another newly developed image file format (Alliance For Open Media, 2022). It is reported to be able to produce high quality images at under half the size of WebP (Archibald, 2020). Despite there being so much potential behind it, we decided not to include it in the guidelines as it still lacks support for Microsoft Edge.

We also mention image optimization tools like ShortPixel and TinyPNG in the guidelines. These tools can be useful for further optimizing your images, without losing out on noticeable image quality (Greenwood, 2021). We ran a test with 11 images from TV2 Live's sports news feed and ran them through ShortPixel's glossy compression. This resulted in the total file size of the images going from 1,52 MB, down to 0,79 MB. This means that the images have been reduced by 48%. These are satisfactory results, however there are some limitations to these tools. You cannot use them to optimize WebP and AVIF (ShortPixel, u.d.). But if your website requires the use of JPEG or PNG, then they are still useful.

Many different users will have different screens, and therefore different needs when it comes to the size of images that gets displayed to them. This has to do with the fact that peoples screen viewing distance varies. For computer monitors, it is recommended that your eyes are between 50-100 cm away from the screen (OSHA, u.d.). Therefore, people using computers will need the images to be large enough so that the details will be visible when your eyes are 50-100 cm away from the monitor. Using the same high image size for mobile would be a waste of resources, as the image will shrink down anyway to fit the smaller screen. This will result in higher load times and higher bandwidth for mobile users, with no benefit.

By using the picture HTML element, you can eliminate those problems. The HTML picture element lets you serve different images for different screen sizes (MDN, 2023). This is a great solution, but it has the drawback of making you use more storage space for extra images. This is since you will have to make lower resolution copies of images for smaller screens. Therefore, you ideally want to figure out which screens your users use the most, and from that choose a few image sizes to use for the picture element.

We also recommend slightly reducing the width and crop of images by cropping around them. Let the cropped parts of the image stay as extra empty space on your website. This

will not only make the images much smaller in file size, but by having extra space around them they will appear much more impactful for users (Nevah, 2021).

Video & animation

58% of businesses have a video on their homepage (Renderforest, 2022), but should so many websites host videos? If a website hosts, videos, it will usually be by far the largest source of carbon emissions. Streaming a YouTube video for an hour produces approximately 10 kg of CO_2 (Preist, et al., 2019). The best way to counter this, is to minimize the amount of and length of videos on your website.

One thing to keep in mind is that users do not always want a video. They are not always the most user-friendly, and they can use up a significant amount of power and data on mobile devices. Joe Jones is the cofounder of design agency Archipelago, and he says that videos often require audio output and if you do not have headphones, it can be awkward to view in public. They also give users little control over how they want to process the information. Videos move in a constant pace which is not ideal for when you want to focus more on certain parts of it (Greenwood, 2021).

Every second matters if you are going to use a video, as a second of video can take up more data than a full-screen JPEG image. If you want to use a short animation instead, a GIF format should not be used. GIFs are an image file format that allows you to have a series of images in one file and have them display chronologically like an animation. That means that for each frame of the animation, the GIF format will use up an equal amount of space as a standalone GIF image. (W3C, 1990). According to Google, when GIF animations are converted to lossy WebP animations, they become 64% smaller in file size. For lossless WebP images it becomes 19% smaller (Google, 2023).

Screen

On many different phones, the screen is the single biggest power draw. One way it affects power is that blue pixels have been found to use 25% more power than green and red pixels. For phones that have an OLED (Organic Light Emitting Diode) display (Organic light-emitting diode), black pixels are the most efficient. A key feature of OLED displays is the fact

that individual pixels can be turned on and off. So, when a pixel is fully black, it will be off and will not cause any power consumption (Tung, 2018).

Even though black pixels being power friendly is only true for OLED display, we still felt it was necessary to include that information because of how popular OLED displays have gotten over the years. Apple has adopted OLED for their phones ever since the release of the iPhone X. Since then, they have only expanded their use of OLED across different devices (Charlton, 2022). In 2018 it was reported that there were over 1 billion phones in the entire world had an OLED display, with an increase of 46% since 2016 (Newzoo, 2018).

This is also why dark mode can be particularly useful for saving power. According to Purdue University, using dark mode on an OLED display with 100% brightness will save an average of 39% - 47% battery power. However, reducing the brightness will massively reduce the amount of power you save from dark mode (Dash & Hu, 2021).

Typography

What fonts a website uses has an impact on its sustainability. Using fonts that are not pre-installed on most systems will lead to more data-transfer for users. This is because the browser will download the font for users when they first visit the website (MDN, 2023). Due to this fact, using a system font will lead to less data-transfer.

Websites will however often benefit stylistically when using a custom font. There are two common ways of using a custom font for a website, by linking to a font service like Google Fonts or Adobe Fonts, or by hosting the font files on your server (MDN, 2023). There are a couple of reasons for why downloading fonts is more sustainable than using a font service. A font service will require more data transfer than self-hosting because fonts from font services will not be cached unlike self-hosted fonts (Karamalegos, 2019).

Secondly, downloading a font can give you more options for optimization. There are tools available that you remove specific characters from a font file. For example, a font includes characters from other languages you know you will not be using will make the file larger than it needs to be. The size of the font file can be reduced significantly by removing languages you know you will not be using. It is important to note that not all Font's licenses will let you edit fonts like this. (Greenwood, 2021).

There are also other small steps to take for font efficiency. You should always use WOFF2 font format, as it is the most efficient in terms of file size (Wicki, 2021). It is also important to only include font files that the website will be using. Fonts typically come in multiple files, for different thicknesses and for italics. If there is uncertainty in what style of the font will be needed, a variable font can be useful. It is a font file that allows for more scalability in terms of its thickness and slant, while still being highly efficient (MDN Web Docs, 2023).

Green web host

One of the most important parts of web sustainability is how you choose to host the website. It has to do with hosting websites on servers that are powered by green energy (Karyotakis & Antonopoulos, 2021). A website's host being completely powered by green energy is a huge step towards sustainability, but it does not cover everything. There will still be CO_2 emissions that come from the end-user device, as well as from the telecoms networks that transfer the data from the host to the user (Freitag, et al., 2021). Therefore, it is still important to optimize so that they require low energy for end-user devices, and so that telecoms networks do not need to deliver an excess amount of data.

But there is more to consider than just what type of energy source is powering the data centre. How close the servers are to your users is also a huge factor. Energy consumption by the internet is significantly affected by data transmission through telecommunication networks. As data travels greater distances, energy expenditure increases. Selecting a data centre near the target audience can reduce energy consumption and enhance user experience by minimizing page load times. For instance, choosing a US-based hosting company for a primary audience in the United Kingdom or Germany would result in wasted energy and slower page loads. Thus, locating a website in a geographically appropriate data centre promotes both user experience and environmental sustainability (Greenwood, 2019).

3.3 Website for displaying the guidelines

Our team decided to develop a website to effectively present our guidelines. Making a website has the advantage of letting people quickly and easily access the document without having to share a file around that people must download and keep on their device as a file.

It also gives us the ability to make it more interactive for the user. Such as by creating a custom navigation bar, and by letting users click on a piece of text to view more information. Lastly, it allows us to demonstrate how a low-impact website can look.

3.4 Tools

When analysing TV2's websites, we used a set of CO2 calculators, to gain deeper insights into their environmental impact and performance. These tools enabled us to assess key aspects of sustainability and provided valuable data for making informed decisions on optimizing website performance, reducing carbon emissions, and enhancing user experience

1 Links to tools.

3.4.1 Google Lighthouse

One of the primary tools we utilized was Google Lighthouse, an open-source tool developed by Google. Designed to improve the quality of web pages, Google Lighthouse audits websites against a set of best practices and performance metrics. It evaluates web pages in categories such as performance, accessibility, progressive web app (PWA), best practices, and search engine optimization (SEO). By focusing on the performance category, we gained in-depth insights into areas for improvement and received detailed suggestions for optimizing the websites to ensure high-quality and performant user experiences.

3.4.2 Digital Beacon

Another valuable tool in our evaluation toolkit was Digital Beacon, an online platform dedicated to calculating the environmental impact of websites. By analysing websites, Digital Beacon generated comprehensive reports that displayed crucial metrics such as page weight and CO2 emissions before and after caching. These reports provided valuable insights into the page load performance for both first-time and subsequent visitors, shedding light on the website's overall sustainability. Additionally, Digital Beacon provided a detailed breakdown of the weight of different components of the website, including scripts, images, fonts, and more. This breakdown allowed us to identify the specific components that contributed the most to the website's weight and CO2 emissions, enabling targeted

optimization efforts. With its comprehensive reports and helpful suggestions, Digital Beacon proved to be an essential tool for website owners seeking to understand and improve the environmental impact of their websites while optimizing their performance.

3.4.3 Ecograder

We leveraged Ecograder, another powerful tool in our evaluation process. Ecograder combines CO2.js from The Green Web Foundation with Google Lighthouse's open-source page metrics to provide a comprehensive assessment of a website's environmental impact. By submitting a website address to Ecograder, we received detailed reports with suggestions for improving the website's performance and user experience. Additionally, Ecograder offered advice on procuring a green web host and reducing website-related emissions. By following the recommendations outlined in the Ecograder reports, website owners could effectively reduce their carbon emissions and improve their overall sustainability score.

3.4.4 CO2.js

We utilized CO2.js, an open-source JavaScript library that serves as a standalone data carbon calculator. While it is used by Ecograder, their way of using it is analysing finished websites by converting the page weight of a website into what it estimates the CO2 out will be. For our testing we needed to use it in a different way, by making a front-end version of the tool, we were able to input a data amount, see how much CO2 that amount of data would be converted to by being downloaded by an user. This gave us a way to see what reductions in CO2 output a website would have if they reduced the page weight of their website.

3.5 Validation of Web sustainability guidelines

To ensure the effectiveness and applicability of our sustainability guidelines, we conducted a validation process. This process involved practical applications of the guidelines, the results were instrumental in refining the guidelines and allowed us to iterate on what we gathered

from our initial research and proved their application in reducing the carbon footprint of TV2's websites.

3.5.1 Website Selection

To display the practical application and impact of implementing our sustainability guidelines, we collaborated with our project owner at TV2, to find a website to work on. We were provided with a comprehensive overview of their services and their tech stack, categorized by TV2's ability to provide support and their accessibility for students to work with.

URL
https://www.tv2.no/
https://www.tv2.no/sport/
https://www.tv2.no/nyheter/innenriks/mann-domt-til-tvungent-psykisk-helsevern-etter-drap-i-bergen/15452640/
https://www.tv2.no/live/ and subpages
https://www.tv2.no/direkte/ and subpages
https://www.tv2.no/vaer/ and subpages
https://www.tv2.no/mat/oppskrifter and subpages
https://www.tv2.no/tvguide/
https://www.tv2.no/spesialer/ and subpages
https://broom.tv2.no/underholdning/broom/biltester/ and subpages
https://www.tv2.no/video/
https://www.tv2.no/video/underholdning/the-voice/jarle-faar-seg-en-gedigen-overraskelse-naar-han-snur-seg/1825333
Categories of complexity to involve students in website development:
Green - Easy to involve students
Yellow - harder but still possible to involve students
Grey - Uncertain, applications are more complex and older.

Initially, we chose tv2.no/live, a yellow-coded website with a high page weight, indicating room for sustainability and optimization improvements. However, due to the challenges encountered and upcoming changes, we opted for an alternative TV2 domain.

We selected tv2.no/mat/oppskrifter, a dedicated food and recipe website. Offering valuable opportunities for sustainability enhancements. Importantly, our product owner, who also served as the project lead for this website, provided extensive support and access, facilitating the implementation of sustainable changes.

During the website selection process, we employed tools such as Google Lighthouse, Digital Beacon, and Ecograder to evaluate the sustainability and performance of the websites, these tools played a crucial role in informing our decision-making process, ensuring that we focused on websites with the greatest potential for sustainability improvement.

3.5.2 Implementation of Sustainability Improvements

We tested out a range of sustainability improvements on the selected websites in accordance with our guidelines. For tv2.no/live, we focused on updating the navigation user interface, to streamline the user experience, improve navigation efficiency, and reduce bounce rates. Additionally, we explored the potential for file size reduction by converting image files from JPEG to more efficient formats such as WEBP and AVIF. These changes aimed to optimize page load times and enhance sustainability.

On tv2.no/mat/oppskrifter, we introduced several improvements to enhance sustainability. These included replacing the standard “<img/> element with the “<picture/> element to serve optimized images based on viewport size. We also explored the difference between WEBP and AVIF image formats to reduce file sizes and implemented individual image sizes for tablet and mobile devices. Furthermore, we tested what impact dark mode would have on an OLED smart phone to improve energy efficiency and user experience.

These evaluations provided valuable insights into the effectiveness of our guidelines and the tangible benefits achieved in terms of sustainability enhancements and user experience improvements. The data collected allowed us to quantitatively measure the improvements achieved and validate the positive impact of our sustainability-focused changes.

4 Results

This chapter will show the findings from our interviews with a competing company, the final sustainability guidelines, including the difference between the iterations. We will also highlight the prototyping and development of the website hosting the guidelines, and the results of the testing of the guidelines on TV2's Live sports website, and TV2's recipe website.

4.1 Results from interviews with competing company

Through the interviews we conducted, valuable insights were gathered regarding that specific company's commitment to web sustainability and their specific practices towards this goal (3 Interview with competing media company. Although the professionals interviewed were not directly involved with website operations, their insights into the company's organizational strategies towards sustainability were informative. We learned about their recent efforts towards generating climate reports based on their overall sustainability, including the sustainability of their web services and the carbon emissions resulting from both transportation and electricity usage within their offices.

Their unique monitoring dashboard, which tracks carbon emissions from all their operations, was particularly enlightening. This data, incorporated into their reports, provides a basis for continuous learning and improvement within that company. The interviewees also highlighted the use of cloud services, as resources for sustainability monitoring.

However, there were limitations to the data collected from the interviewees due to their specific roles within the organization. They recommended consulting with another professional within the company more involved in website development. Unfortunately, due to time constraints, this was not feasible within the scope of this study.

4.2 Web sustainability guidelines

In this section, we explore the process of refining our initial web sustainability guidelines through several iterations. The aim of these revisions was to produce a set of guidelines that

were not only more streamlined and concise but also specifically tailored to meet the needs of TV2. We carefully assessed each part of the guidelines, removing elements that we found were unnecessary or less relevant for TV2's context. In the following subsections, we will present the finalized guidelines and highlight the significant changes that were made during each iteration, underscoring how these modifications contributed to a more efficient and targeted set of recommendations for TV2.

4.2.1 Initial version

- **Overview:** The initial guidelines covered several major areas of web sustainability including planning, design, image optimization, power usage reduction at the end-user level, typography, and hosting. For each of these areas, specific actions were recommended, from setting sustainability budgets and streamlining content to image file type selection, colour optimization, font hosting, Jamstack, content delivery network, page caching and choosing green data centres.
- **Key Principles:** The development of these initial guidelines was guided by a few main principles:
    - **Efficiency:** A central goal was to reduce data transfer, load on end-user devices, and server power consumption. This is reflected in recommendations like reducing the number of pages, optimizing image sizes, and avoiding auto-playing videos.
    - **Sustainability:** The guidelines promoted actions that not only reduce carbon footprint but also set a path towards long-term sustainability. This is evident in the advice to benchmark current sustainability metrics and set achievable yet ambitious goals.
    - **User Experience:** While the focus was on sustainability, the guidelines also acknowledged the importance of user experience. Suggestions were made to design websites in ways that allow users to efficiently navigate and find what they are looking for.
    - **Practicality:** The guidelines recognized the practical constraints of web development. For instance, the guidelines recommended using system fonts

for efficiency but also provided advice on hosting and optimizing other fonts if needed.

4.2.2 Iteration of guidelines

This upcoming text is our iteration of the web sustainability guidelines. It is the result of our research into what causes website to emit CO_2, and what can be done to minimize those emissions. The research that went into these guidelines include current relevant literature, as well as our own testing of TV2's websites. The guidelines are also meant to consider TV2's needs and current knowledge within web sustainability.

Sustainability Guidelines for TV2 Websites

This document outlines strategies to enhance sustainability across various aspects of websites, including planning, design, user experience, content optimization, power consumption, and hosting.

I. Planning

A. Benchmark: Assess the sustainability of your website and compare it with competitor sites.

B. Theoretical Possibility: Determine the best possible metrics for your website under ideal conditions.

C. Sustainability Budget: Set sustainability goals that are achievable and at least on par with industry standards. If there's potential for significant improvement, aim for a higher sustainability budget.

D. Stretch Goals: Establish ambitious targets to pursue once the sustainability budget goals are met.

II. Design and User Experience

A. Avoid Yo-Yo User Journeys: Prevent users from frequently navigating in and out of pages. For example, eliminate the need to return to the homepage to access different pages.

B. Streamline Content: Reevaluate the necessity of your website's pages and content. Less is more for sustainability.

C. Dark Mode: Implement an automatic dark mode or adopt a dark mode-first approach for OLED screens.

III. Content Optimization

A. Images

1. File Type: Use WEBP instead of JPEG for 30% smaller file size. Use PNG or GIF for images with few block colors, like icons.

2. Optimization: Utilize tools like ShortPixel, TinyPNG, or ImageAlpha to reduce image file sizes.

3. Responsive Images: Employ "srcset" and "sizes" attributes in HTML "picture" elements to display images based on screen size.

4. Additional Techniques: Implement blurring, CSS monochrome or grayscale, and SVG optimization to further reduce file size.

5. Image Spacing: Reduce image width and height to decrease file size and enhance impact.

B. Typography

1. System Fonts: Use pre-installed system fonts to avoid data transfer.

2. Font Hosting: Host font files on your server instead of using font services to reduce server requests.

3. Font Files: Remove unneeded files and use variable fonts for multiple font styles. Convert files to WOFF2 format.

4. Optimization: Use tools like Fontdrop and Everything Fonts to remove unused characters, subject to foundry license terms.

IV. Power Consumption

A. Colour: Dark colours use less power on OLED screens. Blue uses less power than green and red.

B. Video: Minimize video usage and autoplay. Opt for images, text, or interactive animations when possible.

C. GIFs: Replace GIF animations with more efficient WEBP files.

D. Animations: Limit front-end animations to reduce CPU usage.

V. Hosting

A. Green Host: Ensure your website is hosted on a data center powered by green energy.

B. Data Center: Select a data center close to your core user base to reduce emissions and latency.

4.2.3 Rationale behind iteration

In this iteration, the guidelines were streamlined and refined to better meet TV2's specific needs. This version maintained the focus on planning, design, user experience, content optimization, power consumption, and hosting, but several changes were made:

- **Key Changes:**
  - **Consolidation:** Sections from the initial version have been combined to create a more cohesive structure. For instance, the "Design" and "User Experience" sections are now merged into a single section, "Design and User Experience."
  - **Simplification:** Some sections have been shortened or removed altogether due to their irrelevance to TV2's context. For example, mentions of Jamstack, page caching, and Content Delivery Networks were removed altogether.
  - **Streamlining Content:** The content of the guidelines was minimized. This involved removing redundant information and focusing on key actionable strategies for TV2.

4.3 Addition of Data Carbon Calculator to Website

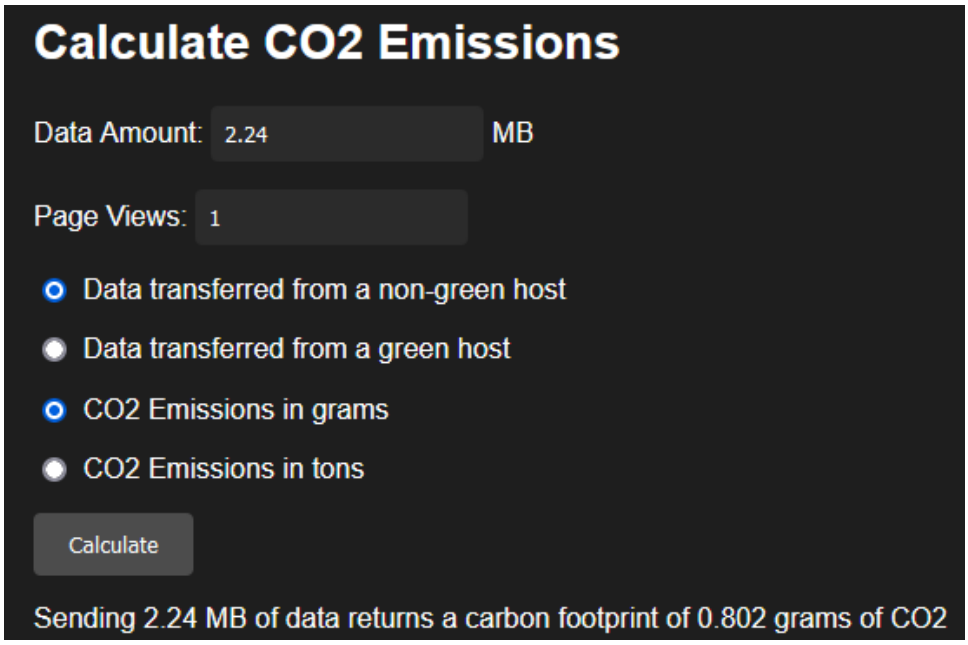
In the final iteration of the website, we also added the Data Carbon Calculator. The reason for this was that we saw its usefulness as a companion tool when implementing and testing the guidelines when updating existing websites.

4.3.1 Why it was added

- **Reasons for Addition of Calculator**

- **Original Idea:** In our initial discussions with TV2's product owner, we contemplated creating a carbon calculator along with the guidelines. However, this idea was shelved to concentrate on the guidelines. Towards the project's conclusion, we developed a front end for CO2.js, which proved invaluable during our tests and could also be beneficial for TV2.
- **Does not exist on the market:** While tools like Google Lighthouse, Ecograder, and Digital Beacon excel at evaluating existing websites, we found no application utilizing CO2.js in the way we have - as a carbon data calculator. Users input data, receive an adjusted CO2 emission based on whether they use a green host, and quickly understand the environmental impact of changes like reducing page weight.
- **Fast Calculations:** Unlike market-available tools that can take over a minute to analyze a website via URL, our CO2.js front end facilitates instant calculations, making it highly efficient for developers needing to amass data swiftly.
- **Natural Companion of Guidelines:** Pairing the guidelines with our CO2.js calculator allows developers to gauge the effects of sustainable changes. Although CO2.js provides a rough estimate of the CO2 output based on website data transfer, it is better than having no estimation at all.

4.3.2 How it is used



Introduction: The Data Carbon Calculator is a tool designed to estimate the amount of carbon dioxide (CO2) emissions generated by your data usage. This guide will walk you through the process of using the calculator effectively.

Step 1: Input Data Amount in Megabytes:

- Start by entering the data amount in megabytes (MB) that you want to calculate the CO2 emissions for. This could represent the size of a webpage or any other digital content.

Step 2: Input Page Views:

- Next, enter the number of page views associated with the data amount you provided in Step 1. This helps estimate the total CO2 emissions generated across multiple views of the content.

Step 3: Choose Green Host Option:

- The calculator offers a choice to select whether you are using a green host or not. Green hosts are providers that utilize renewable energy sources, resulting in lower CO2 emissions. Select the appropriate option using the provided radio buttons.

Step 4: Select CO2 Output Unit:

- Decide how you want to receive the CO2 calculations. The calculator provides two options: grams and tons.
    - If you are interested in the CO2 output for a single page view or smaller numbers, choose grams. This unit is suitable for individual assessments.

- If you need to handle larger numbers, such as monthly CO2 output for websites with millions of page views, select tons. This unit is more convenient for handling significant quantities.

Step 5: Calculate the CO2 Emissions:

- After completing the previous steps, click on the "Calculate" button. The calculator will process your inputs and provide the estimated CO2 emissions based on the selected options.

Conclusion: The Data Carbon Calculator is a valuable tool for understanding the environmental impact of your digital data usage. By inputting the data amount, page views, selecting the appropriate host option, and choosing the preferred CO2 output unit, you can easily calculate and evaluate the carbon footprint associated with your digital content.

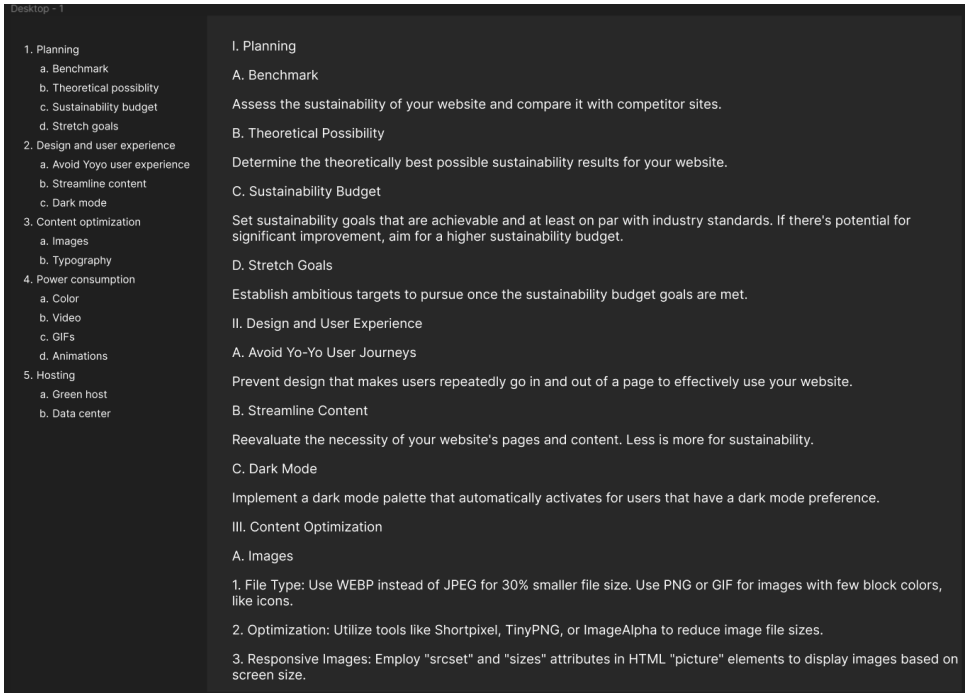
4.4 Development of guidelines website

4.4.1 Prototype of guidelines website

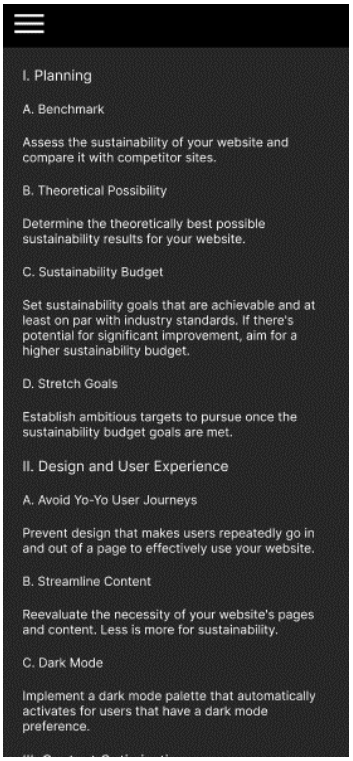
Developing a website that displays the guidelines required some prototyping through Figma. Creating a prototype allows us to get a sense of the layout, user interface, and overall design before investing time and effort into the actual development process. Figma allowed us to collaborate on the design, make necessary adjustments, and ensure that our vision was well-aligned with the end goal.

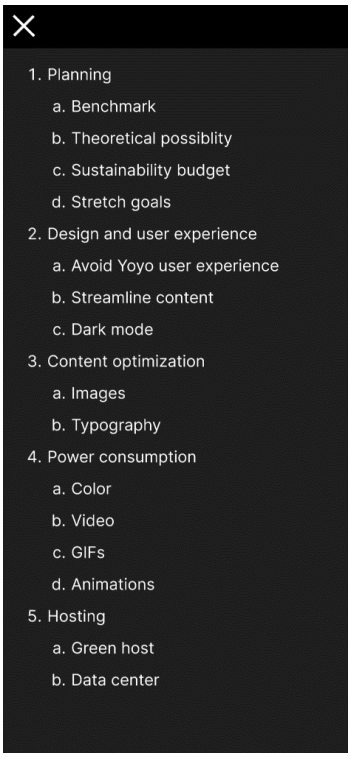
We knew it had to use a dark colour palette, a navigation bar, and responsive to different screens. To make it responsive, we would need to incorporate a hamburger menu. A button that the user can press that brings up the navigation bar and overlays over other content. Here is the prototype we ended up with.

For desktop:

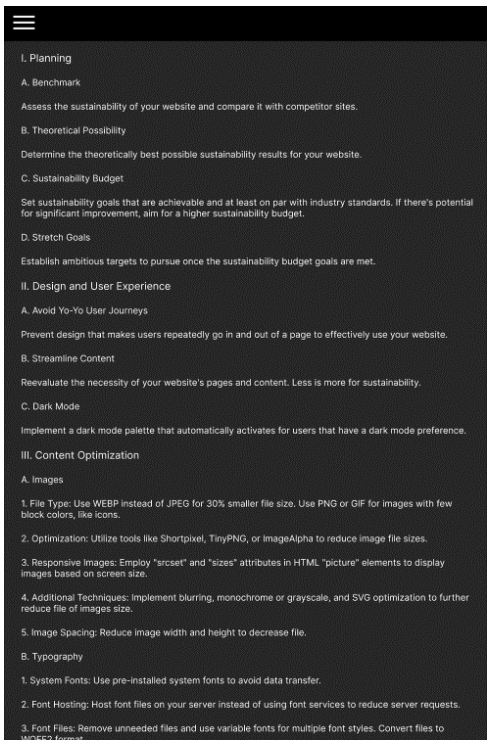


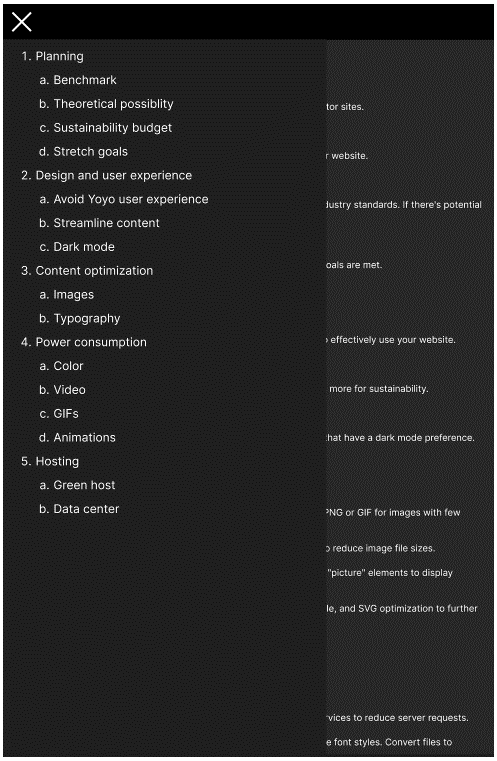
For Mobile devices, before and after opening the hamburger menu:





For Tablet devices, before and after opening the hamburger menu:





4.4.2 Guidelines website implementation

From the prototype, we designed a clear outline for creating the guidelines website. Given the variety of ways to create a website that meets our requirements, we evaluated several potential tech stacks before making our choice. Our evaluation considered usability, efficiency, and environmental impact, as the latter was in line with our focus on sustainability.

Framework	Advantages	Disadvantages	Sustainability Impact
Svelte	Straightforward usage, requires fewer lines of code, smaller bundle size, no use of virtual DOM	Less popular than other frameworks, smaller community	Positive, due to smaller bundle size and lower processing power requirement

React	Highly popular, large community, dedicated support	Requires more lines of code, uses a virtual DOM	Neutral to Negative, due to larger bundle size and higher processing power requirement
Angular	Comprehensive framework, dedicated support	More complex, larger bundle size	Negative, due to largest bundle size

We decided to use Svelte, a component-based JavaScript framework like React. This decision was based on several factors. Firstly, we found Svelte to be more straightforward to use and it required fewer lines of code. Secondly, from a sustainability perspective, Svelte appeared to be more environmentally friendly than other popular JavaScript frameworks. It has a smaller bundle size, meaning that the collection of JavaScript files sent to the user is smaller, leading to a lower page weight. Svelte also does not use a virtual DOM, which means that the browser does not require as much processing power to run a Svelte page as it would with a React page (Bhandari, 2022). According to Sustainable WWW, a simple "Hello World" project in Svelte had a bundle size of 3.8KB. For React and Angular, it was 6.3KB and 180.3KB, respectively (SustainableWWW, 2021).

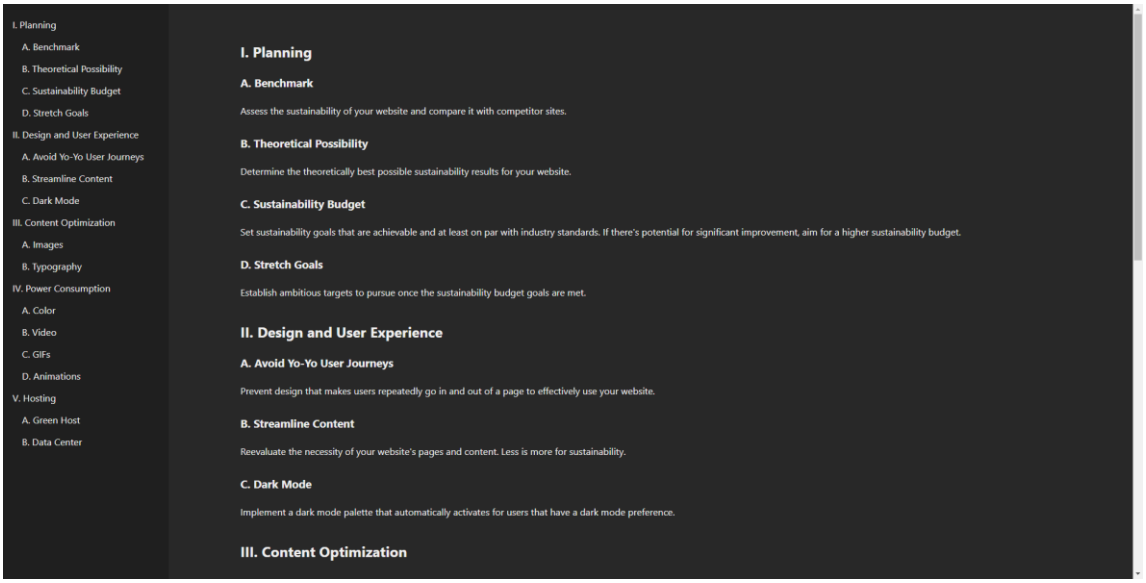
4.4.3 Initial version

- **Overview:** Our initial version of the website covered all the necessities. It was constructed with a horizontal navigation bar on the left and the guidelines' content displayed on the right. The site's design embraced a dark theme and was responsive to various screen dimensions.
- **Key features:** The development of the initial version of the website was guided by the following fundamentals:
    - **Simplicity:** The site maintained a minimalist design, comprised of merely text and a horizontal navigation bar, devoid of superfluous features, thereby facilitating user-friendliness and intuitive navigation.

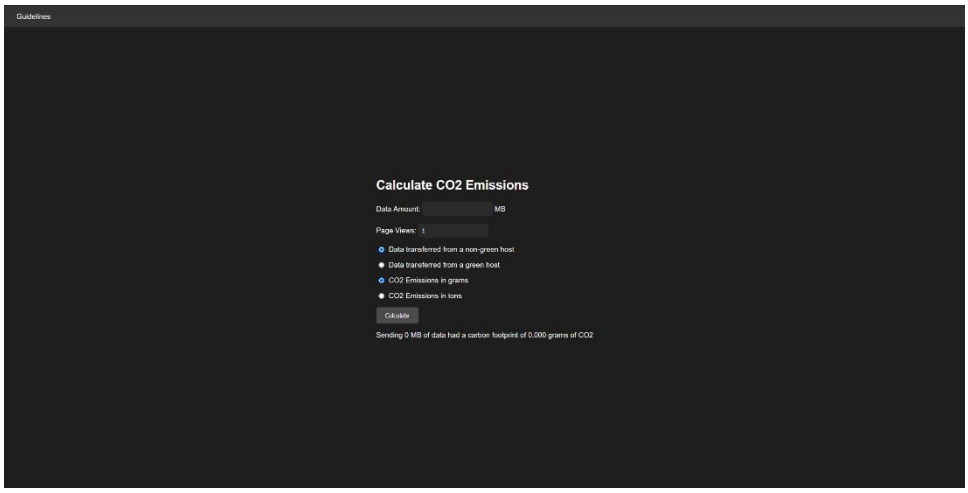
- **Versatility:** The site offered compatibility across an array of devices. On top of that, it enables users to select their desired sections from the navigation bar. This aspect synergized well with the fact that each step in the guideline was designed to function independently.
- **Sustainability:** The adoption of a dark theme was a deliberate choice, aimed at reducing the power consumption of the user's device. Furthermore, the website's simplicity contributed to its sustainability by decreasing the page weight.

Finished website on desktop:

Guidelines

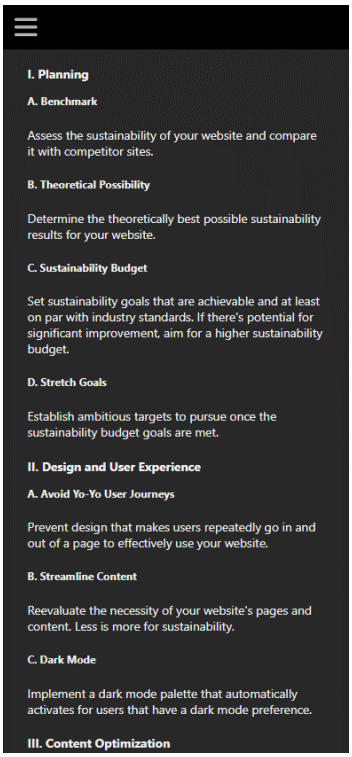


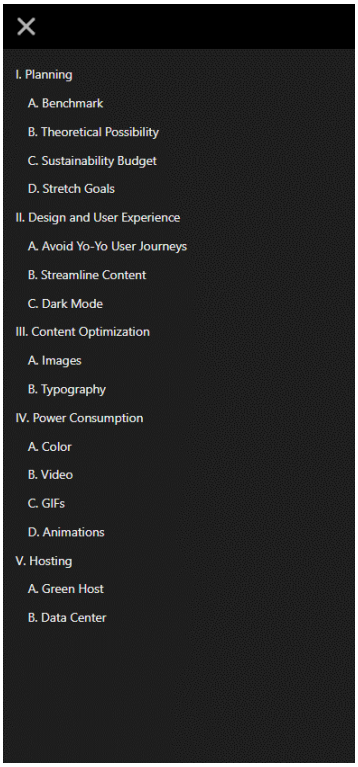
Calculator



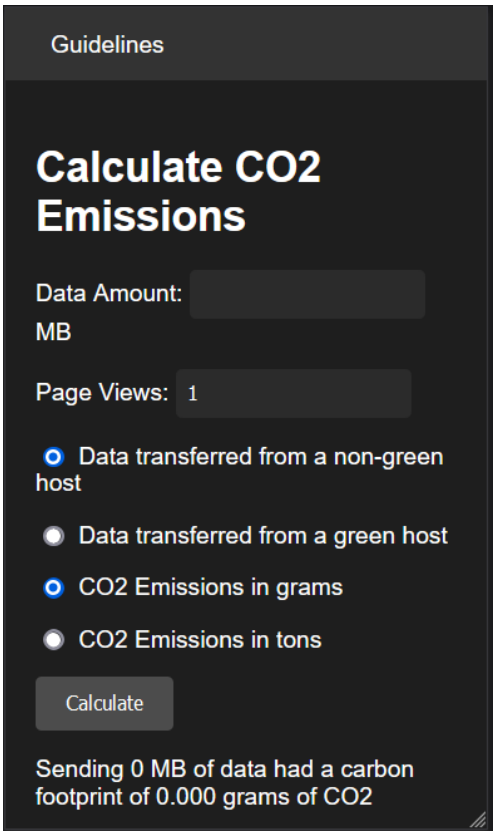
Finished website on mobile:

Guidelines



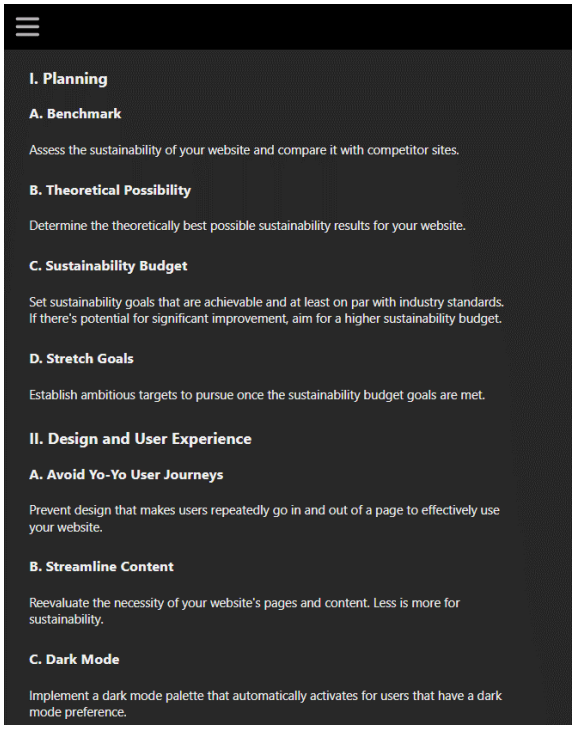


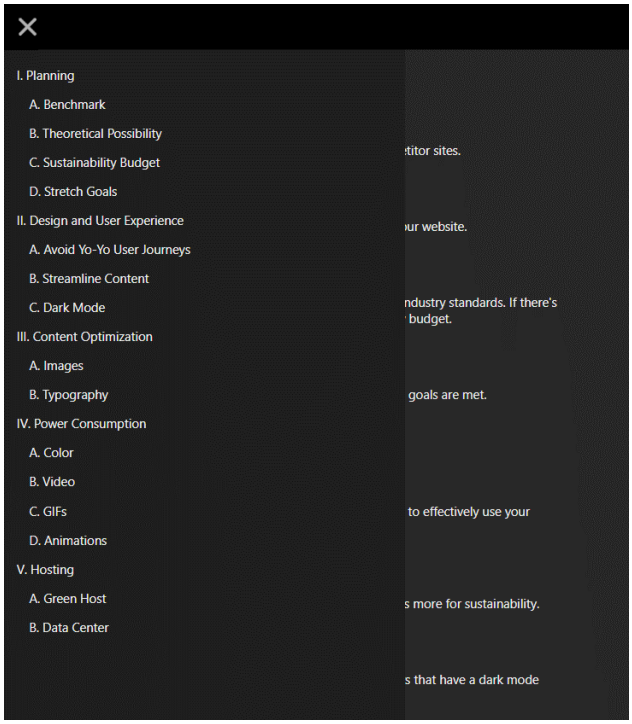
Calculator



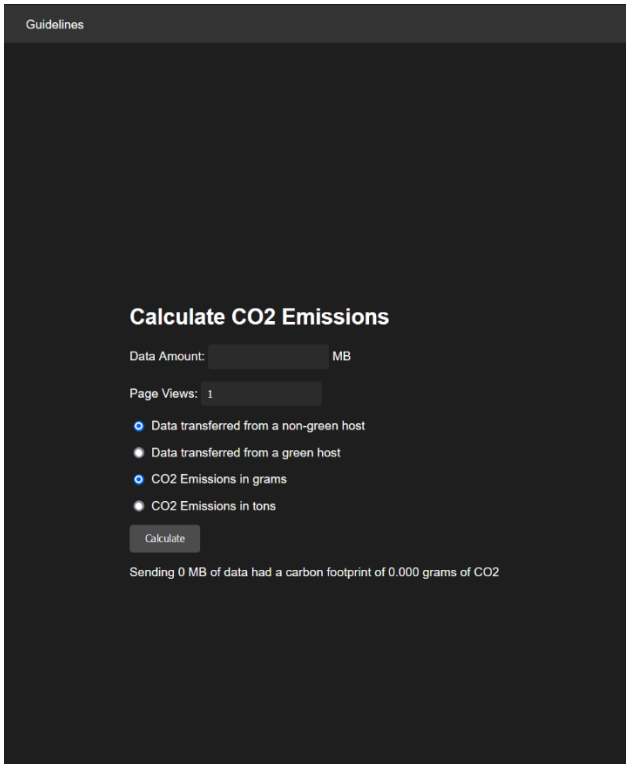
Finished website on tablet:

Guidelines





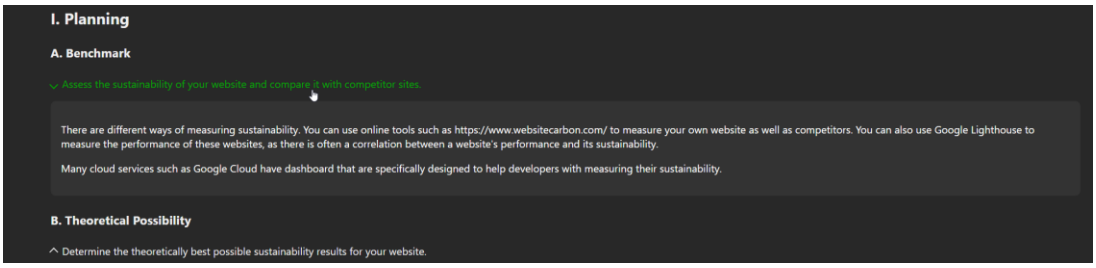
Calculator



4.4.4 Iteration of website

Our team recognized the potential for further enhancements of the website.

- **Key changes:**
    - **Additional context:** Our team believed that several points could benefit from further clarification, context, and links to tools. However, to avoid cluttering the page with excessive text and to maintain ease of overview for TV2, we introduced an interactive feature. Users can now click on a text segment, triggering the display of additional information below. The text changes to green upon hovering, and an upward-pointing arrow appears when the text is clicked, unveiling a box containing supplementary details. These details are rewritten texts from the first version of the guidelines.



    - **Title:** A title was incorporated at the top of the page, accompanied by a brief explanatory note delineating the guidelines' purpose.

We selected Netlify for website hosting, a cloud-based web development platform committed to environmental sustainability. Netlify achieves this by employing modern website architectures such as Jamstack, a web development methodology that pre-builds websites before they go live. This technique, as opposed to traditional approaches that build the website with each visit, reduces server strain and power consumption. Furthermore, Netlify offers automatic scalability, activating additional resources during high traffic periods and shutting them down when traffic decreases. Despite the reliance on key cloud providers such as AWS and Google Cloud, Netlify does not exclusively utilize green hosts. The hosting location of your website depends on the server Netlify assigns (Netlify, 2023).

The guidelines website can be accessed via the following link: https://web-sustainability-guidelines.netlify.app/.

4.5 Results from the changes to tv2.no/live

4.5.1 Navigation change

After implementing the navigation bar changes, we successfully enabled direct access to the subsections that were previously only accessible from the frontpage 2 Images showing changes to TV2 Live. However, it is important to note that we did not conduct extensive testing with external participants beyond our own group. As a result, we are unable to provide empirical data regarding the potential reduction in unnecessary page loads resulting from this change.

4.5.2 Changing from JPEG to WEBP and AVIF

Format	Size (MB)	Resolution	% of Size	% of Reduction
JPEG	1.52	600 x 400	100%	0%
WEBP	0.77	600 x 400	50.6%	49.4%
AVIF	0.30	600 x 400	19.8%	80.2%

By converting the images from JPEG to WEBP, we achieved a reduction in size of the images, the original size of the 11 images, that gets loaded in on entry was 1.52MB, while the images after conversion to WEBP format was 0.77MB. This showed a reduction in size of 49,4%.

By converting the images from JPEG to AVIF, the results showed a bigger reduction in size. From 1.52MB to 0.30MB. A significant drop in size 80.2% from the original, and less than half of the conversion to WEBP.

By using CO2.js we were able to estimate the reduction in Co2 per pageview and how much monthly CO2 they would release after the changes were implemented.

For this test we used the month of January 2023, where tv2.no/live had 2,817,287 visitors.

Image Format	Page Weight (MB)	New Page Weight	CO2 per pageview (original)	CO2 per pageview after conversion	Reduction in overall page weight	CO2 released in a month	CO2 released after changing image format
WEBP	5.06 MB	4.31	1.81g	1.53g	15.47%	5.0099 metric tons	4.302 metric tons.

AVIF	5.06	3.84	1.81g	1.375g	24.03%	5.0099 metric ton	3.874 metric tons.

4.6 Results from the changes to tv2.no/mat/oppskrifter

4.6.1 Transition from '<img/>' to '<picture/> element

To improve the sustainability and performance of tv2.no/mat/oppskrifter, we transitioned from using the <img/> HTML element to the more flexible <picture/> element. The <picture/> element allows for more control over the images displayed, enabling us to optimize based on the user's viewport.

Code snippet:

Original:

```
<img      You, now • Uncommitted changes
    in:fade={{
        duration: 100
    }}
    src={`${import.meta.env.VITE_CLOUDFRONT}/${data.images[0]}`}
    alt={data.title}
/>
```

After change:

```
<section class="hero" in:fade>
    {#if data.images && data.images.length}
        <picture>      You, last month • changed some img to picture …
            <source
                media="(max-width: 495px)"
                srcset={`${import.meta.env.VITE_CLOUDFRONT}/${data.images[1]}`}
                type="image/webp"
            />
            <source
                media="(min-width: 496px)"
                srcset={`${import.meta.env.VITE_CLOUDFRONT}/${data.images[0]}`}
                type="image/webp"
            />
            <img
                src={`${import.meta.env.VITE_CLOUDFRONT}/${data.images[1]}`}
                alt={data.title}
                in:fade={{ duration: 100 }}
            />
        </picture>
```

This modification allows us to deliver images that are better suited to the user s device and display settings. By adjusting the resolution and size of the images according to the user's viewport, we can decrease load times, since the user will not have to download much bigger pictures than what is needed for their device.

4.6.2 Converting WebP to AVIF

The AVIF encoder on avif.io was used to convert a set of 19 images taken from the main page of tv2.no/mat/oppskrifter from WebP format to AVIF format. We recorded the initial size of the images in WebP format and the resulting size of the images in AVIF format.

The initial size of the images in WebP format was 631 kb, and the new size after converting them to AVIF format was 610 kb. This represents a decrease in file size of 3.33%. The resulting AVIF images were of comparable quality to the original WebP images and maintained their visual fidelity.

Image format	Images	Size total kb	Co2 in g
WEBP	19	631	0.226
AVIF	19	610	0.218

4.6.3 Resizing the images for tablet and mobile

Mobile

To enhance page load speed for mobile users, we resized the thumbnail images on the front page. The original thumbnail size was 496 x 368, while the rendered size on mobile devices like the iPhone 12 Pro was 171 x 120. We aimed to strike a balance between image resolution and quality, as it is crucial for displaying appetizing dishes on a food recipe website. Thus, we resized the images to 342 x 240. This reduced the file size of the 18 small thumbnail images from 469.9 KB to 246.2 KB, resulting in a significant reduction given the website's total page load of 2.24 MB.

Image Name	Size (Original) (KB)	Size (Resized) (KB)	Reduction (KB)
image1.webp	26.1	13.3	12.8
image2.webp	22.5	11.6	10.9
image3.webp	20.5	10.7	9.8
image4.webp	16.7	8.9	7.8
image5.webp	29.6	15.0	14.6
image6.webp	36.4	17.3	19.1
image7.webp	21.8	12.0	9.8
image8.webp	43.3	19.6	23.7
image9.webp	28.6	15.6	13.0
image10.webp	43.3	20.2	23.1
image11.webp	34.8	16.6	18.2
image12.webp	22.1	11.3	10.8
image13.webp	24.9	12.7	12.2
image14.webp	24.4	12.1	12.3
image15.webp	16.1	8.3	7.8
image16.webp	27.6	14.7	13.0
image17.webp	22.3	11.7	10.6
image18.webp	40.4	19.9	20.5
Total	496.9	246.2	250.7

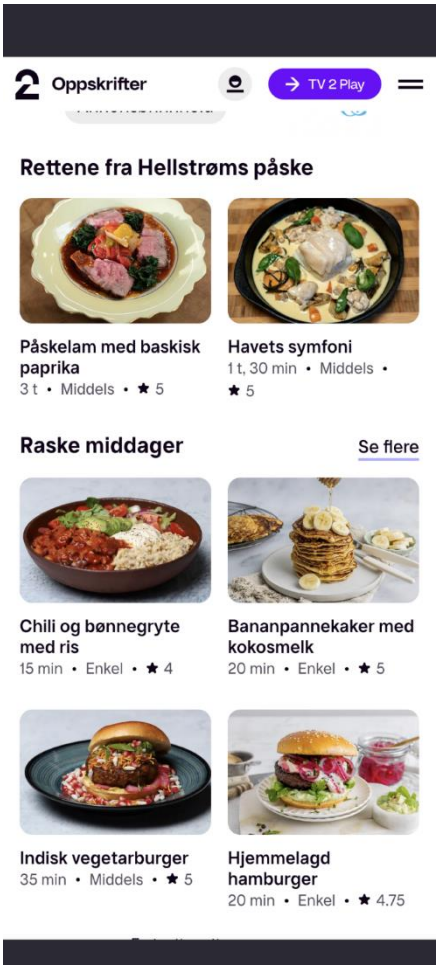
The larger image on the front page, originally 1280 x 720 pixels, is rendered at 390 x 219 pixels for cell phone devices like the iPhone 12 Pro. To optimize it, we resized the image to 400 x 225 pixels.

Image Name	Size (Original) (KB)	Size (Resized) (KB)	Reduction (KB)
NyChrister2.webp	101.2	15.7	85.5

With this we had adjusted the page load of the website for mobile users by 336.2(KB). Using the CO2.js calculator, we estimated the carbon emissions for the original page load to be 0.80 grams of CO2. However, after implementing these adjustments, the new CO2 emissions decreased to 0.682 grams.

4.6.4 Dark Mode Test

Light Mode



Dark Mode

The objective of our experiment was to evaluate the effectiveness of the proposed dark mode implementation on tv2.no/mat/oppskrifter in conserving battery life on OLED screen devices. The test was conducted by fully charging the device, setting the brightness to its maximum level, and observing the battery drain over a specific period.

In the first phase of our test, the device was left idle on the dark-themed footer of tv2.no/mat/oppskrifter. The footer, designed with a dark background and white text, represented our proposed dark mode. After 30 minutes of inactivity, the battery level reduced minimally, from 100% to 99%.

For the second phase, we replenished the device's battery to full capacity and repeated the same test. However, this time, we left the device idle on the main body of the tv2.no/mat/oppskrifter page, which has a light background with various images, representing the current light mode design. After an identical 30-minute interval, the battery had drained to 97%.

These results indicate a measurable difference in battery consumption between the dark mode and light mode. Despite the short duration of the test, the dark mode demonstrated a lower rate of battery depletion, underlining the potential of dark mode to contribute to energy conservation for OLED screen users. This outcome provides a compelling argument for the introduction of a dark mode option on tv2.no/mat/oppskrifter, thereby enhancing the sustainability of the website and offering a customizable user experience.

5 Discussion

In the following section, we will delve deeper into the interpretation and implications of our findings. Through this exploration, we aim to make sense of the results we have obtained and discuss the challenges encountered. Additionally, we will reflect on the implications of our findings for TV2, drawing potential pathways for future research and applications. It is important to note that this discussion is grounded in the specific context of our study, with a focus on creating tailored, sustainable web guidelines for TV2.

5.1 Effectiveness of the guidelines

Existing sustainable web design guidelines have been developed with a broad applicability in mind, ranging from individual projects to large-scale enterprise settings. This universality is beneficial in promoting the message of sustainability to a wide audience. However, it is not without drawbacks.

Guidelines that attempt to remain universally applicable might fail to incorporate specific measures that could prove advantageous for certain types of projects. For instance, a guideline may omit advanced image optimization techniques, which could significantly enhance the sustainability of a media-intensive site.

Conversely, guidelines that strive to encompass a plethora of different use-cases might lack coherence and specificity. Applying a single guideline designed to address e-commerce platforms, blogs, and news portals to a specific use-case, such as a personal blog, could result in an overwhelming and less efficient process.

While universal guidelines serve a crucial role in fostering sustainability, their application may not be entirely suitable or integrable for all specific use-cases. Due to this

This realization of the limitations of universally applicable guidelines led us to develop a tailored set of sustainable web design practices specifically for TV2. Given TV2's unique operational context and specific use-cases, a tailored approach allows us to address its specific needs more effectively and comprehensively.

Creating a tailored guideline for TV2 enables us to focus on and implement sustainability measures that are most relevant and beneficial for TV2's web services, considering the

specifics of their content, audience, and technological infrastructure. This custom guideline not only streamlines the process of making TV2's web services more sustainable but also ensures that all proposed measures are feasible and effective within their specific context.

By creating guidelines specifically for TV2, we aim to maximize the potential for sustainability improvements while minimizing unnecessary complexity and inefficiency that might arise from a one-size-fits-all approach.

5.1.2 Guidelines website

Keeping the guidelines on a separate website helps us show them in action. We can show useful web programming practices linked to certain parts of the guidelines. We can also display design choices that promote sustainability, like using a dark colour theme. This mix of direct examples and design tips gives a clear guide for developers who want to make their website more sustainable. It highlights the need to consider sustainability in all parts of web development, from coding to design.

5.2 Challenges

Throughout the work of this project, our team encountered many different challenges, often in relation to our objectives and collaboration with TV2. Our initial goal was to collaborate with TV2 and contribute to their sustainability initiatives. However, what direction to go from there that would be best for this project remained uncertain.

Our plan included conducting research and using the findings to construct a sustainability guideline. But we also wanted to create some sort of web application to go along with it. So, we thought of creating a website sustainability measurer that is specifically designed for TV2 and their needs. Despite this, we wanted to further integrate TV2 into our project work.

The proposed solution was to directly engage with TV2’s codebase, implementing and testing parts of our guidelines within their website framework. This approach marked a strategic shift in our project focus, moving from the development of a standalone guideline website to an emphasis on direct application within TV2’s codebase. As a result, our guideline development maintained its importance, but the creation of a sustainability measurer was scrapped in favour of a more hands-on approach with TV2’s digital infrastructure.

5.2.1 Implementation challenges

While engaging with TV2's codebase, additional challenges were confronted. One of them involved securing access to TV2 Live repositories on Bitbucket. This process required some trial and error, dealing with issues related to passwords and access tokens. Given that cloning the repository seemed to be impossible, we were told by TV2 to download the repository as a zip file as an alternative solution.

After setting up the downloaded repository, we were faced with the task of running the TV2 Live website on our local machines. This presented yet another challenge, as running it required Node 16, whereas we had been using Node 18, the latest version. This required the installation of Node Version Manager (NVM), a tool that facilitates the switching between different versions of Node (Harband, 2022).

After successfully getting the website running, we observed a significant delay in startup times, typically spanning several minutes. Additionally, making alterations to the code and saving them led to a comparable duration of latency for the changes to be reflected on the website. Collectively, these issues brought on substantial delays on our testing and development activities on TV2's websites, thereby presenting us with an unexpected challenge to navigate within our project timeline.

5.3 Future work

5.3.1 Potential areas for further research

For future enhancement of the guidelines, it would be beneficial to systematically validate each proposed solution through rigorous testing on TV2's websites. This approach would help substantiate the effectiveness of each guideline and assist in refining or discarding any steps that do not yield the desired results for TV2.

With less time constraints, a practical approach would be too incorporate select recommendations from the guidelines into the production builds of the websites. By allowing a specific period, such as a month, to elapse, and leveraging analytics, we could then come to know the impact of these modifications on user behaviour. This method could provide invaluable insights into how certain alterations influence user interaction metrics, such as the frequency of page loads compared to how long they stay on the pages.

Moreover, extending our investigation through additional interviews is advisable. Our preliminary interactions led us to key stakeholders within the organization who could provide in-depth knowledge about website management. Unfortunately, due to time constraints, we were unable to engage in such discussions. Expanding the pool of interviewees to encompass other companies would also enrich our research, fostering a more comprehensive understanding of sustainable practices in the industry. Such interviews could potentially lead to substantial improvements in the guidelines, providing a broader perspective on the strategies employed by various media firms to enhance the sustainability of their web presence.

5.3.2 Potential improvements to guidelines

The sustainability guidelines for web development are designed to be dynamic, adapting to emerging research, test results, and evolving technologies. Enhancing the usability of these guidelines is also a pertinent area of focus. It would be beneficial to conduct user tests, assessing the ease with which individuals comprehend and apply the guidelines. Feedback from these tests could trigger modifications, whether it involves adding clarity to certain solutions or integrating more visual explanations to aid understanding.

The guidelines' website also requires further enhancement. Primarily, it lacks accessibility features, rendering it unusable for individuals' reliant on-screen readers. While rectifying this oversight should be straightforward, time constraints prevented us from addressing it in this phase. Additionally, some guideline steps need more comprehensive explanatory text that users can access. User testing could be instrumental in identifying areas where clarity is lacking and could further enhance the usability of the site.

Finally, adopting a green hosting provider for the website would not only align with our sustainability goals but also serve as a strong model for others. By choosing hosting services powered by renewable energy sources, we would be taking concrete action towards reducing our digital carbon footprint, thereby leading by example in the pursuit of web sustainability.

6 Conclusion

Our bachelor report set out to address the problem statement of developing tailored web sustainability guidelines specifically for TV2 by testing and refining them on tv2.no/mat/oppskrifter, their food recipe website. Through extensive research, iterative testing, and analysis, we have achieved our objectives and provided valuable insights into enhancing sustainability in TV2's web services.

We delved into the concept of sustainable web design and extracted key principles and guidelines from the existing literature. These guidelines were adapted and refined based on comprehensive tests conducted on tv2.no/live and tv2.no/mat/oppskrifter. The results yielded compelling evidence supporting the effectiveness of various measures, including optimizing image file types and dimensions, and evaluating the impact of dark mode on OLED screens of smartphones.

To present our refined sustainability guidelines, we developed a dedicated website serving as a comprehensive resource. This platform displays the guidelines as well as incorporating a CO2 output calculator, powered by CO2.js, to estimate the potential reduction in carbon emissions resulting from the suggested changes.

Our research demonstrates the feasibility of developing and tailoring web sustainability guidelines specifically for TV2. The evidence collected through our tests validates the positive impact of implementing these guidelines in reducing image file sizes, optimizing dimensions for mobile users, and potentially lowering CO2 output.

By bridging the gap between theory and practice, our report provides TV2 with practical and effective solutions to enhance the sustainability of their web services. These tailored guidelines offer recommendations to improve user experience while reducing the environmental impact associated with web development.

In conclusion, our study contributes to the field of sustainable web design and not only provides TV2 with a set of customized guidelines to implement sustainable practices on their web services, but also aligns with the UN's 13th Sustainable Development Goal, "Climate Action.".

The findings highlight the potential for reduced resource consumption, improved user experience, and decreased environmental footprint. By implementing these guidelines, TV2 can embrace sustainability in their web services and contribute to a greener digital ecosystem.

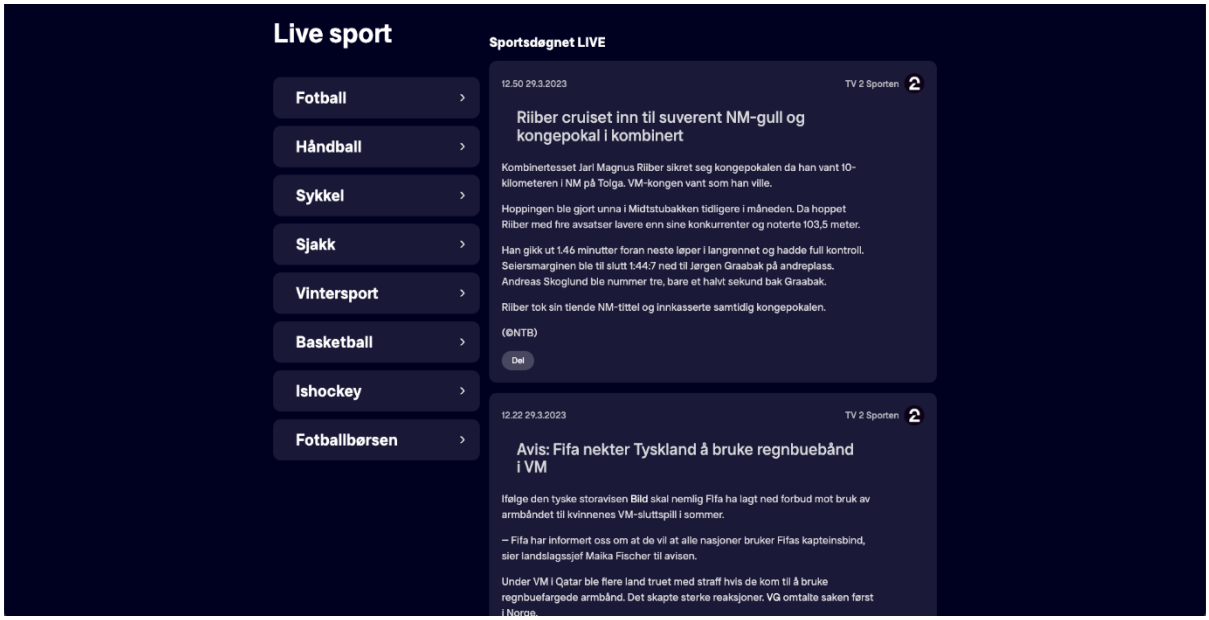
Appendix

1 Links to tools

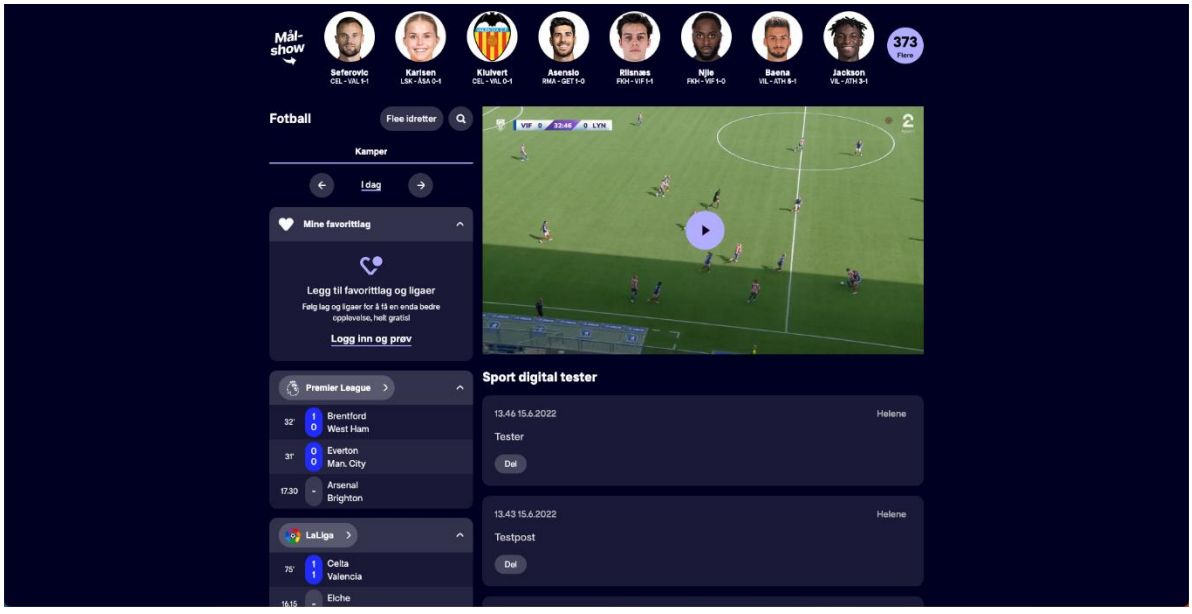
- **Booster Conference 2022: Green Code**
  - https://2022.boosterconf.no/talk/23-green-code/
- **Google Lighthouse**
  - https://developer.chrome.com/docs/lighthouse/overview/
- **Digital Beacon**
  - https://digitalbeacon.co/
- **Ecograder**
  - https://ecograder.com/
- **CO2.js**
  - https://developers.thegreenwebfoundation.org/co2js/overview/
- **ShortPixel**
  - https://shortpixel.com/
- **TinyPNG**
  - https://tinypng.com/
- **ImageAlpha**
  - https://pngmini.com/
- **FontDrop**
  - https://fontdrop.info/
- **Everything Fonts**
  - https://everythingfonts.com/

2 Images showing changes to TV2 Live

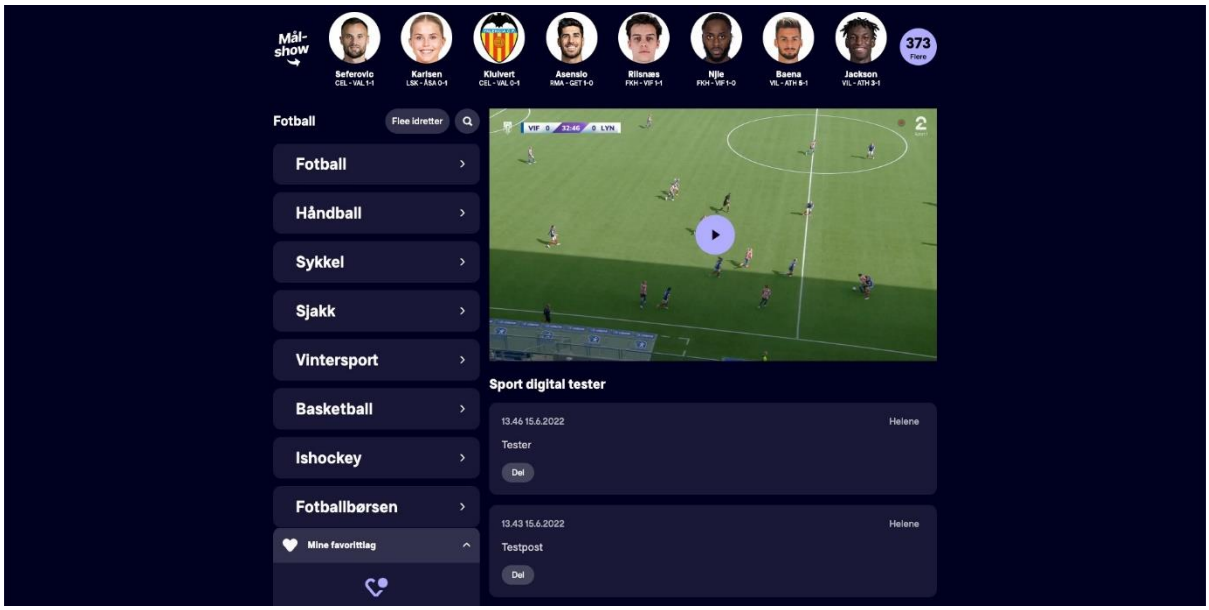
TV2 Live home page:



TV2 Live sport page:



TV2 Live sport page after implementing changes and "Flere idretter" button is pressed:



3 Interview with competing media company

Åpningsspørsmål:

1. Kan du fortelle litt om din rolle og ansvarsområder i [company name]
   - Svar 1: Litt i transisjons fase, sitter i devops team i [Portion redacted for privacy]
   - Svar 2: [Portion redacted for privacy], databaser, sertifikater, blant annet.,

Mest relevante spørsmål:

6. Kan du kort forklare [company name] forpliktelse til bærekraft, spesielt i forhold til deres nettjenester?
   - Svar 1: 2 år siden ble det satt opp grønn produksjon, satt opp prinsipper rundt bærekraft. [First and last name] er leder for det. Mulig å ta en prat med henne. De sender inn klimarapporter til de som har ansvar for grønn produksjon. Utviklet klimadashboard som viser klima utslipp for hver forskjellig tjeneste.
   - Svar 2: Nylig opprettet en stilling om det her. Ser på hele [company name] bærekraft. Skriver rapporten om alt. Hvor mye strøm og kjøing blir brukt på datatjenestene.

2. Hvilke tiltak har [Company name] implementert for å redusere mengden data som overføres mellom server og klient, som komprimering, hurtigbufring eller innholdsleveringsnettverk (CDN)? Hvordan har disse tiltakene påvirket bærekraften til nettjenestene deres?
   - Svar 1: Alle de tingene. Ikke vært så mye fokus på co2 energiforbruk, men generell optimalisering (akamai). Høy grad caching.
   - Svar 2: Ikke for bærekraftens skyld, mer for å hindre belastning.

3. Hvordan optimaliserer [Company name] ytelsen til nettstedet for å redusere energiforbruket, både på server- og klient-siden?
   - Svar 1: Ikke noe konkret initiativ der, finnes forbedrings potensial. Ingen guidelines for utvikling.
   - Svar 2: Right side sync. Både kostnad spørsmål også. Vet ikke om bildeformat vil bli endret.

4. Hvilke tiltak tar [Company name] for å minimere miljøpåvirkningen fra webhosting og serverinfrastruktur, spesielt i forbindelse med skytjenester?
- Svar 1: var ikke noe bevisst valg å bruke grønn host.
- Svar 2: Var et bevisst valg å bruke en grønn host.

5. Hvordan overvåker og sporer [Company name] energiforbruket til nettjenestene deres, og hvilke verktøy eller metrikker bruker dere for å måle bærekraften deres?
- Svar 1: Samler rapporter fra forskjellige leverandører. [Cloud services].
- Svar 2: [Cloud services] har dashboarder for dette her. Får hele dataen på hva man bruker, blir brukt for rapportering.

Relevante spørsmål:

7. Hvilke retningslinjer eller beste praksis følger [Company name] for å sikre at nettjenestene deres er designet med bærekraft i tankene?
- Svar 1: har ikke
- Svar 2: Tenker på hvor data skal flyte. Det som er for publikum, ligger allerede hos [Cloud service]. De prosesserer og behandler all data. Hvis man har tatt opp noe så blir det redigert på klient siden før det blir tatt til skyen.

13. Hvordan holder [Company name] seg oppdatert på de siste trendene og forskningen innen bærekraftig webutvikling, og hvordan integrerer dere denne kunnskapen i prosjektene deres?
- Svar 1:
- Svar 2: [Portion redacted for privacy] Ellers mye om det på konferanser man er på.

14. Hvilke fremtidige planer har [Company name] for å forbedre bærekraften i nettjenestene deres ytterligere?
- Svar 1: en del mål i grønn produksjon. Har dokumenter om det i intranettet sitt.
- Svar 2: Ingen co2 mål han vet om. Men nye kontor snart som kan komme med nye muligheter.

Å bytte fra jpeg til webp er noe de tenker på, men det ligger litt bak i køen bak andre ting de vil jobbe med først.
Bærekraft for videotjenester? Det kommer inn i nye kontrakter.
Hør med [First name] om forskjellige relevante prosjekter.

4. Initial Gantt chart

5. Lighthouse report of TV2 Live pages

URL	Performance Score (%)	First Contentful Paint (s)	Speed Index (ms)	Largest Contentful Paint (s)	Time to Interactive (s)	Total Blocking Time (ms)
https://www.tv2.no/live/	19	21007,452	52668,75338	56572,945	68685,995	45058,043
https://www.tv2.no/live/fotball	12	21685,006	66883,79572	66676,56	85384,271	58314,765
https://www.tv2.no/live/sykkel	25	22134,253	46096,28095	33018,148	69240,084	44723,831
https://www.tv2.no/live/sjakk	17	20766,59	42489,33637	32023,862	80042,486	55185,896
https://www.tv2.no/live/vinterspo	25	23496,248	44032,45743	35835,227	74811,38	49092,632
https://www.tv2.no/live/basketba	25	21867,449	39247,11328	36807,716	71913,326	47794,377
https://www.tv2.no/live/ishockey	19	26116,785	52343,2286	40578,869	77294,869	47742,584
https://www.tv2.no/live/fotballbo	19	22753,293	51009,61316	33837,2535	81021,587	54969,294

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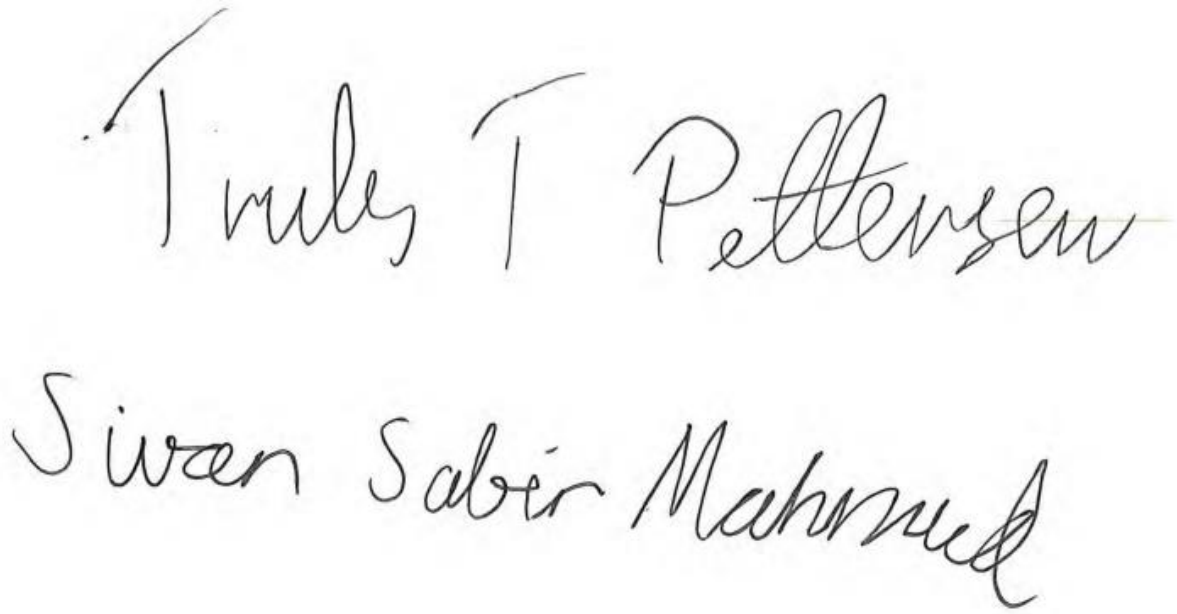
Foreword

This bachelor thesis in web development at NTNU (Norwegian University of Science and Technology) in Gjøvik explores the potential for improving the sustainability of web platforms for a major media company like TV2. By enhancing sustainability, we aim to positively impact the user experience for their audience.

Throughout the project, we have collaborated closely with TV2 and would like to extend our gratitude to Arild Rugsveen, our product owner at TV2, who has been invaluable in providing data and access to TV2's codebase. We also want to express our appreciation to our tutors Yavuz Inal and Carlos Vicient-Monllaò, who have guided us through our selected project.

February 28th, 2023, Gjøvik, Norway.



Abstract

Title: Embracing Digital Sustainability: Guideline Development and Implementation for TV2

Date: 15.05.2023

Participants: Truls Teige Pettersen, Sivan Sabir Mahmud

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Project owner: Arild Rugsveen

Subject: Web development

Keywords: Sustainability, web development, optimization, environment, design, development

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This thesis scrutinizes the potential of sustainable web design guidelines to enhance the efficiency of TV2's websites, specifically targeting its page weight reduction, load times, and energy costs. As a practical application of these guidelines, we developed a website displaying these sustainable guidelines as well as a data carbon calculator to serve as a companion tool. Following this, we put into action selected strategies from the guidelines on a couple of TV2's websites, with a primary focus on their food recipe website. The results match that of existing research in that implementing sustainable web design will reduce a website's page weight. This not only affirms the positive implications of incorporating sustainable web design practices but also indicates their potential for optimizing TV2's web services by enhancing speed, energy efficiency, and overall performance.

Abstract (Norwegian)

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Dato: 15.05.2023

Deltakere: Truls Teige Pettersen, Sivan Sabir Mahmud

Veiledere: Yavuz Inal

Medveileder: Carlos Vicient-Monllaò

Oppdragsgiver: TV2 AS

Prosjekteier: Arild Rugsveen

Emne: Webutvikling

Nøkkelord: Bærekraft, webutvikling, optimalisering, miljø, design, utvikling

Antall sider: 48 + 13

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Denne oppgaven undersøker potensialet for retningslinjer for bærekraftig webdesign for å forbedre effektiviteten til TV2 sine nettsider, spesielt med mål om å redusere sidens vekt, lastetider og energikostnader. Som en praktisk anvendelse av disse retningslinjene, utviklet vi en nettside hvor vi viser disse bærekraftige retningslinjene sammen med en datakarbonkalkulator som et tilleggsverktøy. Deretter satte vi i verk utvalgte strategier fra disse retningslinjene på et par av TV2 sine nettsider, med mest fokus på TV2 sin mat oppskrift nettside.. Resultatene fra vårt arbeid bekreftet at våre revisjoner betydelig reduserte sidens vekt. Dette bekrefter ikke bare de positive implikasjonene ved å innarbeide praksis for bærekraftig webdesign, men indikerer også deres potensial for å optimalisere TV2s webtjenester ved å forbedre hastighet, energieffektivitet og generell ytelse.

Table of contents

1 Introduction

This bachelor's thesis aims to provide TV2 with a comprehensive set of guidelines for sustainable web design. These guidelines, accessible on a dedicated Svelte-based website, offer practical recommendations for developing environmentally friendly websites. As part of this project, we have conducted testing to validate the accuracy and effectiveness of select guidelines. The overarching goal of the thesis is to address the United Nations' Sustainable Development Goal 13: Climate Action by promoting the development of more sustainable websites.

As the world's population continues to grow, so does the demand for access to the Internet, currently 62% of world's population has access to the internet, and there are 500,000 new internet users every single day (Flynn, 2023). While this has the potential to bring many benefits, such as greater connectivity and access to information, it also comes with a significant environmental cost. The internet currently accounts for a large and rapidly growing share of global greenhouse gas emissions it is estimated that by 2025 the internet if counted as a country would be the 4th most polluting country in the world behind China, The United States, and India (S. Larsen, 2018). This is due to a combination of factors, including the energy required to power data centres and the devices used to access the internet, as well as the carbon emissions associated with manufacturing and shipping these devices. To solve these problems, a more sustainable design philosophy is needed, and there comes Sustainable Web Design.

Sustainable web design is essential for minimizing the environmental impact of the internet. By adopting practices such as optimizing website code, using renewable energy sources for web hosting, and promoting accessibility, web designers can reduce the energy and resource consumption of their websites, and minimize the carbon emissions associated with their creation and use. This not only helps to mitigate the negative impact of the internet on the environment but also ensures that access to the internet can continue to expand in a sustainable way, benefiting people around the world for generations to come.

Sustainable web design combines principles of environmental conservation with performance-based web and usability standards. By integrating these practices into the life

cycle of websites, apps, and online media, efficiency, utility, and performance can be maximized. Moreover, sustainable web design can significantly reduce the environmental impact of digital products and services by employing strategies such as green hosting, carbon measurement and reduction, and minimizing electricity consumption.

The practices of sustainable web design according to Wholegrain Digital (Frick, 2023) a pioneer in the field, can be categorized as follows:

1. Web Performance Optimization: How efficiently do assets download on users' devices?
2. Content Findability: How quickly and effectively can users locate relevant content?
3. Usability: How easily can users across various devices and platforms accomplish tasks, considering different bandwidth speeds?
4. Green Web Hosting: Does the hosting infrastructure utilize renewable energy sources to power digital products and services?

While TV2 currently incorporates some sustainable web design practices, the company lacks official guidelines to implement them consistently. Since spring 2022, TV2 has become increasingly aware of the environmental impact of its digital services and has expressed a commitment to enhancing sustainability within its web services.

This thesis examines the process of designing and developing guidelines for implementing sustainable web design practices. Additionally, we present the results of testing some of these guidelines on selected TV2 websites. The study aims to provide insights into the effective implementation of sustainable web design practices, contributing to TV2's efforts to create more environmentally friendly web services.

1.1 Who is TV2 and what is their impact?

TV2, one of Norway's prominent media companies, holds the 5th position for web traffic among Norwegian websites (similarweb, 2023). In January alone, they garnered a staggering 44 million monthly visitors. To assess the environmental impact of TV2's website, we can

estimate their carbon dioxide (CO2) emissions for a given month by multiplying the total monthly visitors with the average number of pages visited per user and the average CO2 output per page visit. Based on this calculation, it is estimated that TV2's website emitted 212 metric tons of CO2 in January 2023.

Company	Visits in the month of January	Average pages visited per user	Average Co2 per page	Co2 for the month of January
TV2	44,412,776	3.73	1.28g	212 tons of Co2

The team responsible for managing tv2.no and its sub-websites is determined to make it the most visited media website in Norway. Since spring 2022, they have shifted their focus towards web sustainability after some members of their IT staff attended the Booster Conference 2022 and viewed a presentation titled "Green Code". Inspired by this event, TV2 has implemented sustainability upgrades across its services, such as replacing JPEG files with WEBP format and prioritizing data caching. However, they still lack a comprehensive set of guidelines on sustainability that can be utilized when developing new services or updating existing ones.

1.2 How sustainable web design would benefit TV2.

TV2 has a crucial role to play in providing information and entertainment to its audiences while minimizing the environmental impact of their online content. The internet, as previously mentioned, is a significant contributor to global greenhouse gas emissions, and media companies like TV2 that have a large digital presence in Norway can have a particularly large carbon footprint.

By adopting sustainable web design practices, TV2 can reduce their environmental impact while also benefiting their bottom line. For example, optimizing website code and reducing page load times can improve website performance and user experience, which can in turn increase engagement and reduce bounce rates. Similarly, using renewable energy sources for web hosting can not only reduce energy costs over the long term, but also demonstrate TV2's commitment to sustainability to their audience and stakeholders.

Overall, sustainable web design is both a moral and business imperative for TV2, and adopting these practices can help them achieve their goal of becoming the most visited news website in Norway while also aligning with their values and contributing to a more sustainable future.

1.3 Problem statement

The problem statement is defined as follows:

Is it possible to develop and tailor a set of web sustainability guidelines specifically for TV2 by testing and refining them on their food recipe website?

1.3.1 Definition of concepts in problem statement

- **Web sustainability guidelines:** A set of practices that are aimed at reducing the environmental impact of a website.
- **Tailor:** In this context, tailoring means to adjust the guidelines to fit the specific needs, characteristics, and constraints of TV2. It does not mean that the guidelines are only relevant for TV2's websites, however it does mean that every aspect of them holds relevance for TV2, ensuring their comprehensive applicability.
- **Testing:** This refers to the process of applying parts of the sustainability guidelines to TV2's food recipe website and monitoring the outcomes. This is done to determine the effectiveness of these guidelines.
- **Food Recipe Website:** This is a specific website run by TV2 where they share various food recipes. In this context, it is being used as the testbed for the sustainability guidelines. The URL to the website is https://www.tv2.no/mat/oppskrifter and it will from here on be referred to by its URL.

1.4 Report structure

Our bachelor thesis is structured as follows:

- **Background:** Here we aim to promote a comprehensive understanding of web sustainability, starting with an exploration of how to measure web services' carbon footprint and the factors impacting it, followed by a review of relevant literature.
- **Methods:** In this part, we share the research methods employed, including interviews, the research used for creating the web sustainability guidelines, and the tools used in the process.
- **Results:** This section presents the findings from our research and the development process. It includes results from interviews, iterations of the guidelines and the guidelines website, and the effects of changes made to specific areas of the TV2 site.
- **Discussion:** Here, we discuss the implications of our findings, the challenges we faced, and potential areas for future research and improvements to the guidelines.
- **Conclusion:** We wrap up the report with a summary of our findings.

The report also includes an appendix with relevant links and a complete list of references for further reading.

2. Background

In the following section, we are going to lay the groundwork for our project. We will first tackle how to measure the carbon footprint of web services. We will talk about several factors that affect a website's sustainability. Next, we will dive into a review of relevant literature on sustainable web design. Tom Greenwood's "Sustainable Web Design," will gain extra attention, as it is a book which offers some great insights into making websites that are efficient, resilient, and sustainable. By exploring these areas, we hope to give ourselves and you a solid understanding of web sustainability.

2.1 Measuring the Carbon Footprint of Web Services

Determining the exact carbon footprint of a website can be a challenging task, we cannot measure the fumes coming out of our laptops like we can with exhaust pipes for cars. However, the most reliable methods we currently have at our disposal involve analysing two main components: data transfer and the carbon intensity of electricity (Greenwood, 2021).

2.1.1 Data Transfer

A common metric used to gauge energy efficiency in this context is kilowatt-hours per gigabyte (kWh/GB), which measures the energy required to transfer data across the internet when a website or application is accessed. The total data transfer for a single visit to a web page is often calculated using the page weight, which is the transfer size of the page in kilobytes upon an initial. As of 2020, the median page weight for desktop websites was 1.97 MB, a 36% increase from 2016. Notably, images account for about half of this weight, making them the largest contributor to carbon emissions on an average website.

While faster performance can sometimes reduce emissions, it may only decrease the subjective perceived load times of pages. Using page weight and transfer size as benchmarks provides a more objective and reliable measure of emissions. A page weight

budget which we suggest later can be established as a limit for data size, which can be set relative to industry averages or the previous version of a website. To further optimize efficiency, transfer size for repeat visitors can be considered, helping to establish page weight budgets beyond the initial visit.

2.1.2 Carbon intensity of electricity

Carbon intensity refers to the grams of CO2 emitted per kilowatt-hour of electricity (gCO2/kWh). Renewable energy and nuclear energy sources have low carbon intensities (less than 10 - 30 gCO2/kWh, including construction), while energy made by fossil fuels range from 200 to 800 gCO2/kWh. Norway for example is mostly powered by waterpower (88%) and wind power (9%) and the estimate is 11 gCO2/kWh for all power produced in Norway in total (Tuset, 2023).

Most electricity is sourced from national or state grids, where energy from various sources is combined. As end-users, web servers, and telecom networks may all utilize power from different grids, the selection of the appropriate data centre to host a website becomes a crucial factor in controlling the carbon footprint. Each data centre relies on different grids with varying electricity sources, and by choosing the right data centre, the carbon emissions associated with web services can be significantly influenced.

This concept of “megabyte miles” refers to the distance between the data centre and the website’s core user base. By analysing website analytics, the core user base location can be identified, and the distance to the data centre can be calculated. If this distance is too great, it may be advantageous to select a closer data centre, which would reduce both emissions and latency for users. By focusing on the strategic selection of data centres, web designers can have greater control over the carbon footprint of their web services.

2.2 Literature review

What are the key principles and practices of sustainable web design?

A sustainable web design approach aims to minimize the environmental impact of websites and web applications while maximizing their accessibility and usability for users. This literature review critically examines published research literature relevant to sustainable web design, with the objective of establishing familiarity with current thinking and research in this area. The purpose of this review is to identify key issues, trends, and best practices for designing sustainable web applications and sites.

The scope of this literature review encompasses published and unpublished works on sustainable web design, in English, from various locations. The focus will be on works that address practices that are relevant and up to date with current design trends and technologies. We will exclude works related to non-web-based digital design, non-English works. Due to the nature of how quickly the design practices and technologies surrounding web development change, older writings will be excluded from this thesis. That is unless they relate to technologies and design practices that are still in use today.

2.2.2 Sustainable Web Design by Tom Greenwood

In "Sustainable Web Design," Tom Greenwood explores the concept and practice of sustainable web design for addressing the increasing demand for data worldwide while simultaneously reducing pollution and moving towards a zero-carbon economy. Greenwood identifies several fundamental principles for a sustainable web, including clean, efficient, open, honest, regenerative, and resilient design practices.

Clean web services require hosts that utilize 100% renewable energy. Efficient websites need to adapt to increasing traffic by resizing images properly, using only necessary code, and removing redundant lines of code. Such practices not only make the website more energy-efficient but also increase its speed. Openness and honesty are crucial for fostering collaboration and raising awareness about sustainability. Regenerative and resilient design involves mitigating harm and ensuring the web can reliably serve information during crises.

Measuring the carbon footprint of web services requires assessing data transfer and the carbon intensity of electricity. Data transfer can be estimated with the page weight, which is the transfer size of the page in kilobytes when a user first visits the page. Researchers use kilowatt-hours per gigabyte (kWh/GB) as a metric to measure energy efficiency when examining data transferred over the internet. Carbon intensity refers to the grams of CO2

emitted for every kilowatt hour of electricity (gCO2/kWh). Renewable and nuclear energy sources have low carbon intensity, while fossil fuels have significantly higher carbon intensity.

To set a sustainability budget for a website, it is crucial to benchmark relevant metrics, estimate what is theoretically possible, set achievable budget goals, and establish stretch goals for further improvement. Additionally, considering the embodied carbon of digital projects, which refers to the carbon emitted during the production, manufacturing, and delivery of a physical product, is essential for understanding the overall environmental impact of a website.

Greenwood emphasizes the importance of minimalist web design, streamlined content, lightweight imagery, efficient typography, and careful use of motion in creating low-carbon websites. Furthermore, sustainable web development involves well-written, efficient code that reduces server load and energy consumption. Utilizing technologies such as Progressive Web Apps and Jamstack can improve a website's speed, security, reliability, and energy efficiency. Compressing code and blocking unwanted bots also contribute to energy-efficient web hosting.

In conclusion, Tom Greenwood's "Sustainable Web Design" offers valuable insights and techniques for designing and developing sustainable websites that meet the increasing demand for data while minimizing environmental impacts. By adopting these principles and practices, web developers can contribute to a more sustainable and eco-friendly digital landscape.

3 Methods

This section outlines the strategies and methodologies we employed to gather data, develop our web sustainability guidelines, and validate their effectiveness. Our approach incorporated a blend of qualitative interviews, creation of tailored sustainability guidelines, use of various assessment tools, and making plans on how to practically implement guidelines in order to verify their effectiveness. Through this multi-faceted methodology, we sought to ensure a comprehensive understanding of web sustainability, develop practical and relevant guidelines, and test their effectiveness in a real-world setting. The process involved working closely with TV2 and making decisions based on their specific needs and operational framework.

3.1 Interviews

Interviews were a pivotal component of our research methodology, providing first-hand, nuanced information from professionals in the field of sustainable web design. Our rationale for choosing interviews over other research methods such as surveys or secondary data analysis was driven by several factors. Firstly, interviews allowed us to delve into the practical aspects of web sustainability, learning about specific practices, tools, and strategies employed by organizations. Secondly, they enabled us to understand the mechanisms employed by organizations to monitor their sustainability performance. Lastly, through the interviews, we aimed to stay informed about the latest trends, challenges, and opportunities in sustainable web design.

With this objective, two professionals from a competing Norwegian media company, were identified and interviewed for this study. The subjects were chosen based on their positions within the company: a Chief Engineer specializing in DevOps and a Senior-Engineer.

3.2 Web sustainability guidelines

This section of the thesis goes through the process of creating the web sustainability guidelines.

3.2.1 Requirements

A lot of insight was gathered from talking to Arild Rugsveen from TV2, and from looking at TV2's websites. The guidelines must give a short, concise, and accurate overview of web sustainability. It should be quick and easy to implement into your work, and not require too much time to set up. The guidelines also must be relevant to TV2, and how they currently operate their websites. It should not include solutions to problems that TV2 does not have.

The guidelines will follow a chronological order. It will follow this path:

- Researching and figuring out your goals for sustainability.
- Vital things to keep in mind while designing the website.
- Programming the website in a sustainable manner.
- Hosting the website.

There will be multiple steps within each of these points. Going from top to bottom will give you the best order for working on sustainability on your website, however it might be the case that some people will want to focus on, for example how to host the website first. For that reason, each step of the guideline will be stand alone. They can be read and understood by themselves, and you will not be expected to have read and worked on previous steps.

3.2.2 Guidelines content

This section covers every topic that is to be included in the guidelines, and why they are important.

The guideline starts off with telling you about how to plan a course of action to make your website more sustainable. This includes measuring the sustainability of your current website as well as your competitors, finding out what are theoretically best metrics for your website, and how you should set your goals after having all those metrics written down (Greenwood, 2021).

Yoyo user journey

The guideline mentions certain design choices that are detrimental to the sustainability of websites. One of these is referred to as the yoyo user journey. Some websites are designed in such a way where it pushes the user to go back to the homepage, to navigate to a

different page. A common example of this is websites making you go to the shopping cart page to see what items are in the shopping cart. A solution to this would be to have the functions of the shopping cart display on whichever page you are on. Then the user can quickly check the contents, before continuing to browse for other items (Greenwood, 2021).

TV2 Live's current website design forces users to return to the homepage to navigate between different sports sections. For instance, while on the football page, a user must click "Other sports," leading them back to the homepage to access a list of different sports. This design choice compromises sustainability, as it necessitates loading two pages instead of one to switch sports, thus increasing data transfer and energy usage.

When designing a website, it is vital to bear in mind that adopting a "less is more" approach contributes significantly to creating a sustainable online presence. By embracing a minimalist philosophy, designers can ensure that the website's design, content, and functionality are streamlined and focused, leading to decreased energy consumption, reduced data transfer, and minimized carbon emissions. Careful consideration of each design element, optimization of images and code, and prioritization of user experience enable the creation of a website that not only caters to users' needs but also promotes a sustainable and eco-friendly digital environment.

Images

The images that a website decides to host are a huge factor in sustainability. On average, they are the single biggest source of carbon emissions on a given website (Lahan, 2020). For optimal web sustainability, you should consider how many websites your website needs. Additionally, it is important to learn about the diverse ways you can optimize images so that they get a significantly reduced file size.

The most used image format for websites is JPEG. Almost 80% of all websites use JPEG in some way (W3Techs, 2023). However, JPEG is far from being the best choice of image file formats when it comes to sustainability. WebP is an image file format developed by Google (Calore, 2010). It has the features and the quality of any well-known image file format, but what is great about this one is that its images are around 30% smaller in file size compared to JPEG images (Google, 2023).

AVIF (AV1 Image File) is another newly developed image file format (Alliance For Open Media, 2022). It is reported to be able to produce high quality images at under half the size of WebP (Archibald, 2020). Despite there being so much potential behind it, we decided not to include it in the guidelines as it still lacks support for Microsoft Edge.

We also mention image optimization tools like ShortPixel and TinyPNG in the guidelines. These tools can be useful for further optimizing your images, without losing out on noticeable image quality (Greenwood, 2021). We ran a test with 11 images from TV2 Live's sports news feed and ran them through ShortPixel's glossy compression. This resulted in the total file size of the images going from 1,52 MB, down to 0,79 MB. This means that the images have been reduced by 48%. These are satisfactory results, however there are some limitations to these tools. You cannot use them to optimize WebP and AVIF (ShortPixel, u.d.). But if your website requires the use of JPEG or PNG, then they are still useful.

Many different users will have different screens, and therefore different needs when it comes to the size of images that gets displayed to them. This has to do with the fact that peoples screen viewing distance varies. For computer monitors, it is recommended that your eyes are between 50-100 cm away from the screen (OSHA, u.d.). Therefore, people using computers will need the images to be large enough so that the details will be visible when your eyes are 50-100 cm away from the monitor. Using the same high image size for mobile would be a waste of resources, as the image will shrink down anyway to fit the smaller screen. This will result in higher load times and higher bandwidth for mobile users, with no benefit.

By using the picture HTML element, you can eliminate those problems. The HTML picture element lets you serve different images for different screen sizes (MDN, 2023). This is a great solution, but it has the drawback of making you use more storage space for extra images. This is since you will have to make lower resolution copies of images for smaller screens. Therefore, you ideally want to figure out which screens your users use the most, and from that choose a few image sizes to use for the picture element.

We also recommend slightly reducing the width and crop of images by cropping around them. Let the cropped parts of the image stay as extra empty space on your website. This

will not only make the images much smaller in file size, but by having extra space around them they will appear much more impactful for users (Nevah, 2021).

Video & animation

58% of businesses have a video on their homepage (Renderforest, 2022), but should so many websites host videos? If a website hosts, videos, it will usually be by far the largest source of carbon emissions. Streaming a YouTube video for an hour produces approximately 10 kg of CO_2 (Preist, et al., 2019). The best way to counter this, is to minimize the amount of and length of videos on your website.

One thing to keep in mind is that users do not always want a video. They are not always the most user-friendly, and they can use up a significant amount of power and data on mobile devices. Joe Jones is the cofounder of design agency Archipelago, and he says that videos often require audio output and if you do not have headphones, it can be awkward to view in public. They also give users little control over how they want to process the information. Videos move in a constant pace which is not ideal for when you want to focus more on certain parts of it (Greenwood, 2021).

Every second matters if you are going to use a video, as a second of video can take up more data than a full-screen JPEG image. If you want to use a short animation instead, a GIF format should not be used. GIFs are an image file format that allows you to have a series of images in one file and have them display chronologically like an animation. That means that for each frame of the animation, the GIF format will use up an equal amount of space as a standalone GIF image. (W3C, 1990). According to Google, when GIF animations are converted to lossy WebP animations, they become 64% smaller in file size. For lossless WebP images it becomes 19% smaller (Google, 2023).

Screen

On many different phones, the screen is the single biggest power draw. One way it affects power is that blue pixels have been found to use 25% more power than green and red pixels. For phones that have an OLED (Organic Light Emitting Diode) display (Organic light-emitting diode), black pixels are the most efficient. A key feature of OLED displays is the fact

that individual pixels can be turned on and off. So, when a pixel is fully black, it will be off and will not cause any power consumption (Tung, 2018).

Even though black pixels being power friendly is only true for OLED display, we still felt it was necessary to include that information because of how popular OLED displays have gotten over the years. Apple has adopted OLED for their phones ever since the release of the iPhone X. Since then, they have only expanded their use of OLED across different devices (Charlton, 2022). In 2018 it was reported that there were over 1 billion phones in the entire world had an OLED display, with an increase of 46% since 2016 (Newzoo, 2018).

This is also why dark mode can be particularly useful for saving power. According to Purdue University, using dark mode on an OLED display with 100% brightness will save an average of 39% - 47% battery power. However, reducing the brightness will massively reduce the amount of power you save from dark mode (Dash & Hu, 2021).

Typography

What fonts a website uses has an impact on its sustainability. Using fonts that are not pre-installed on most systems will lead to more data-transfer for users. This is because the browser will download the font for users when they first visit the website (MDN, 2023). Due to this fact, using a system font will lead to less data-transfer.

Websites will however often benefit stylistically when using a custom font. There are two common ways of using a custom font for a website, by linking to a font service like Google Fonts or Adobe Fonts, or by hosting the font files on your server (MDN, 2023). There are a couple of reasons for why downloading fonts is more sustainable than using a font service. A font service will require more data transfer than self-hosting because fonts from font services will not be cached unlike self-hosted fonts (Karamalegos, 2019).

Secondly, downloading a font can give you more options for optimization. There are tools available that you remove specific characters from a font file. For example, a font includes characters from other languages you know you will not be using will make the file larger than it needs to be. The size of the font file can be reduced significantly by removing languages you know you will not be using. It is important to note that not all Font’s licenses will let you edit fonts like this. (Greenwood, 2021).

There are also other small steps to take for font efficiency. You should always use WOFF2 font format, as it is the most efficient in terms of file size (Wicki, 2021). It is also important to only include font files that the website will be using. Fonts typically come in multiple files, for different thicknesses and for italics. If there is uncertainty in what style of the font will be needed, a variable font can be useful. It is a font file that allows for more scalability in terms of its thickness and slant, while still being highly efficient (MDN Web Docs, 2023).

Green web host

One of the most important parts of web sustainability is how you choose to host the website. It has to do with hosting websites on servers that are powered by green energy (Karyotakis & Antonopoulos, 2021). A website's host being completely powered by green energy is a huge step towards sustainability, but it does not cover everything. There will still be CO_2 emissions that come from the end-user device, as well as from the telecoms networks that transfer the data from the host to the user (Freitag, et al., 2021). Therefore, it is still important to optimize so that they require low energy for end-user devices, and so that telecoms networks do not need to deliver an excess amount of data.

But there is more to consider than just what type of energy source is powering the data centre. How close the servers are to your users is also a huge factor. Energy consumption by the internet is significantly affected by data transmission through telecommunication networks. As data travels greater distances, energy expenditure increases. Selecting a data centre near the target audience can reduce energy consumption and enhance user experience by minimizing page load times. For instance, choosing a US-based hosting company for a primary audience in the United Kingdom or Germany would result in wasted energy and slower page loads. Thus, locating a website in a geographically appropriate data centre promotes both user experience and environmental sustainability (Greenwood, 2019).

3.3 Website for displaying the guidelines

Our team decided to develop a website to effectively present our guidelines. Making a website has the advantage of letting people quickly and easily access the document without having to share a file around that people must download and keep on their device as a file.

It also gives us the ability to make it more interactive for the user. Such as by creating a custom navigation bar, and by letting users click on a piece of text to view more information. Lastly, it allows us to demonstrate how a low-impact website can look.

3.4 Tools

When analysing TV2's websites, we used a set of CO2 calculators, to gain deeper insights into their environmental impact and performance. These tools enabled us to assess key aspects of sustainability and provided valuable data for making informed decisions on optimizing website performance, reducing carbon emissions, and enhancing user experience

1 Links to tools.

3.4.1 Google Lighthouse

One of the primary tools we utilized was Google Lighthouse, an open-source tool developed by Google. Designed to improve the quality of web pages, Google Lighthouse audits websites against a set of best practices and performance metrics. It evaluates web pages in categories such as performance, accessibility, progressive web app (PWA), best practices, and search engine optimization (SEO). By focusing on the performance category, we gained in-depth insights into areas for improvement and received detailed suggestions for optimizing the websites to ensure high-quality and performant user experiences.

3.4.2 Digital Beacon

Another valuable tool in our evaluation toolkit was Digital Beacon, an online platform dedicated to calculating the environmental impact of websites. By analysing websites, Digital Beacon generated comprehensive reports that displayed crucial metrics such as page weight and CO2 emissions before and after caching. These reports provided valuable insights into the page load performance for both first-time and subsequent visitors, shedding light on the website's overall sustainability. Additionally, Digital Beacon provided a detailed breakdown of the weight of different components of the website, including scripts, images, fonts, and more. This breakdown allowed us to identify the specific components that contributed the most to the website's weight and CO2 emissions, enabling targeted

optimization efforts. With its comprehensive reports and helpful suggestions, Digital Beacon proved to be an essential tool for website owners seeking to understand and improve the environmental impact of their websites while optimizing their performance.

3.4.3 Ecograder

We leveraged Ecograder, another powerful tool in our evaluation process. Ecograder combines CO2.js from The Green Web Foundation with Google Lighthouse's open-source page metrics to provide a comprehensive assessment of a website's environmental impact. By submitting a website address to Ecograder, we received detailed reports with suggestions for improving the website's performance and user experience. Additionally, Ecograder offered advice on procuring a green web host and reducing website-related emissions. By following the recommendations outlined in the Ecograder reports, website owners could effectively reduce their carbon emissions and improve their overall sustainability score.

3.4.4 CO2.js

We utilized CO2.js, an open-source JavaScript library that serves as a standalone data carbon calculator. While it is used by Ecograder, their way of using it is analysing finished websites by converting the page weight of a website into what it estimates the CO2 out will be. For our testing we needed to use it in a different way, by making a front-end version of the tool, we were able to input a data amount, see how much CO2 that amount of data would be converted to by being downloaded by an user. This gave us a way to see what reductions in CO2 output a website would have if they reduced the page weight of their website.

3.5 Validation of Web sustainability guidelines

To ensure the effectiveness and applicability of our sustainability guidelines, we conducted a validation process. This process involved practical applications of the guidelines, the results were instrumental in refining the guidelines and allowed us to iterate on what we gathered

from our initial research and proved their application in reducing the carbon footprint of TV2's websites.

3.5.1 Website Selection

To display the practical application and impact of implementing our sustainability guidelines, we collaborated with our project owner at TV2, to find a website to work on. We were provided with a comprehensive overview of their services and their tech stack, categorized by TV2's ability to provide support and their accessibility for students to work with.

URL
https://www.tv2.no/
https://www.tv2.no/sport/
https://www.tv2.no/nyheter/innenriks/mann-domt-til-tvungent-psykisk-helsevern-etter-drap-i-bergen/15452640/
https://www.tv2.no/live/ and subpages
https://www.tv2.no/direkte/ and subpages
https://www.tv2.no/vaer/ and subpages
https://www.tv2.no/mat/oppskrifter and subpages
https://www.tv2.no/tvguide/
https://www.tv2.no/spesialer/ and subpages
https://broom.tv2.no/underholdning/broom/biltester/ and subpages
https://www.tv2.no/video/
https://www.tv2.no/video/underholdning/the-voice/jarle-faar-seg-en-gedigen-overraskelse-naar-han-snur-seg/1825333
Categories of complexity to involve students in website development:
Green - Easy to involve students
Yellow - harder but still possible to involve students
Grey - Uncertain, applications are more complex and older.

Initially, we chose tv2.no/live, a yellow-coded website with a high page weight, indicating room for sustainability and optimization improvements. However, due to the challenges encountered and upcoming changes, we opted for an alternative TV2 domain.

We selected tv2.no/mat/oppskrifter, a dedicated food and recipe website. Offering valuable opportunities for sustainability enhancements. Importantly, our product owner, who also served as the project lead for this website, provided extensive support and access, facilitating the implementation of sustainable changes.

During the website selection process, we employed tools such as Google Lighthouse, Digital Beacon, and Ecograder to evaluate the sustainability and performance of the websites, these tools played a crucial role in informing our decision-making process, ensuring that we focused on websites with the greatest potential for sustainability improvement.

3.5.2 Implementation of Sustainability Improvements

We tested out a range of sustainability improvements on the selected websites in accordance with our guidelines. For tv2.no/live, we focused on updating the navigation user interface, to streamline the user experience, improve navigation efficiency, and reduce bounce rates. Additionally, we explored the potential for file size reduction by converting image files from JPEG to more efficient formats such as WEBP and AVIF. These changes aimed to optimize page load times and enhance sustainability.

On tv2.no/mat/oppskrifter, we introduced several improvements to enhance sustainability. These included replacing the standard “<img/> element with the “<picture/> element to serve optimized images based on viewport size. We also explored the difference between WEBP and AVIF image formats to reduce file sizes and implemented individual image sizes for tablet and mobile devices. Furthermore, we tested what impact dark mode would have on an OLED smart phone to improve energy efficiency and user experience.

These evaluations provided valuable insights into the effectiveness of our guidelines and the tangible benefits achieved in terms of sustainability enhancements and user experience improvements. The data collected allowed us to quantitatively measure the improvements achieved and validate the positive impact of our sustainability-focused changes.

4 Results

This chapter will show the findings from our interviews with a competing company, the final sustainability guidelines, including the difference between the iterations. We will also highlight the prototyping and development of the website hosting the guidelines, and the results of the testing of the guidelines on TV2's Live sports website, and TV2's recipe website.

4.1 Results from interviews with competing company

Through the interviews we conducted, valuable insights were gathered regarding that specific company's commitment to web sustainability and their specific practices towards this goal (3 Interview with competing media company. Although the professionals interviewed were not directly involved with website operations, their insights into the company's organizational strategies towards sustainability were informative. We learned about their recent efforts towards generating climate reports based on their overall sustainability, including the sustainability of their web services and the carbon emissions resulting from both transportation and electricity usage within their offices.

Their unique monitoring dashboard, which tracks carbon emissions from all their operations, was particularly enlightening. This data, incorporated into their reports, provides a basis for continuous learning and improvement within that company. The interviewees also highlighted the use of cloud services, as resources for sustainability monitoring.

However, there were limitations to the data collected from the interviewees due to their specific roles within the organization. They recommended consulting with another professional within the company more involved in website development. Unfortunately, due to time constraints, this was not feasible within the scope of this study.

4.2 Web sustainability guidelines

In this section, we explore the process of refining our initial web sustainability guidelines through several iterations. The aim of these revisions was to produce a set of guidelines that

were not only more streamlined and concise but also specifically tailored to meet the needs of TV2. We carefully assessed each part of the guidelines, removing elements that we found were unnecessary or less relevant for TV2's context. In the following subsections, we will present the finalized guidelines and highlight the significant changes that were made during each iteration, underscoring how these modifications contributed to a more efficient and targeted set of recommendations for TV2.

4.2.1 Initial version

- **Overview:** The initial guidelines covered several major areas of web sustainability including planning, design, image optimization, power usage reduction at the end-user level, typography, and hosting. For each of these areas, specific actions were recommended, from setting sustainability budgets and streamlining content to image file type selection, colour optimization, font hosting, Jamstack, content delivery network, page caching and choosing green data centres.
- **Key Principles:** The development of these initial guidelines was guided by a few main principles:
    - **Efficiency:** A central goal was to reduce data transfer, load on end-user devices, and server power consumption. This is reflected in recommendations like reducing the number of pages, optimizing image sizes, and avoiding auto-playing videos.
    - **Sustainability:** The guidelines promoted actions that not only reduce carbon footprint but also set a path towards long-term sustainability. This is evident in the advice to benchmark current sustainability metrics and set achievable yet ambitious goals.
    - **User Experience:** While the focus was on sustainability, the guidelines also acknowledged the importance of user experience. Suggestions were made to design websites in ways that allow users to efficiently navigate and find what they are looking for.
    - **Practicality:** The guidelines recognized the practical constraints of web development. For instance, the guidelines recommended using system fonts

for efficiency but also provided advice on hosting and optimizing other fonts if needed.

4.2.2 Iteration of guidelines

This upcoming text is our iteration of the web sustainability guidelines. It is the result of our research into what causes website to emit CO_2, and what can be done to minimize those emissions. The research that went into these guidelines include current relevant literature, as well as our own testing of TV2's websites. The guidelines are also meant to consider TV2's needs and current knowledge within web sustainability.

Sustainability Guidelines for TV2 Websites

This document outlines strategies to enhance sustainability across various aspects of websites, including planning, design, user experience, content optimization, power consumption, and hosting.

I. Planning

A. Benchmark: Assess the sustainability of your website and compare it with competitor sites.

B. Theoretical Possibility: Determine the best possible metrics for your website under ideal conditions.

C. Sustainability Budget: Set sustainability goals that are achievable and at least on par with industry standards. If there's potential for significant improvement, aim for a higher sustainability budget.

D. Stretch Goals: Establish ambitious targets to pursue once the sustainability budget goals are met.

II. Design and User Experience

A. Avoid Yo-Yo User Journeys: Prevent users from frequently navigating in and out of pages. For example, eliminate the need to return to the homepage to access different pages.

B. Streamline Content: Reevaluate the necessity of your website's pages and content. Less is more for sustainability.

C. Dark Mode: Implement an automatic dark mode or adopt a dark mode-first approach for OLED screens.

III. Content Optimization

A. Images

1. File Type: Use WEBP instead of JPEG for 30% smaller file size. Use PNG or GIF for images with few block colors, like icons.

2. Optimization: Utilize tools like ShortPixel, TinyPNG, or ImageAlpha to reduce image file sizes.

3. Responsive Images: Employ "srcset" and "sizes" attributes in HTML "picture" elements to display images based on screen size.

4. Additional Techniques: Implement blurring, CSS monochrome or grayscale, and SVG optimization to further reduce file size.

5. Image Spacing: Reduce image width and height to decrease file size and enhance impact.

B. Typography

1. System Fonts: Use pre-installed system fonts to avoid data transfer.

2. Font Hosting: Host font files on your server instead of using font services to reduce server requests.

3. Font Files: Remove unneeded files and use variable fonts for multiple font styles. Convert files to WOFF2 format.

4. Optimization: Use tools like Fontdrop and Everything Fonts to remove unused characters, subject to foundry license terms.

IV. Power Consumption

A. Colour: Dark colours use less power on OLED screens. Blue uses less power than green and red.

B. Video: Minimize video usage and autoplay. Opt for images, text, or interactive animations when possible.

C. GIFs: Replace GIF animations with more efficient WEBP files.

D. Animations: Limit front-end animations to reduce CPU usage.

V. Hosting

A. Green Host: Ensure your website is hosted on a data center powered by green energy.

B. Data Center: Select a data center close to your core user base to reduce emissions and latency.

4.2.3 Rationale behind iteration

In this iteration, the guidelines were streamlined and refined to better meet TV2's specific needs. This version maintained the focus on planning, design, user experience, content optimization, power consumption, and hosting, but several changes were made:

- **Key Changes:**
  - **Consolidation:** Sections from the initial version have been combined to create a more cohesive structure. For instance, the "Design" and "User Experience" sections are now merged into a single section, "Design and User Experience."
  - **Simplification:** Some sections have been shortened or removed altogether due to their irrelevance to TV2's context. For example, mentions of Jamstack, page caching, and Content Delivery Networks were removed altogether.
  - **Streamlining Content:** The content of the guidelines was minimized. This involved removing redundant information and focusing on key actionable strategies for TV2.

4.3 Addition of Data Carbon Calculator to Website

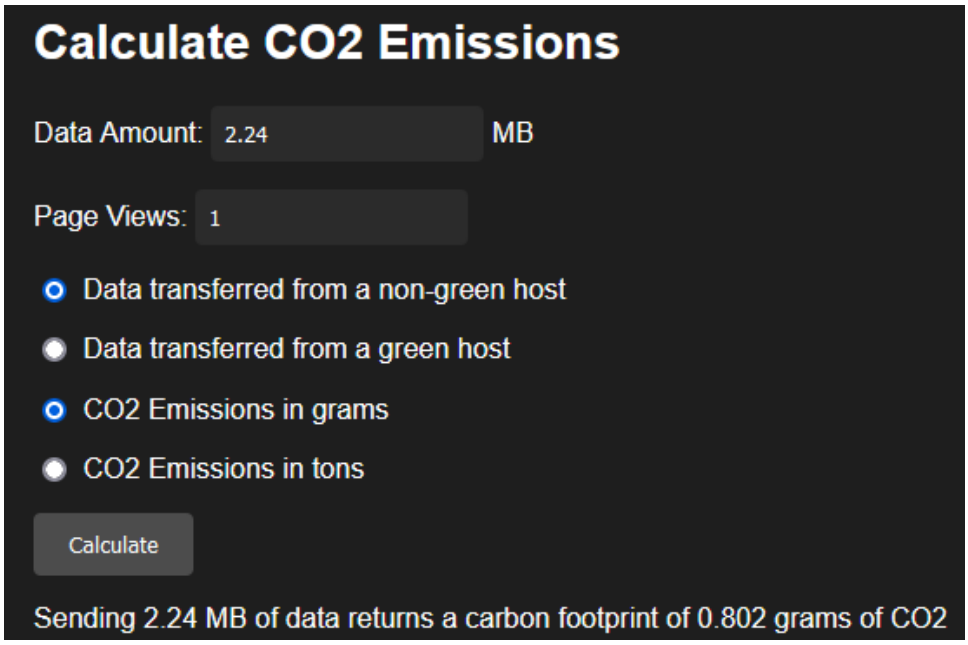
In the final iteration of the website, we also added the Data Carbon Calculator. The reason for this was that we saw its usefulness as a companion tool when implementing and testing the guidelines when updating existing websites.

4.3.1 Why it was added

- **Reasons for Addition of Calculator**

- **Original Idea:** In our initial discussions with TV2's product owner, we contemplated creating a carbon calculator along with the guidelines. However, this idea was shelved to concentrate on the guidelines. Towards the project's conclusion, we developed a front end for CO2.js, which proved invaluable during our tests and could also be beneficial for TV2.
- **Does not exist on the market:** While tools like Google Lighthouse, Ecograder, and Digital Beacon excel at evaluating existing websites, we found no application utilizing CO2.js in the way we have - as a carbon data calculator. Users input data, receive an adjusted CO2 emission based on whether they use a green host, and quickly understand the environmental impact of changes like reducing page weight.
- **Fast Calculations:** Unlike market-available tools that can take over a minute to analyze a website via URL, our CO2.js front end facilitates instant calculations, making it highly efficient for developers needing to amass data swiftly.
- **Natural Companion of Guidelines:** Pairing the guidelines with our CO2.js calculator allows developers to gauge the effects of sustainable changes. Although CO2.js provides a rough estimate of the CO2 output based on website data transfer, it is better than having no estimation at all.

4.3.2 How it is used



Introduction: The Data Carbon Calculator is a tool designed to estimate the amount of carbon dioxide (CO2) emissions generated by your data usage. This guide will walk you through the process of using the calculator effectively.

Step 1: Input Data Amount in Megabytes:

- Start by entering the data amount in megabytes (MB) that you want to calculate the CO2 emissions for. This could represent the size of a webpage or any other digital content.

Step 2: Input Page Views:

- Next, enter the number of page views associated with the data amount you provided in Step 1. This helps estimate the total CO2 emissions generated across multiple views of the content.

Step 3: Choose Green Host Option:

- The calculator offers a choice to select whether you are using a green host or not. Green hosts are providers that utilize renewable energy sources, resulting in lower CO2 emissions. Select the appropriate option using the provided radio buttons.

Step 4: Select CO2 Output Unit:

- Decide how you want to receive the CO2 calculations. The calculator provides two options: grams and tons.
    - If you are interested in the CO2 output for a single page view or smaller numbers, choose grams. This unit is suitable for individual assessments.

- If you need to handle larger numbers, such as monthly CO2 output for websites with millions of page views, select tons. This unit is more convenient for handling significant quantities.

Step 5: Calculate the CO2 Emissions:

- After completing the previous steps, click on the "Calculate" button. The calculator will process your inputs and provide the estimated CO2 emissions based on the selected options.

Conclusion: The Data Carbon Calculator is a valuable tool for understanding the environmental impact of your digital data usage. By inputting the data amount, page views, selecting the appropriate host option, and choosing the preferred CO2 output unit, you can easily calculate and evaluate the carbon footprint associated with your digital content.

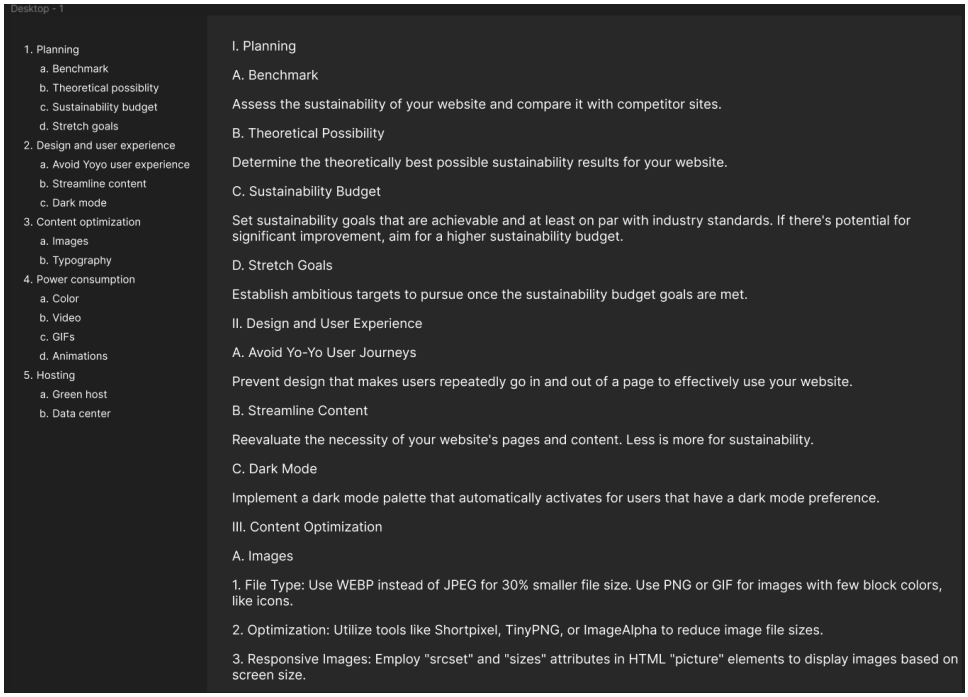
4.4 Development of guidelines website

4.4.1 Prototype of guidelines website

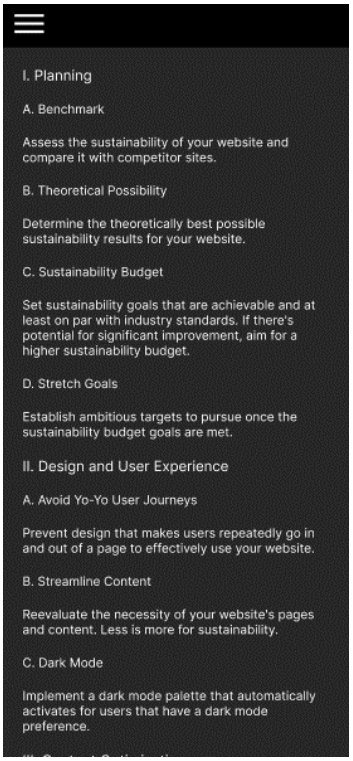
Developing a website that displays the guidelines required some prototyping through Figma. Creating a prototype allows us to get a sense of the layout, user interface, and overall design before investing time and effort into the actual development process. Figma allowed us to collaborate on the design, make necessary adjustments, and ensure that our vision was well-aligned with the end goal.

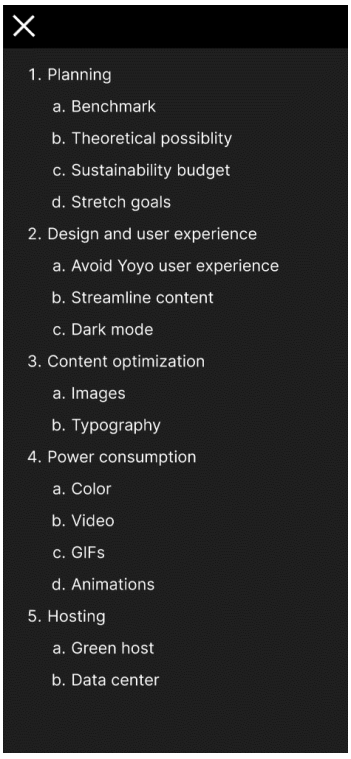
We knew it had to use a dark colour palette, a navigation bar, and responsive to different screens. To make it responsive, we would need to incorporate a hamburger menu. A button that the user can press that brings up the navigation bar and overlays over other content. Here is the prototype we ended up with.

For desktop:

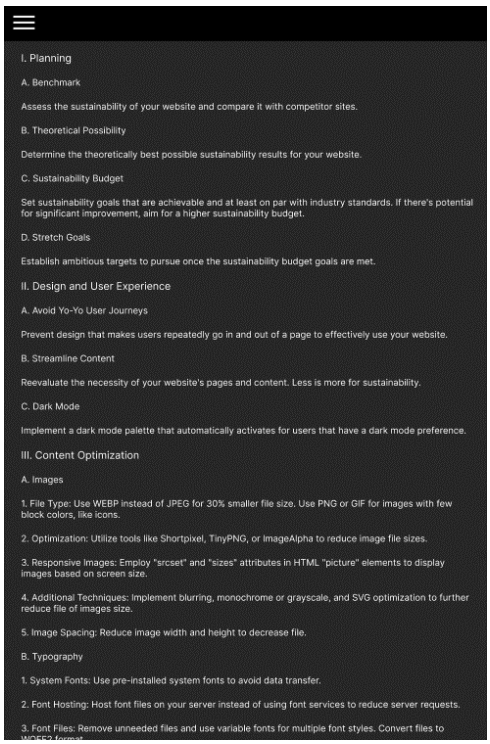


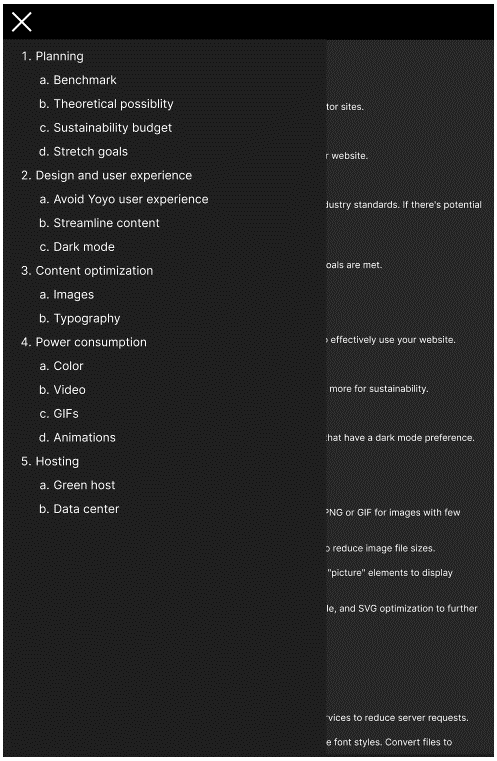
For Mobile devices, before and after opening the hamburger menu:





For Tablet devices, before and after opening the hamburger menu:





4.4.2 Guidelines website implementation

From the prototype, we designed a clear outline for creating the guidelines website. Given the variety of ways to create a website that meets our requirements, we evaluated several potential tech stacks before making our choice. Our evaluation considered usability, efficiency, and environmental impact, as the latter was in line with our focus on sustainability.

Framework	Advantages	Disadvantages	Sustainability Impact
Svelte	Straightforward usage, requires fewer lines of code, smaller bundle size, no use of virtual DOM	Less popular than other frameworks, smaller community	Positive, due to smaller bundle size and lower processing power requirement

React	Highly popular, large community, dedicated support	Requires more lines of code, uses a virtual DOM	Neutral to Negative, due to larger bundle size and higher processing power requirement
Angular	Comprehensive framework, dedicated support	More complex, larger bundle size	Negative, due to largest bundle size

We decided to use Svelte, a component-based JavaScript framework like React. This decision was based on several factors. Firstly, we found Svelte to be more straightforward to use and it required fewer lines of code. Secondly, from a sustainability perspective, Svelte appeared to be more environmentally friendly than other popular JavaScript frameworks. It has a smaller bundle size, meaning that the collection of JavaScript files sent to the user is smaller, leading to a lower page weight. Svelte also does not use a virtual DOM, which means that the browser does not require as much processing power to run a Svelte page as it would with a React page (Bhandari, 2022). According to Sustainable WWW, a simple "Hello World" project in Svelte had a bundle size of 3.8KB. For React and Angular, it was 6.3KB and 180.3KB, respectively (SustainableWWW, 2021).

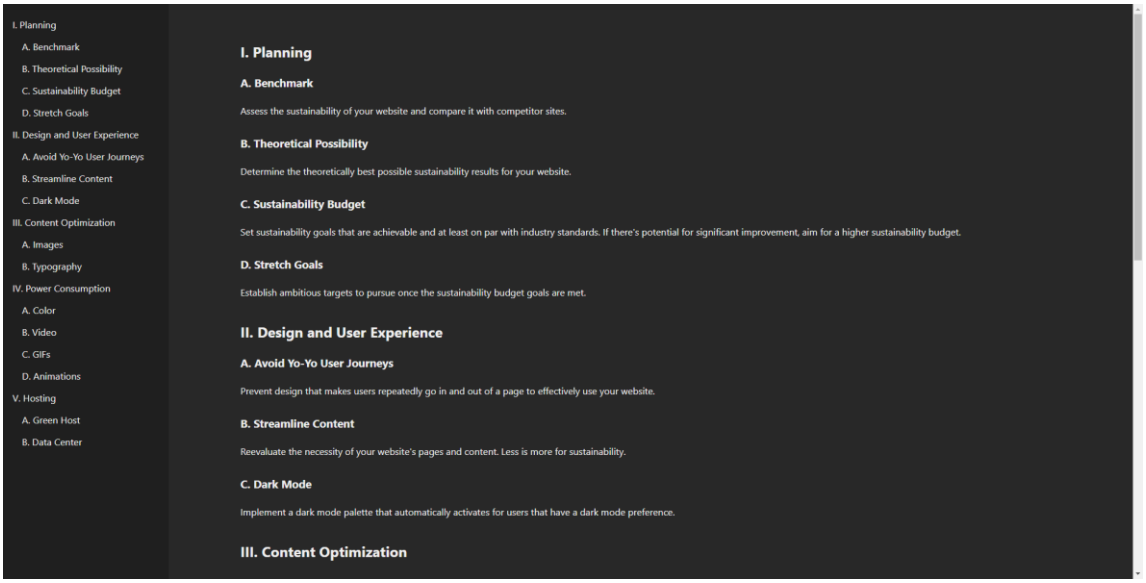
4.4.3 Initial version

- **Overview:** Our initial version of the website covered all the necessities. It was constructed with a horizontal navigation bar on the left and the guidelines' content displayed on the right. The site's design embraced a dark theme and was responsive to various screen dimensions.
- **Key features:** The development of the initial version of the website was guided by the following fundamentals:
    - **Simplicity:** The site maintained a minimalist design, comprised of merely text and a horizontal navigation bar, devoid of superfluous features, thereby facilitating user-friendliness and intuitive navigation.

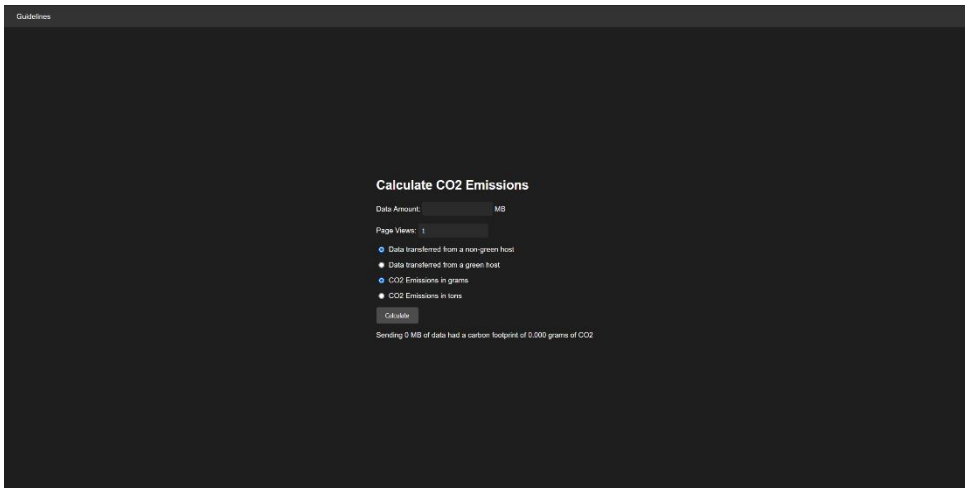
- **Versatility:** The site offered compatibility across an array of devices. On top of that, it enables users to select their desired sections from the navigation bar. This aspect synergized well with the fact that each step in the guideline was designed to function independently.
- **Sustainability:** The adoption of a dark theme was a deliberate choice, aimed at reducing the power consumption of the user's device. Furthermore, the website's simplicity contributed to its sustainability by decreasing the page weight.

Finished website on desktop:

Guidelines

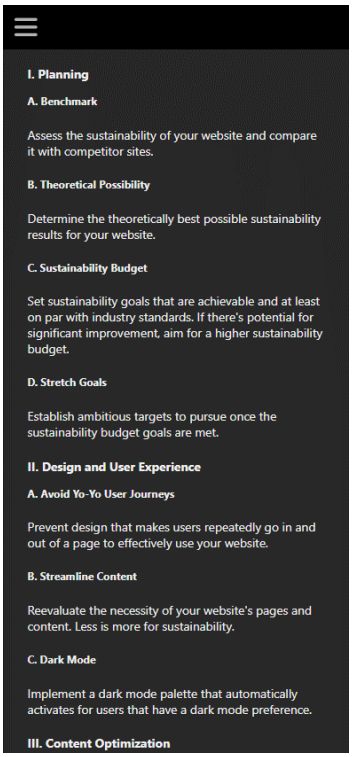


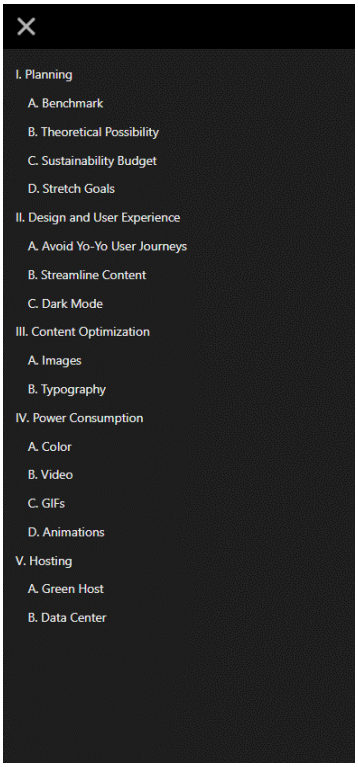
Calculator



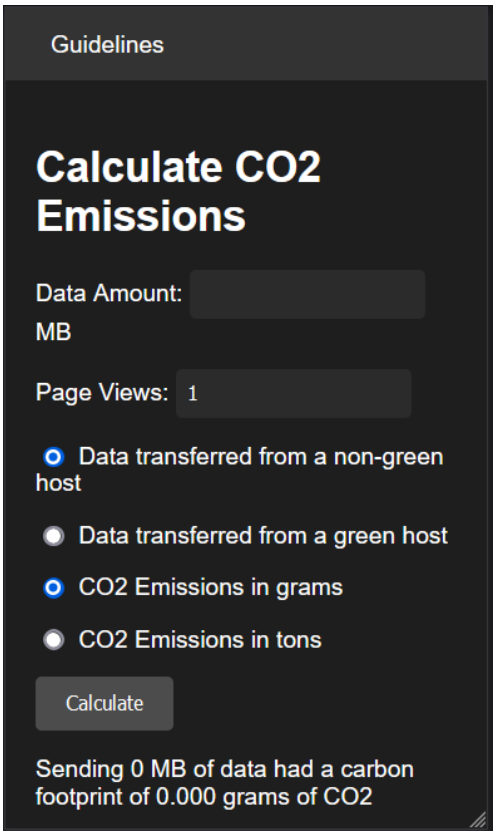
Finished website on mobile:

Guidelines



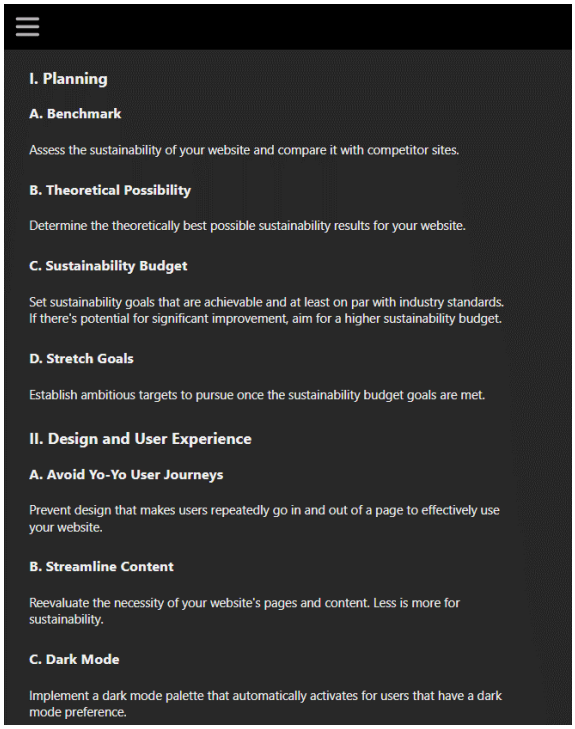


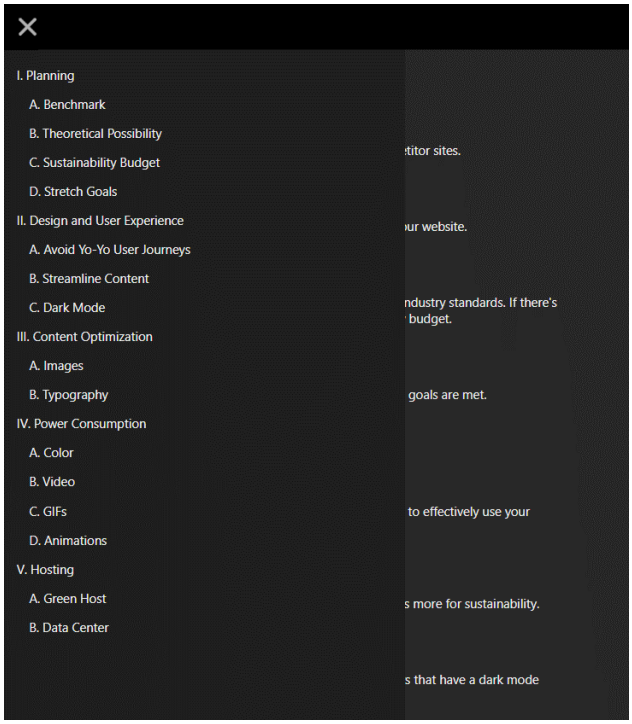
Calculator



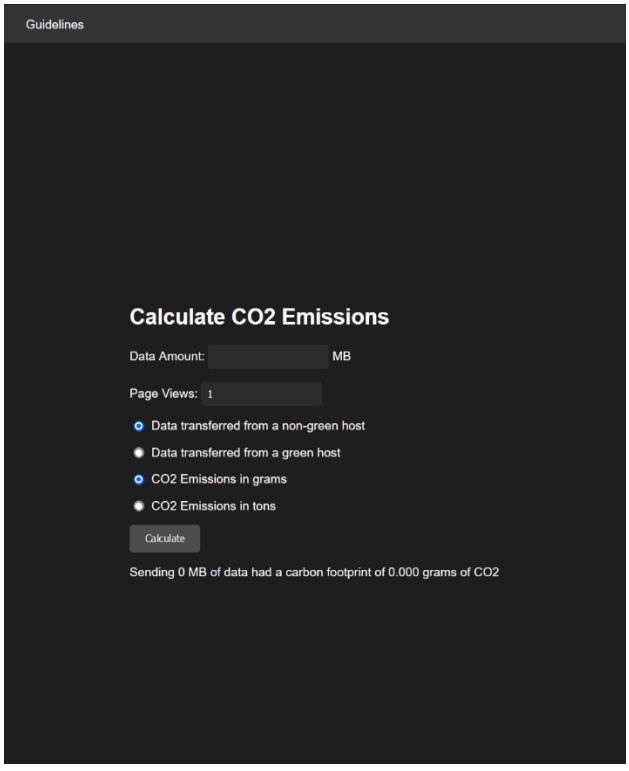
Finished website on tablet:

Guidelines





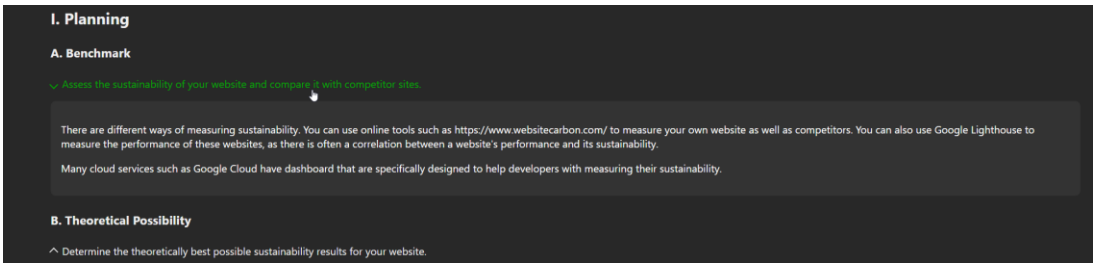
Calculator



4.4.4 Iteration of website

Our team recognized the potential for further enhancements of the website.

- **Key changes:**
    - **Additional context:** Our team believed that several points could benefit from further clarification, context, and links to tools. However, to avoid cluttering the page with excessive text and to maintain ease of overview for TV2, we introduced an interactive feature. Users can now click on a text segment, triggering the display of additional information below. The text changes to green upon hovering, and an upward-pointing arrow appears when the text is clicked, unveiling a box containing supplementary details. These details are rewritten texts from the first version of the guidelines.



    - **Title:** A title was incorporated at the top of the page, accompanied by a brief explanatory note delineating the guidelines' purpose.

We selected Netlify for website hosting, a cloud-based web development platform committed to environmental sustainability. Netlify achieves this by employing modern website architectures such as Jamstack, a web development methodology that pre-builds websites before they go live. This technique, as opposed to traditional approaches that build the website with each visit, reduces server strain and power consumption. Furthermore, Netlify offers automatic scalability, activating additional resources during high traffic periods and shutting them down when traffic decreases. Despite the reliance on key cloud providers such as AWS and Google Cloud, Netlify does not exclusively utilize green hosts. The hosting location of your website depends on the server Netlify assigns (Netlify, 2023).

The guidelines website can be accessed via the following link: https://web-sustainability-guidelines.netlify.app/.

4.5 Results from the changes to tv2.no/live

4.5.1 Navigation change

After implementing the navigation bar changes, we successfully enabled direct access to the subsections that were previously only accessible from the frontpage 2 Images showing changes to TV2 Live. However, it is important to note that we did not conduct extensive testing with external participants beyond our own group. As a result, we are unable to provide empirical data regarding the potential reduction in unnecessary page loads resulting from this change.

4.5.2 Changing from JPEG to WEBP and AVIF

Format	Size (MB)	Resolution	% of Size	% of Reduction
JPEG	1.52	600 x 400	100%	0%
WEBP	0.77	600 x 400	50.6%	49.4%
AVIF	0.30	600 x 400	19.8%	80.2%

By converting the images from JPEG to WEBP, we achieved a reduction in size of the images, the original size of the 11 images, that gets loaded in on entry was 1.52MB, while the images after conversion to WEBP format was 0.77MB. This showed a reduction in size of 49,4%.

By converting the images from JPEG to AVIF, the results showed a bigger reduction in size. From 1.52MB to 0.30MB. A significant drop in size 80.2% from the original, and less than half of the conversion to WEBP.

By using CO2.js we were able to estimate the reduction in Co2 per pageview and how much monthly CO2 they would release after the changes were implemented.

For this test we used the month of January 2023, where tv2.no/live had 2,817,287 visitors.

Image Format	Page Weight (MB)	New Page Weight	CO2 per pageview (original)	CO2 per pageview after conversion	Reduction in overall page weight	CO2 released in a month	CO2 released after changing image format
WEBP	5.06 MB	4.31	1.81g	1.53g	15.47%	5.0099 metric tons	4.302 metric tons.

AVIF	5.06	3.84	1.81g	1.375g	24.03%	5.0099 metric ton	3.874 metric tons.

4.6 Results from the changes to tv2.no/mat/oppskrifter

4.6.1 Transition from '<img/>' to '<picture/> element

To improve the sustainability and performance of tv2.no/mat/oppskrifter, we transitioned from using the <img/> HTML element to the more flexible <picture/> element. The <picture/> element allows for more control over the images displayed, enabling us to optimize based on the user's viewport.

Code snippet:

Original:

```
<img      You, now • Uncommitted changes
    in:fade={{
        duration: 100
    }}
    src={`${import.meta.env.VITE_CLOUDFRONT}/${data.images[0]}`}
    alt={data.title}
/>
```

After change:

```
<section class="hero" in:fade>
    {#if data.images && data.images.length}
        <picture>      You, last month • changed some img to picture …
            <source
                media="(max-width: 495px)"
                srcset={`${import.meta.env.VITE_CLOUDFRONT}/${data.images[1]}`}
                type="image/webp"
            />
            <source
                media="(min-width: 496px)"
                srcset={`${import.meta.env.VITE_CLOUDFRONT}/${data.images[0]}`}
                type="image/webp"
            />
            <img
                src={`${import.meta.env.VITE_CLOUDFRONT}/${data.images[1]}`}
                alt={data.title}
                in:fade={{ duration: 100 }}
            />
        </picture>
```

This modification allows us to deliver images that are better suited to the user s device and display settings. By adjusting the resolution and size of the images according to the user's viewport, we can decrease load times, since the user will not have to download much bigger pictures than what is needed for their device.

4.6.2 Converting WebP to AVIF

The AVIF encoder on avif.io was used to convert a set of 19 images taken from the main page of tv2.no/mat/oppskrifter from WebP format to AVIF format. We recorded the initial size of the images in WebP format and the resulting size of the images in AVIF format.

The initial size of the images in WebP format was 631 kb, and the new size after converting them to AVIF format was 610 kb. This represents a decrease in file size of 3.33%. The resulting AVIF images were of comparable quality to the original WebP images and maintained their visual fidelity.

Image format	Images	Size total kb	Co2 in g
WEBP	19	631	0.226
AVIF	19	610	0.218

4.6.3 Resizing the images for tablet and mobile

Mobile

To enhance page load speed for mobile users, we resized the thumbnail images on the front page. The original thumbnail size was 496 x 368, while the rendered size on mobile devices like the iPhone 12 Pro was 171 x 120. We aimed to strike a balance between image resolution and quality, as it is crucial for displaying appetizing dishes on a food recipe website. Thus, we resized the images to 342 x 240. This reduced the file size of the 18 small thumbnail images from 469.9 KB to 246.2 KB, resulting in a significant reduction given the website's total page load of 2.24 MB.

Image Name	Size (Original) (KB)	Size (Resized) (KB)	Reduction (KB)
image1.webp	26.1	13.3	12.8
image2.webp	22.5	11.6	10.9
image3.webp	20.5	10.7	9.8
image4.webp	16.7	8.9	7.8
image5.webp	29.6	15.0	14.6
image6.webp	36.4	17.3	19.1
image7.webp	21.8	12.0	9.8
image8.webp	43.3	19.6	23.7
image9.webp	28.6	15.6	13.0
image10.webp	43.3	20.2	23.1
image11.webp	34.8	16.6	18.2
image12.webp	22.1	11.3	10.8
image13.webp	24.9	12.7	12.2
image14.webp	24.4	12.1	12.3
image15.webp	16.1	8.3	7.8
image16.webp	27.6	14.7	13.0
image17.webp	22.3	11.7	10.6
image18.webp	40.4	19.9	20.5
Total	496.9	246.2	250.7

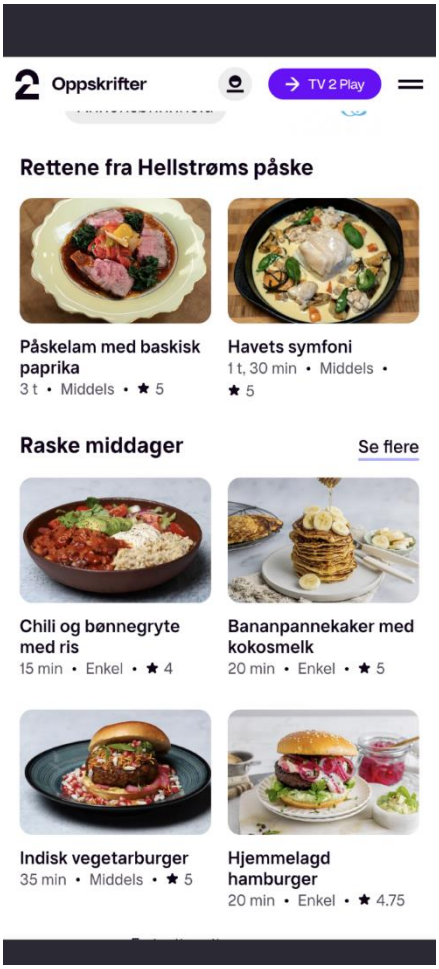
The larger image on the front page, originally 1280 x 720 pixels, is rendered at 390 x 219 pixels for cell phone devices like the iPhone 12 Pro. To optimize it, we resized the image to 400 x 225 pixels.

Image Name	Size (Original) (KB)	Size (Resized) (KB)	Reduction (KB)
NyChrister2.webp	101.2	15.7	85.5

With this we had adjusted the page load of the website for mobile users by 336.2(KB). Using the CO2.js calculator, we estimated the carbon emissions for the original page load to be 0.80 grams of CO2. However, after implementing these adjustments, the new CO2 emissions decreased to 0.682 grams.

4.6.4 Dark Mode Test

Light Mode



Dark Mode

The objective of our experiment was to evaluate the effectiveness of the proposed dark mode implementation on tv2.no/mat/oppskrifter in conserving battery life on OLED screen devices. The test was conducted by fully charging the device, setting the brightness to its maximum level, and observing the battery drain over a specific period.

In the first phase of our test, the device was left idle on the dark-themed footer of tv2.no/mat/oppskrifter. The footer, designed with a dark background and white text, represented our proposed dark mode. After 30 minutes of inactivity, the battery level reduced minimally, from 100% to 99%.

For the second phase, we replenished the device's battery to full capacity and repeated the same test. However, this time, we left the device idle on the main body of the tv2.no/mat/oppskrifter page, which has a light background with various images, representing the current light mode design. After an identical 30-minute interval, the battery had drained to 97%.

These results indicate a measurable difference in battery consumption between the dark mode and light mode. Despite the short duration of the test, the dark mode demonstrated a lower rate of battery depletion, underlining the potential of dark mode to contribute to energy conservation for OLED screen users. This outcome provides a compelling argument for the introduction of a dark mode option on tv2.no/mat/oppskrifter, thereby enhancing the sustainability of the website and offering a customizable user experience.

5 Discussion

In the following section, we will delve deeper into the interpretation and implications of our findings. Through this exploration, we aim to make sense of the results we have obtained and discuss the challenges encountered. Additionally, we will reflect on the implications of our findings for TV2, drawing potential pathways for future research and applications. It is important to note that this discussion is grounded in the specific context of our study, with a focus on creating tailored, sustainable web guidelines for TV2.

5.1 Effectiveness of the guidelines

Existing sustainable web design guidelines have been developed with a broad applicability in mind, ranging from individual projects to large-scale enterprise settings. This universality is beneficial in promoting the message of sustainability to a wide audience. However, it is not without drawbacks.

Guidelines that attempt to remain universally applicable might fail to incorporate specific measures that could prove advantageous for certain types of projects. For instance, a guideline may omit advanced image optimization techniques, which could significantly enhance the sustainability of a media-intensive site.

Conversely, guidelines that strive to encompass a plethora of different use-cases might lack coherence and specificity. Applying a single guideline designed to address e-commerce platforms, blogs, and news portals to a specific use-case, such as a personal blog, could result in an overwhelming and less efficient process.

While universal guidelines serve a crucial role in fostering sustainability, their application may not be entirely suitable or integrable for all specific use-cases. Due to this

This realization of the limitations of universally applicable guidelines led us to develop a tailored set of sustainable web design practices specifically for TV2. Given TV2's unique operational context and specific use-cases, a tailored approach allows us to address its specific needs more effectively and comprehensively.

Creating a tailored guideline for TV2 enables us to focus on and implement sustainability measures that are most relevant and beneficial for TV2's web services, considering the

specifics of their content, audience, and technological infrastructure. This custom guideline not only streamlines the process of making TV2's web services more sustainable but also ensures that all proposed measures are feasible and effective within their specific context.

By creating guidelines specifically for TV2, we aim to maximize the potential for sustainability improvements while minimizing unnecessary complexity and inefficiency that might arise from a one-size-fits-all approach.

5.1.2 Guidelines website

Keeping the guidelines on a separate website helps us show them in action. We can show useful web programming practices linked to certain parts of the guidelines. We can also display design choices that promote sustainability, like using a dark colour theme. This mix of direct examples and design tips gives a clear guide for developers who want to make their website more sustainable. It highlights the need to consider sustainability in all parts of web development, from coding to design.

5.2 Challenges

Throughout the work of this project, our team encountered many different challenges, often in relation to our objectives and collaboration with TV2. Our initial goal was to collaborate with TV2 and contribute to their sustainability initiatives. However, what direction to go from there that would be best for this project remained uncertain.

Our plan included conducting research and using the findings to construct a sustainability guideline. But we also wanted to create some sort of web application to go along with it. So, we thought of creating a website sustainability measurer that is specifically designed for TV2 and their needs. Despite this, we wanted to further integrate TV2 into our project work.

The proposed solution was to directly engage with TV2’s codebase, implementing and testing parts of our guidelines within their website framework. This approach marked a strategic shift in our project focus, moving from the development of a standalone guideline website to an emphasis on direct application within TV2’s codebase. As a result, our guideline development maintained its importance, but the creation of a sustainability measurer was scrapped in favour of a more hands-on approach with TV2’s digital infrastructure.

5.2.1 Implementation challenges

While engaging with TV2's codebase, additional challenges were confronted. One of them involved securing access to TV2 Live repositories on Bitbucket. This process required some trial and error, dealing with issues related to passwords and access tokens. Given that cloning the repository seemed to be impossible, we were told by TV2 to download the repository as a zip file as an alternative solution.

After setting up the downloaded repository, we were faced with the task of running the TV2 Live website on our local machines. This presented yet another challenge, as running it required Node 16, whereas we had been using Node 18, the latest version. This required the installation of Node Version Manager (NVM), a tool that facilitates the switching between different versions of Node (Harband, 2022).

After successfully getting the website running, we observed a significant delay in startup times, typically spanning several minutes. Additionally, making alterations to the code and saving them led to a comparable duration of latency for the changes to be reflected on the website. Collectively, these issues brought on substantial delays on our testing and development activities on TV2's websites, thereby presenting us with an unexpected challenge to navigate within our project timeline.

5.3 Future work

5.3.1 Potential areas for further research

For future enhancement of the guidelines, it would be beneficial to systematically validate each proposed solution through rigorous testing on TV2's websites. This approach would help substantiate the effectiveness of each guideline and assist in refining or discarding any steps that do not yield the desired results for TV2.

With less time constraints, a practical approach would be too incorporate select recommendations from the guidelines into the production builds of the websites. By allowing a specific period, such as a month, to elapse, and leveraging analytics, we could then come to know the impact of these modifications on user behaviour. This method could provide invaluable insights into how certain alterations influence user interaction metrics, such as the frequency of page loads compared to how long they stay on the pages.

Moreover, extending our investigation through additional interviews is advisable. Our preliminary interactions led us to key stakeholders within the organization who could provide in-depth knowledge about website management. Unfortunately, due to time constraints, we were unable to engage in such discussions. Expanding the pool of interviewees to encompass other companies would also enrich our research, fostering a more comprehensive understanding of sustainable practices in the industry. Such interviews could potentially lead to substantial improvements in the guidelines, providing a broader perspective on the strategies employed by various media firms to enhance the sustainability of their web presence.

5.3.2 Potential improvements to guidelines

The sustainability guidelines for web development are designed to be dynamic, adapting to emerging research, test results, and evolving technologies. Enhancing the usability of these guidelines is also a pertinent area of focus. It would be beneficial to conduct user tests, assessing the ease with which individuals comprehend and apply the guidelines. Feedback from these tests could trigger modifications, whether it involves adding clarity to certain solutions or integrating more visual explanations to aid understanding.

The guidelines' website also requires further enhancement. Primarily, it lacks accessibility features, rendering it unusable for individuals' reliant on-screen readers. While rectifying this oversight should be straightforward, time constraints prevented us from addressing it in this phase. Additionally, some guideline steps need more comprehensive explanatory text that users can access. User testing could be instrumental in identifying areas where clarity is lacking and could further enhance the usability of the site.

Finally, adopting a green hosting provider for the website would not only align with our sustainability goals but also serve as a strong model for others. By choosing hosting services powered by renewable energy sources, we would be taking concrete action towards reducing our digital carbon footprint, thereby leading by example in the pursuit of web sustainability.

6 Conclusion

Our bachelor report set out to address the problem statement of developing tailored web sustainability guidelines specifically for TV2 by testing and refining them on tv2.no/mat/oppskrifter, their food recipe website. Through extensive research, iterative testing, and analysis, we have achieved our objectives and provided valuable insights into enhancing sustainability in TV2's web services.

We delved into the concept of sustainable web design and extracted key principles and guidelines from the existing literature. These guidelines were adapted and refined based on comprehensive tests conducted on tv2.no/live and tv2.no/mat/oppskrifter. The results yielded compelling evidence supporting the effectiveness of various measures, including optimizing image file types and dimensions, and evaluating the impact of dark mode on OLED screens of smartphones.

To present our refined sustainability guidelines, we developed a dedicated website serving as a comprehensive resource. This platform displays the guidelines as well as incorporating a CO2 output calculator, powered by CO2.js, to estimate the potential reduction in carbon emissions resulting from the suggested changes.

Our research demonstrates the feasibility of developing and tailoring web sustainability guidelines specifically for TV2. The evidence collected through our tests validates the positive impact of implementing these guidelines in reducing image file sizes, optimizing dimensions for mobile users, and potentially lowering CO2 output.

By bridging the gap between theory and practice, our report provides TV2 with practical and effective solutions to enhance the sustainability of their web services. These tailored guidelines offer recommendations to improve user experience while reducing the environmental impact associated with web development.

In conclusion, our study contributes to the field of sustainable web design and not only provides TV2 with a set of customized guidelines to implement sustainable practices on their web services, but also aligns with the UN's 13th Sustainable Development Goal, "Climate Action.".

The findings highlight the potential for reduced resource consumption, improved user experience, and decreased environmental footprint. By implementing these guidelines, TV2 can embrace sustainability in their web services and contribute to a greener digital ecosystem.

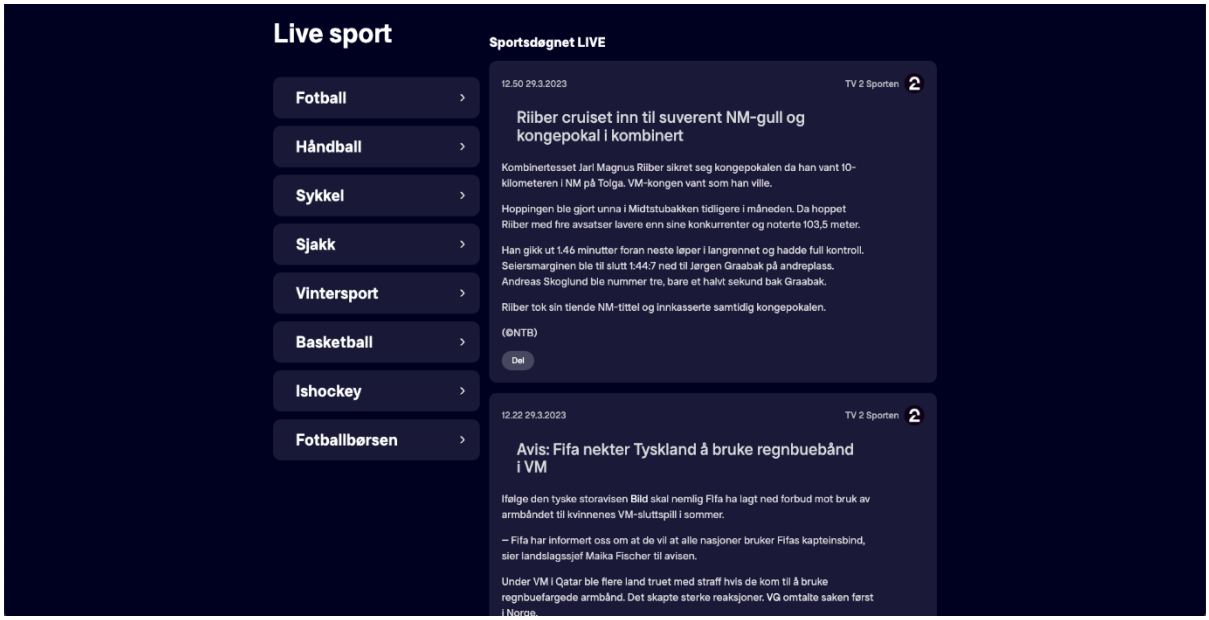
Appendix

1 Links to tools

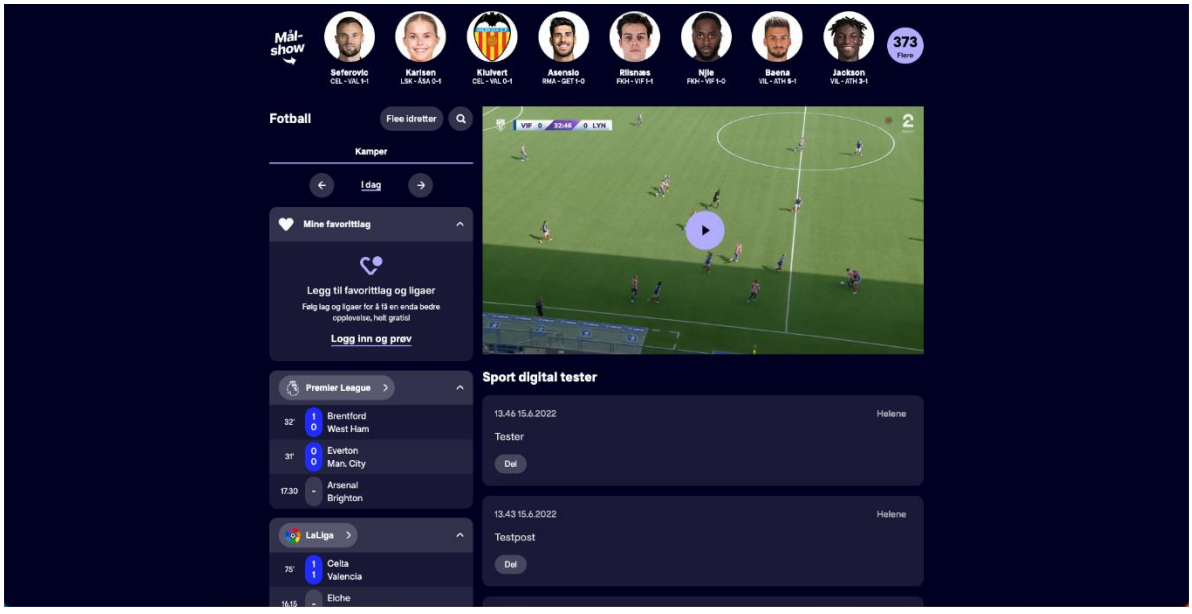
- **Booster Conference 2022: Green Code**
  - https://2022.boosterconf.no/talk/23-green-code/
- **Google Lighthouse**
  - https://developer.chrome.com/docs/lighthouse/overview/
- **Digital Beacon**
  - https://digitalbeacon.co/
- **Ecograder**
  - https://ecograder.com/
- **CO2.js**
  - https://developers.thegreenwebfoundation.org/co2js/overview/
- **ShortPixel**
  - https://shortpixel.com/
- **TinyPNG**
  - https://tinypng.com/
- **ImageAlpha**
  - https://pngmini.com/
- **FontDrop**
  - https://fontdrop.info/
- **Everything Fonts**
  - https://everythingfonts.com/

2 Images showing changes to TV2 Live

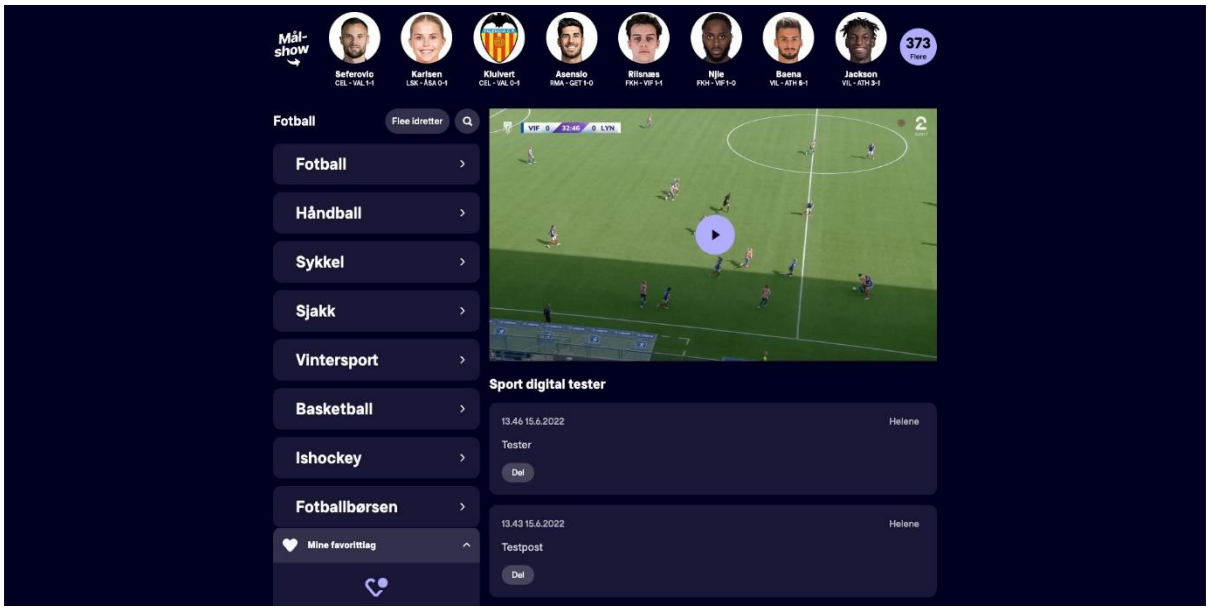
TV2 Live home page:



TV2 Live sport page:



TV2 Live sport page after implementing changes and "Flere idretter" button is pressed:



3 Interview with competing media company

Åpningsspørsmål:

1. Kan du fortelle litt om din rolle og ansvarsområder i [company name]
   - Svar 1: Litt i transisjons fase, sitter i devops team i [Portion redacted for privacy]
   - Svar 2: [Portion redacted for privacy], databaser, sertifikater, blant annet.,

Mest relevante spørsmål:

6. Kan du kort forklare [company name] forpliktelse til bærekraft, spesielt i forhold til deres nettjenester?
   - Svar 1: 2 år siden ble det satt opp grønn produksjon, satt opp prinsipper rundt bærekraft. [First and last name] er leder for det. Mulig å ta en prat med henne. De sender inn klimarapporter til de som har ansvar for grønn produksjon. Utviklet klimadashboard som viser klima utslipp for hver forskjellig tjeneste.
   - Svar 2: Nylig opprettet en stilling om det her. Ser på hele [company name] bærekraft. Skriver rapporten om alt. Hvor mye strøm og kjøing blir brukt på datatjenestene.

2. Hvilke tiltak har [Company name] implementert for å redusere mengden data som overføres mellom server og klient, som komprimering, hurtigbufring eller innholdsleveringsnettverk (CDN)? Hvordan har disse tiltakene påvirket bærekraften til nettjenestene deres?
   - Svar 1: Alle de tingene. Ikke vært så mye fokus på co2 energiforbruk, men generell optimalisering (akamai). Høy grad caching.
   - Svar 2: Ikke for bærekraftens skyld, mer for å hindre belastning.

3. Hvordan optimaliserer [Company name] ytelsen til nettstedet for å redusere energiforbruket, både på server- og klient-siden?
   - Svar 1: Ikke noe konkret initiativ der, finnes forbedrings potensial. Ingen guidelines for utvikling.
   - Svar 2: Right side sync. Både kostnad spørsmål også. Vet ikke om bildeformat vil bli endret.

4. Hvilke tiltak tar [Company name] for å minimere miljøpåvirkningen fra webhosting og serverinfrastruktur, spesielt i forbindelse med skytjenester?
- Svar 1: var ikke noe bevisst valg å bruke grønn host.
- Svar 2: Var et bevisst valg å bruke en grønn host.

5. Hvordan overvåker og sporer [Company name] energiforbruket til nettjenestene deres, og hvilke verktøy eller metrikker bruker dere for å måle bærekraften deres?
- Svar 1: Samler rapporter fra forskjellige leverandører. [Cloud services].
- Svar 2: [Cloud services] har dashboarder for dette her. Får hele dataen på hva man bruker, blir brukt for rapportering.

Relevante spørsmål:

7. Hvilke retningslinjer eller beste praksis følger [Company name] for å sikre at nettjenestene deres er designet med bærekraft i tankene?
- Svar 1: har ikke
- Svar 2: Tenker på hvor data skal flyte. Det som er for publikum, ligger allerede hos [Cloud service]. De prosesserer og behandler all data. Hvis man har tatt opp noe så blir det redigert på klient siden før det blir tatt til skyen.

13. Hvordan holder [Company name] seg oppdatert på de siste trendene og forskningen innen bærekraftig webutvikling, og hvordan integrerer dere denne kunnskapen i prosjektene deres?
- Svar 1:
- Svar 2: [Portion redacted for privacy] Ellers mye om det på konferanser man er på.

14. Hvilke fremtidige planer har [Company name] for å forbedre bærekraften i nettjenestene deres ytterligere?
- Svar 1: en del mål i grønn produksjon. Har dokumenter om det i intranettet sitt.
- Svar 2: Ingen co2 mål han vet om. Men nye kontor snart som kan komme med nye muligheter.

Å bytte fra jpeg til webp er noe de tenker på, men det ligger litt bak i køen bak andre ting de vil jobbe med først.
Bærekraft for videotjenester? Det kommer inn i nye kontrakter.
Hør med [First name] om forskjellige relevante prosjekter.

4. Initial Gantt chart

5. Lighthouse report of TV2 Live pages

URL	Performance Score (%)	First Contentful Paint (s)	Speed Index (ms)	Largest Contentful Paint (s)	Time to Interactive (s)	Total Blocking Time (ms)
https://www.tv2.no/live/	19	21007,452	52668,75338	56572,945	68685,995	45058,043
https://www.tv2.no/live/fotball	12	21685,006	66883,79572	66676,56	85384,271	58314,765
https://www.tv2.no/live/sykkel	25	22134,253	46096,28095	33018,148	69240,084	44723,831
https://www.tv2.no/live/sjakk	17	20766,59	42489,33637	32023,862	80042,486	55185,896
https://www.tv2.no/live/vinterspo	25	23496,248	44032,45743	35835,227	74811,38	49092,632
https://www.tv2.no/live/basketba	25	21867,449	39247,11328	36807,716	71913,326	47794,377
https://www.tv2.no/live/ishockey	19	26116,785	52343,2286	40578,869	77294,869	47742,584
https://www.tv2.no/live/fotballbo	19	22753,293	51009,61316	33837,2535	81021,587	54969,294

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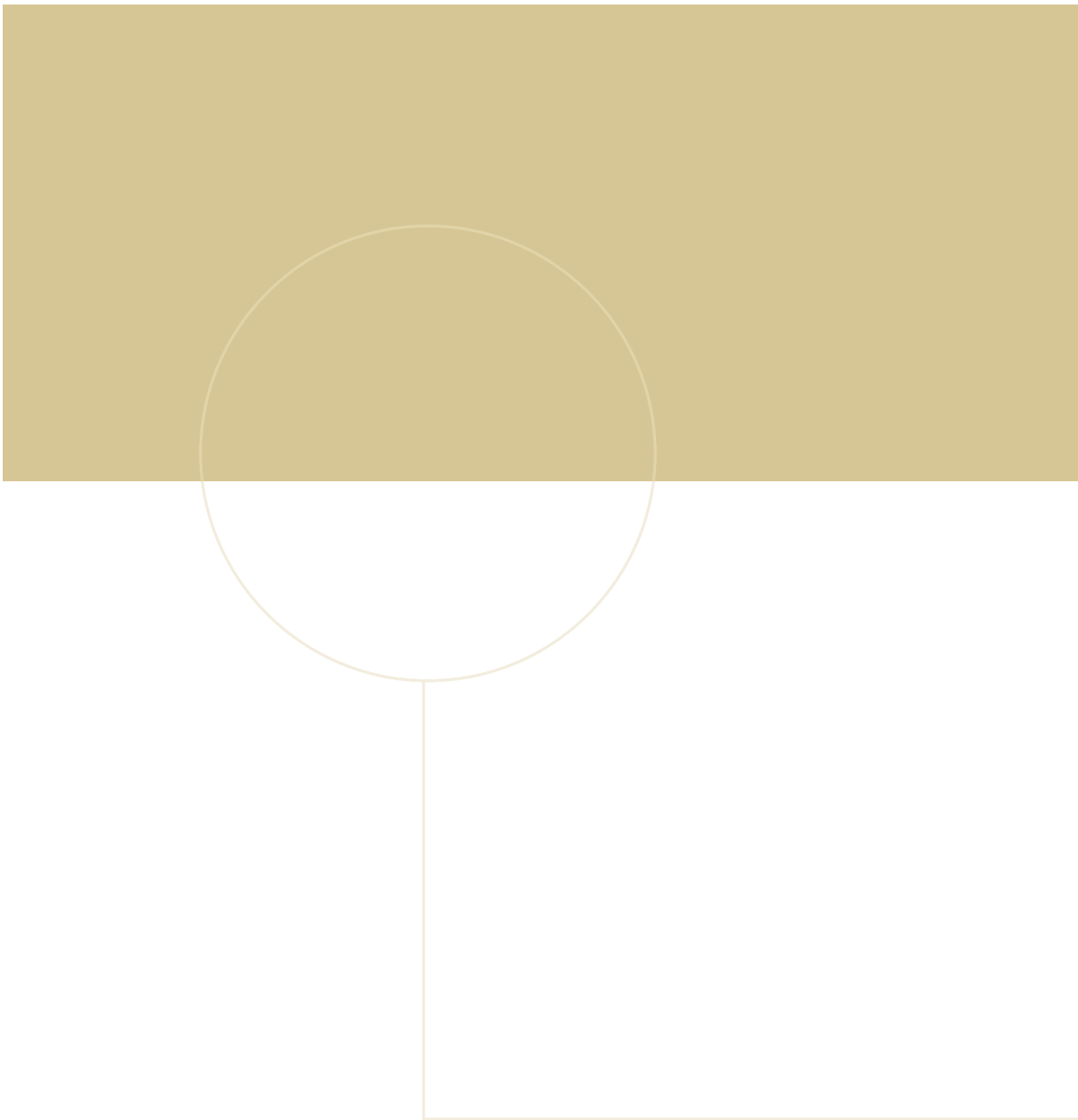

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