Bachelor of Science (B.Sc.) - Software Engineering

Reasons and strategies for sustainable web development in Web 2.0

Presented by:	Severin Glaser
	[redacted]
	Switzerland
Email:	[redacted]

Study Program:	Bachelor of Science (B.Sc.) – Software Engineering
Semester:	Synthesis Semester, Fall 2022
Enrollment Number:	[redacted]

Supervisor I:	[redacted]
Supervisor II:	[redacted]
Place and date:	[redacted], Switzerland, 17.01.2023
Preliminary hand-in deadline:	20.01.2023

Declaration

I hereby confirm that I have written the thesis titled *"Reasons and strategies for sustainable web development in Web 2.0"* by myself, without contributions from any sources other than those cited in the text and bibliography. This also applies to all graphics, drawings, and images included in the thesis.

Furthermore, I confirm that neither this work nor parts of it have been previously or concurrently used as an assessment submission in other courses or in other examination proceedings.

[redacted]

[redacted], Switzerland, 17.01.2023

____

Severin Glaser

Table of Figures

Table of Contents

List of Tables

List of abbreviations

AMOLED .... Active-matrix Organic Light-emitting Diode
API...Application Programming Interface
AVIF .... AV1 Image File Format
CPU .... Central Processing Unit
CRT .... Cathode Ray Tube
CSS .... Cascading Style Sheets
EC .... European Commission
EXIF .... Exchangeable Image File Format
g CO_2/kWh.. Gram of CO_2 per Kilowatt Hour
GHG .... Greenhouse Gas
HTTP .... Hypertext Transfer Protocol
IPTC .... IPTC-IIM-Standard
JPGs .... Joint Photographic Experts Group
kWh/GB .... Kilowatt Hour per Gigabyte
LCD .... Liquid Crystal Display
OLED .... Organic Light-Emitting Diode
PNG .... Portable Network Graphics
SDGs... Sustainable Development Goals
SVG .... Scalable Vector Graphics
TWh .... Terawatt Hour
UI .... User Interface Design
UI/UX .... User Interface/User Experience
URL .... Uniform Resource Locator
WebP .... Web Press Corporation
WWW .... World Wide Web
XMP .... Extensible Metadata Platform

1. Introduction

Over the past 20 years, the internet has experienced a significant expansion, and websites have become more complex. In June 2011, the average web page size was 523 KB (Teague, 2022), but in May 2022, the median website size was 2,299 KB (Indigo & Smart, 2022). Such an increase results in longer loading times, which lead to higher energy consumption. Greenpeace (2017) claimed that 7% of global carbon emissions in 2017 were caused by the World Wide Web. Meanwhile, climate change and its effects gained visibility; thus, society became increasingly aware of the impact of the internet's power consumption.

To keep the internet operating, data centres must host servers to ensure that applications and websites are constantly accessible. Jones (2018) predicted that the total energy demand for the web would increase from 2,000 TWh to over 9,000 TWh by 2030. Data centres account for the largest volume of consumption (Jones, 2018). If the internet were a country, it would rank sixth in carbon emissions, directly after Germany (Greenwood, 2021).

Web 2.0 is a major contributor to the emergence of the internet, as it is commonly referred to today. It provides a focus on the web as a platform and offers possibilities for collaboration, functionality, different applications, and user-generated input (Hall, 2022). In 2006, the term Web 2.0 appeared for the first time (Webdesign-Podcast.de, 2012). However, the term Web 2.0 has lost its meaning. The terms "web", "internet", and "social media" are now used synonymously and describe interactive internet content (Fuchs Media Solutions, n.d.).

This bachelor's thesis analyses sustainability and green web development. It investigates how sustainable web applications can be developed to consider environmental, social, and sustainable perspectives. This work aimed to determine how sustainable the internet is with respect to web development in terms of climate neutrality.

A quantitative study was undertaken to analyse current data from digital, creative, and web agencies, resulting in a comparison of working methods and perspectives in relation to sustainability regarding web development. The hypotheses and research questions listed in Appendix 7.1 are addressed in the theoretical section, the questionnaire, and the literature review.

The thesis consists of three sections:

- An introduction to theoretical principles
- A quantitative questionnaire
- The evaluation of strategies based on theoretical concepts and the questionnaire

The first section of the thesis discusses the literature based on theoretical foundations. Subsequently, the empirical part of the paper considers the collection and analysis of a quantitative survey. The final chapter outlines possible strategies and methods based on empirical results and theoretical considerations.

2. The Internet in Connection with Sustainability

The central elements of this thesis are sustainability and the web. They are examined because they provide a substantial theoretical foundation. Initially, the topic of sustainability in relation to greenhouse gas (GHG) emissions is examined, and the principles for web development and web design are presented and considered in the context of sustainability. In the second section of this chapter, relevant aspects of the web are defined.

2.1 Definition of Sustainability

Before addressing the subsequent chapters, an explanation of sustainability concepts is essential. Sustainability is the concept of preserving an economic, ecological, or social system over generations (Erek et al., 2009). Resources will therefore only be exploited if they can regenerate within a reasonable regeneration cycle (Erek et al., 2009). The concept of sustainability has become crucial in the 21st century, as both enterprises and individuals face increasing demands to approach climate change in a solution-oriented way (Issa & Isaias, 2022).

Considering sustainability, this work focuses on the contemporary web and its impact on climate change. Climate change, also known as global warming or climate variability, has been an evolving issue since the late 1970s (Halsey, 2022). At that time, scientists noticed that the ozone layer, the part of the Earth's stratosphere that absorbs solar radiation, had been depleting (Halsey, 2022). Halsey (2022) noted that a public and political debate about the causes and potential consequences of ozone depletion for the planet did not begin until the 1990s. From 2013 onwards, the EC took a more adversarial approach to climate targets. By 2030, greenhouse gases should be reduced from 1990 levels by at least 40%, and 32% of renewable energy should be produced (Europäische Kommission, n.d.a). Moreover, the Europäische Kommission (n.d.b) indicated its focus on taking concrete action in subsequent years by establishing 17 sustainable development goals. Goal 9 (industry, innovation, and infrastructure), 12 (responsible production and production), and 13 (climate action) are relevant to sustainable web development.

2.1.1 Making Sustainability Measurable

Most industries use common SI units for measurement, for example, litres per 100 km in the automobile industry. In web development, clear definitions are not specified, as emissions cannot be easily measured (Greenwood, 2021). According to Greenwood (2021), two main metrics can be used as indicators for carbon emissions:

- Data transmission and loading time
- The CO_2 intensity of electricity

Researchers measure data transfer in kWh/GB (Greenwood, 2021). According to Greenwood (2021), this measurement processes the amount of data transmitted via the internet when a web page is accessed. Typically, the more data transferred, the higher the energy consumption.

Independent of energy efficiency, the degree of environmental pollution from digital products depends on the CO_2 intensity of the energy used to operate a device (Greenwood, 2021). Greenwood (2021) specified that CO_2 intensity indicates how many grams of CO_2 are generated per kWh of electricity. This measurability varies considerably. Renewable energy sources and nuclear energy have a low CO_2 intensity of less than 10g CO_2/kWh, but fossil fuels generate a high CO_2 intensity of 200–400 g CO_2/kWh (Greenwood, 2021).

2.1.2 Definition of Software Sustainability

In this paper, sustainability refers to a dependency on emissions and energy sources. Collins (n.d.) described the term as the ability to sustain something on a constant level without depleting natural reserves or causing ecological damage.

Calero et al. (2021) defined the terminology for sustainable software as environmental sustainability, human sustainability, and economic sustainability, which collectively establish cohesion. Environmental sustainability refers to how the product and its development, maintenance, and utilisation impact the consumption of natural resources (Calero et al., 2021). Primarily, green software is perceived as showing environmental sustainability in software development. Human sustainability refers to how the creation and use of software affects the sociological and psychological aspects of software development, including work–life balance, labour rights, mental health, social support, and social justice (Calero et al., 2021). Economic sustainability refers to the protection of investment in software development by securing benefits, reducing risks, and preserving stakeholders' assets (Calero et al., 2021).

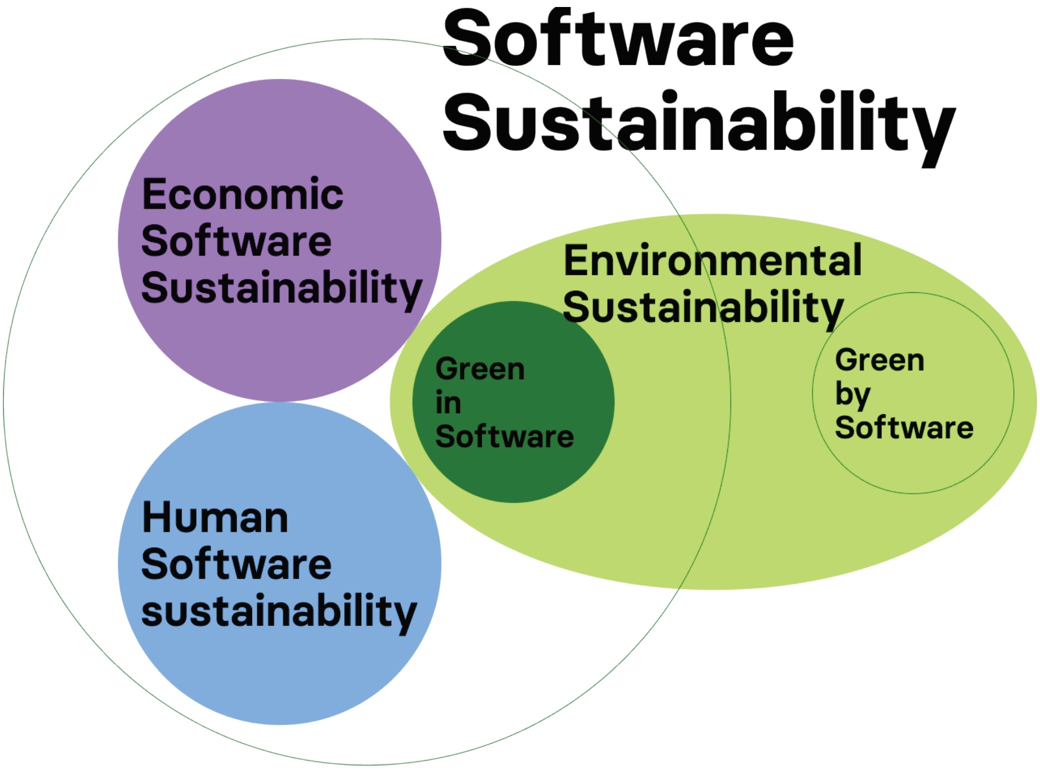

Figure 1 – Software sustainability dimensions in accordance with Calero et al. (2021)

As shown in Figure 1, the three dimensions of sustainable software impact one another. Environmental sustainability can be divided into green in software and green by software. Green in software signifies that any environmental problems relate to the software itself. In contrast, green by software means that when software is a tool for supporting sustainability goals in any area, but this dimension is not a regular part of the software itself. Nevertheless, green by software remains a component of environmental sustainability.

2.1.3 Definition of Sustainable Web Development

According to Klatt (2021), the internet and computers are responsible for 1.8–2.8% of global greenhouse gas emissions. Klatt (2021) observed that if the amount is adjusted for the supply chain, the percentage increases to 3.9%. In fact, the internet, web servers, and computers cause more climate damage than air travel, which generated 3.01% of global CO_2 emissions in 2018 (Klatt, 2021).

To counteract this situation, green web development focuses on creating and expanding websites based on their environmental impact (Schmidt, n.d.). The goal is to make a website's carbon footprint and lifespan as sustainable as possible. In addition, a suitable design, web hosting, page architecture, website size, and the development process correlate with one another and contribute to sustainable development (Wächter, 2022).

2.1.4 Definition of Sustainable Web Design

Sustainable web design is an intrinsic effort to design web services prioritising environmental protection. Its main goal is to reduce CO_2 emissions and energy consumption (Greenwood, 2021). Greenwood (2021) mentions the following fundamental principles of sustainable web design:

- **Clean** means that all web projects should be CO_2 neutral, particularly in terms of energy consumption.
- **Efficient** use of clean energy means that the products and services consume the lowest amount of energy and resources.
- **Open** means that companies and individuals do not prevent each other from sustainable web development. The products and services should be accessible, enable open information exchange, and give users control over their data.
- **Honest** means that products and services must not mislead or exploit users through either their design or their content.
- **Regenerative** focus is crucial for the rehabilitation of ecosystems. The products and services support an economy that feeds people and the planet.
- **Resilience** is indispensable to the internet. The web provides information and services to people in crisis areas.

Brux (2019) divides the concept of sustainable web design into the following six sections:

- **Sustainable web hosting**. A lasting website should be hosted so that it is carbon neutral.
- **Sustainable web design**. The website design should be timeless and durable. Sustainable design equally considers colour selection, font choice, the conscious use of image and video, aesthetics, functionality, user friendliness, and ecology.
- **Page architecture**. The navigation of a website should be intuitive and effective to avoid loading processes.

- **Sustainable web development**. The cleaner a website is, the faster and more energy efficient it loads. External services should be avoided and self-hosted.
- **Sustainable data consumption**. A website that loads less content generates less CO_2 when accessed.
- **Sustainable production**. A website's production process should be as CO_2 neutral as possible.

2.2 Definition of the Internet

In the following section, the web and its principles are explained more precisely. Along with sustainability, the terms "internet" and "web" form a core element of this thesis. To define the terms in context, the history of the internet up to the modern web is examined more specifically.

2.2.1 History of the Internet

The origin of today's internet dates to 29 October 1969, when the first data transmission occurred (Großkortenhaus, 2020). In the 1970s, the fundamental phase of internet development began when the internet evolved from military to academic use (Fonial, n.d.). From 1989 to the 1990s, Tim Berners-Lee introduced the concept of the World Wide Web, browsers, web servers, first drafts for the HTML markup language, the HTTP protocol and created URLs to link different websites (Großkortenhaus, 2020). As shown in Figure 2, the web developed from company-focused to community-focused. Today, its focus is on individuals (Terra, 2022). The internet has been referred to chronologically as Web 1.0, Web 2.0, and Web 3.0, which are defined as follows:

- **Web 1.0**: Described the internet from 1990 to 2000 (Borini et al. 2022). It referred to a read-only web that only allowed individuals to view information (Ejeke, 2022).
- **Web 2.0**: Specific years cannot be assigned to this term. However, Borini et al. (2022) dated Web 2.0 from 2000 to 2020, while Terra (2022) dated it from 1999 to 2012. The term Web 2.0 is therefore frequently criticised as imprecise jargon, especially since its characteristics had already been central to the internet from its inception (Polyas, n.d.). However, a clear definition can be made that this stage is a read–write web permitting individuals to retrieve and write information simultaneously (Ejeke, 2022).
- **Web 3.0**: Different sources refer to this term appearing in different years, too. According to Stuck (2019), the term first arose in 2006. However, Borini et al.

(2022) claimed that the Web 3.0 has only existed since 2020, and the Relevanzmacher Team (2022) claimed that the Web 3.0 still does not exist. This stage of the internet is a read–write interaction that may use artificial intelligence to manage the user experience and allow audiences to participate in activities interactively (Ejeke, 2022).

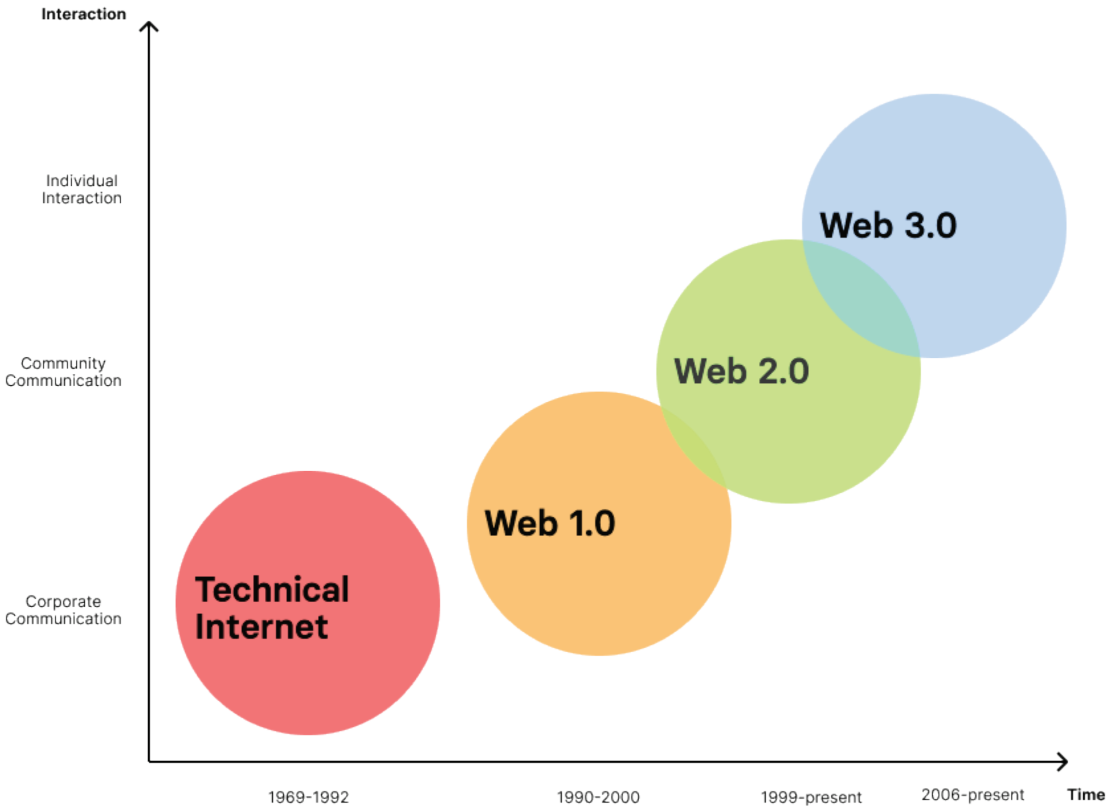

Figure 2 – Timeline in relation to the development of the internet in accordance with Borini et al. (2022), Ejeke (2022), and Terra (2022)

The internet, the WWW, and its stages Web 1.0, Web 2.0, and Web 3.0 are terms that are frequently used synonymously. They describe the internet as a worldwide network that connects individual computer networks (Großkortenhaus, 2020).

3. Quantitative Analysis

Various research methods are available for data collection and the evaluation of surveys. Quantitative questionnaires have advantages over qualitative interviews when exploring multiple companies, as more surveys can be conducted, and specific conclusions can be drawn. Quantitative analysis is a procedure using mathematical and statistical modelling, analysis, and research to explain behaviour (Kenton, 2020).

3.1 Research Design

To conduct research analysis, a research design is necessary. It provides a framework, structures the process of conducting qualitative research, and divides the evaluation into various stages. A linear approach was applied in this context. This procedure consisted of devising a comprehensive research design at the beginning of the survey to address a specific research question and hypothesis (Witt, 2001). This phase was followed by the iterative main research phase and ended with the results presentation phase.

In respect to the research questions and the hypotheses, the survey questions are elaborated on Appendix, chapter 7.2. The survey was based on the research questions and hypotheses, which are explained in more detail in Appendix, chapter 7.1. In this context, the researcher conducted the quantitative survey using closed questions. This method allows for the collection of fixed, measurable, and statistically evaluable data (Warzecha, 2022). Regarding the thesis, the questions are formulated diversely, meaning that the participants may answer the questions in their area of competence. At the end of the evaluation, the last four questions were deliberately kept open so that respondents could express their thoughts and answer comprehensively in their own words. Based on the text responses, conclusions are drawn, and statements are reinforced. An overview of the anonymous replies is available in Appendix, chapter 7.3.

3.2 Research Evaluation

The next chapter introduces metadata and a general overview of the evaluation processes. A total of 66 randomly selected Central European web, digital, creative, and sustainability agencies, as well as other companies and freelancers engaged in web development, were surveyed. A total of 25 companies responded to the questionnaire, corresponding to a participation rate of 37.8%. Company size was classified into the following categories:

Designation	**Number of employees in the company**
Micro enterprises	1–9 employees
Small enterprises	10–49 employees
Medium-sized enterprises	50–249 employees
Large enterprises	>250 employees

Table 1 – Company sizes. Adapted from Kleine und mittlere Unternehmen*, by Bundesamt für Statistik, 2022 (https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen/unternehmen-beschaeftigte/wirtschaftsstruktur-unternehmen/kmu.html).*

For a detailed analysis, respondents were asked to provide information about age, gender, employment level, and company size, with the possibility of doing so anonymously. A detailed overview of the relevant person-related information is shown in Figure 3.

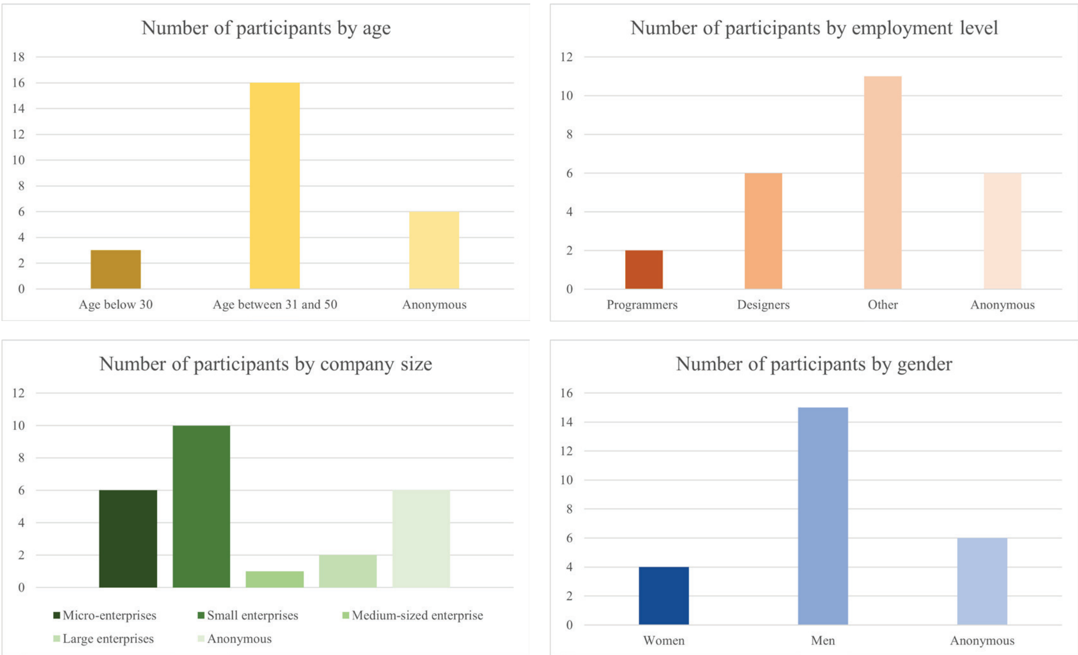

Figure 3 – Evaluation of the participants

Regarding company size (and age), a precise and representative comparison is difficult to make, as a different number of respondents answered in each case. Nevertheless, the evaluation shows a tendency from which conclusions can be drawn.

In relation to the research question, five questions, excluding sub-questions, were evaluated. Questions 1, 2, and 3 were closed questions with yes and no options, and Questions 4 and 5 were based on the Likert scale. Figure 4 shows the spectrum on the five-point scale through which respondents can indicate how much they agree or disagree with a particular statement.

Figure 4 – Likert scale. Adapted from Likert Scale Definition, Examples and Analysis, *by McLeod, 2019 (https://www.simplypsychology.org/likert-scale.html)*

The yes and no answers were evaluated in the same way as the Likert scale, as indicated in Figure 5.

Figure 5 – Percentage evaluation

3.3 Quantitative Survey

The survey was conducted over three weeks. Participants accessed the survey via a web application specifically developed for the study. In the following chapter, the evaluation of the qualitative observations is presented in detail.

3.3.1 Question 1: Sustainability in Projects

Agencies' perception of the internet relative to its emissions (the thesis' research question 2) and the thesis that companies are generally interested in sustainability but do not seem to implement them (hypothesis 3) were confirmed in the first question of the survey: To what extent has a company already dealt with sustainability in the development of web projects? As shown in Figure 6, this question was answered positively by 15 people, resulting in an approval rate of 60%.

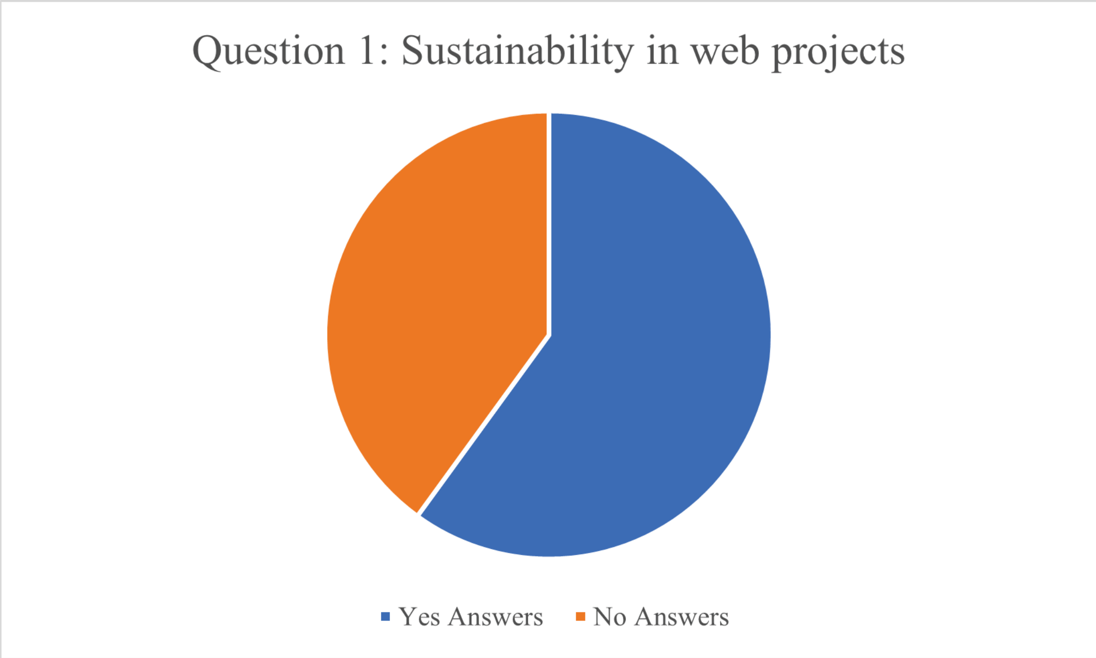

Figure 6 – Question 1 evaluation: total answers

Figure 7 shows that mainly micro-sized, medium-sized, and larger companies have adopted sustainable web development. However, only 30% of small enterprises answered yes to the question. From the text responses, it can be concluded that participants apply similar strategies, such as effective UX, clean code for fast loading times, data economy, and green energy–powered hosting providers. Contrasting opinions were also prevalent, such as that energy savings do not originate within a company and that generating GHG savings from individuals is more important.

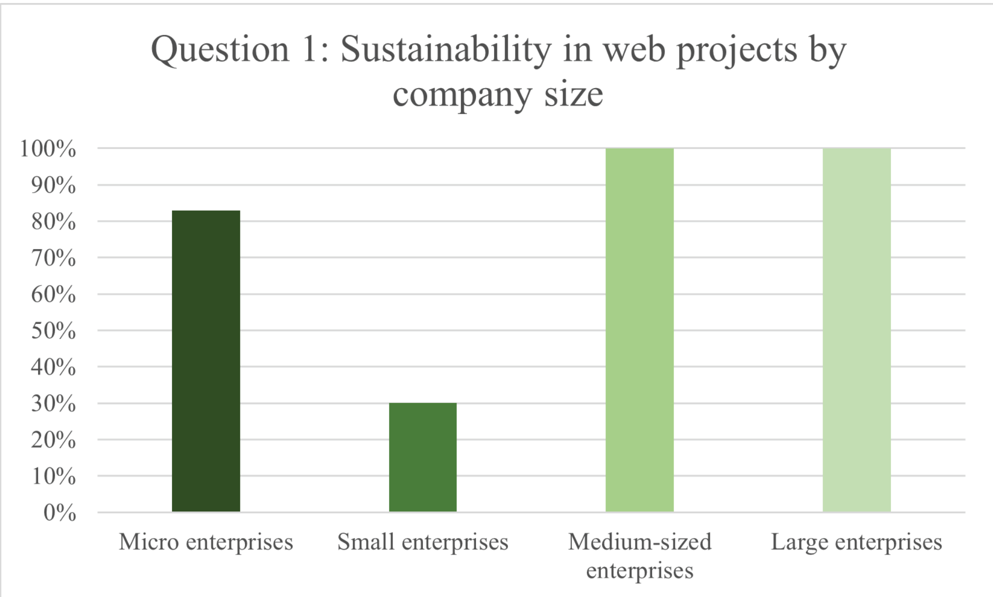

Figure 7– Question 1 evaluation: answers by company size

3.3.2 Question 2: Conventional Methodologies

The second question regarding the sustainability of a website in contrast to conventional methodologies was positively answered by a total of 13 people, resulting in an approval rate of 52%, as shown in Figure 8. This survey question aids in the evaluation of research questions 1 and 2, ascertaining the sustainability of the internet in terms of GHG emission and the agencies' perception of the internet's emissions. The undecided result revealed that the participants were critical of modern web applications and did not see a connection between web applications and traditional practices.

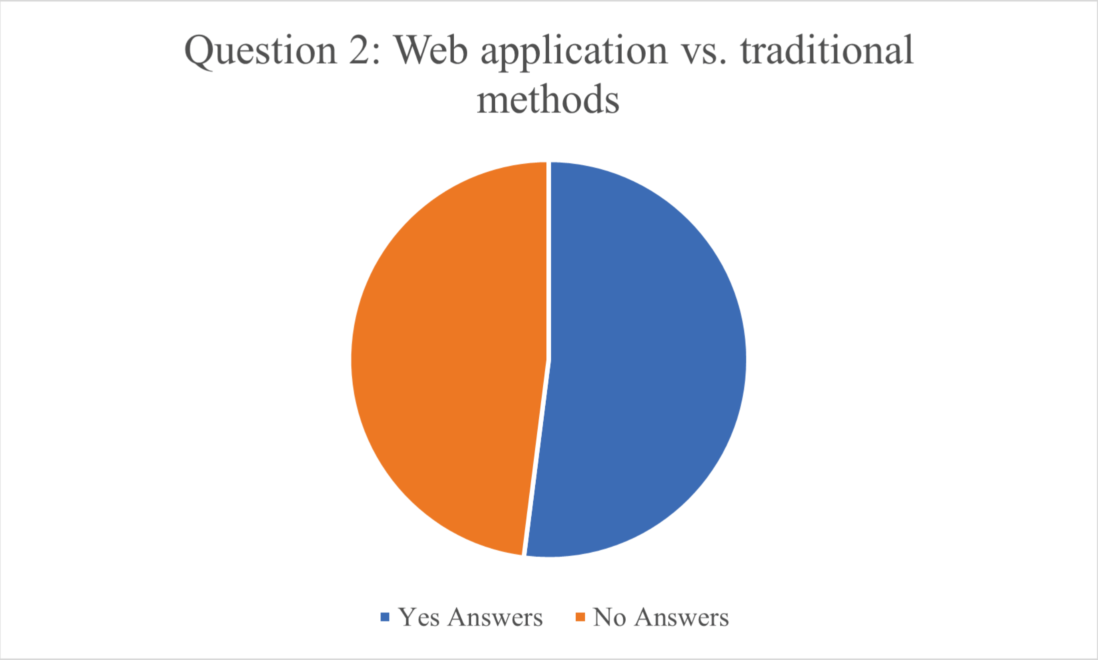

Figure 8 – Question 2 evaluation: total answers

A similar ambivalent evaluation of the survey can be observed across the different sizes of businesses, as shown in Figure 8. As Figure 9 indicates, participants from micro, small, and large enterprises each responded with an approval rate of 50%, but medium-sized enterprises disagreed with the question.

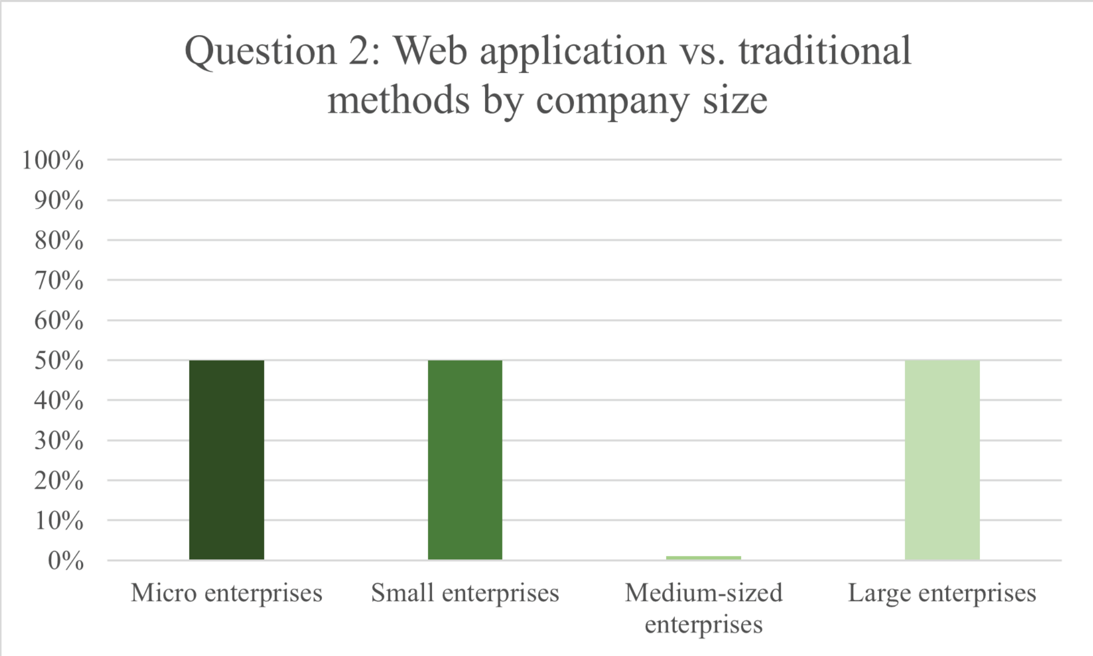

Figure 9 – Question 2 based on company size

One individual commented that the modern web is more sustainable because information can be stored in a way that was previously only possible with books. Greenwood (2021) explained this behaviour and the outcome of the question when claiming that the awareness of and correlation between the concept of sustainability and web development is non-existent. Consequently, Greenwood (2021) indicated that individuals or firms do not prioritise sustainability – the idea of sustainability may be interesting, but cost reduction and aesthetics usually dominate any project.

3.3.3 Question 3: Green Web Hosting

Survey question 3, which asked whether a company employs green web hosting, was partially proven. In addition, hypothesis 1 (strategies for sustainable web development are applied differently in larger and smaller agencies) could be partially refuted, whereas hypothesis 2 – green web hosting is perceived differently by larger and smaller companies – could be confirmed. A total of 12 people answered survey question 3 positively, but only 48% of participants agreed with it, as shown in Figure 10. This ambivalent evaluation indicated that the majority of companies do not use green web hosting. This finding contradicted the individual textual responses, in which 5 people stated that green web hosting is a useful, efficient strategy for a sustainable web. Furthermore, it can be assumed that hypothesis 3 is also partially applicable. According to the text responses, the participants were familiar enough with the subject to respond to it. As this survey question revealed, the need for sustainable web development exists, but is only occasionally implemented.

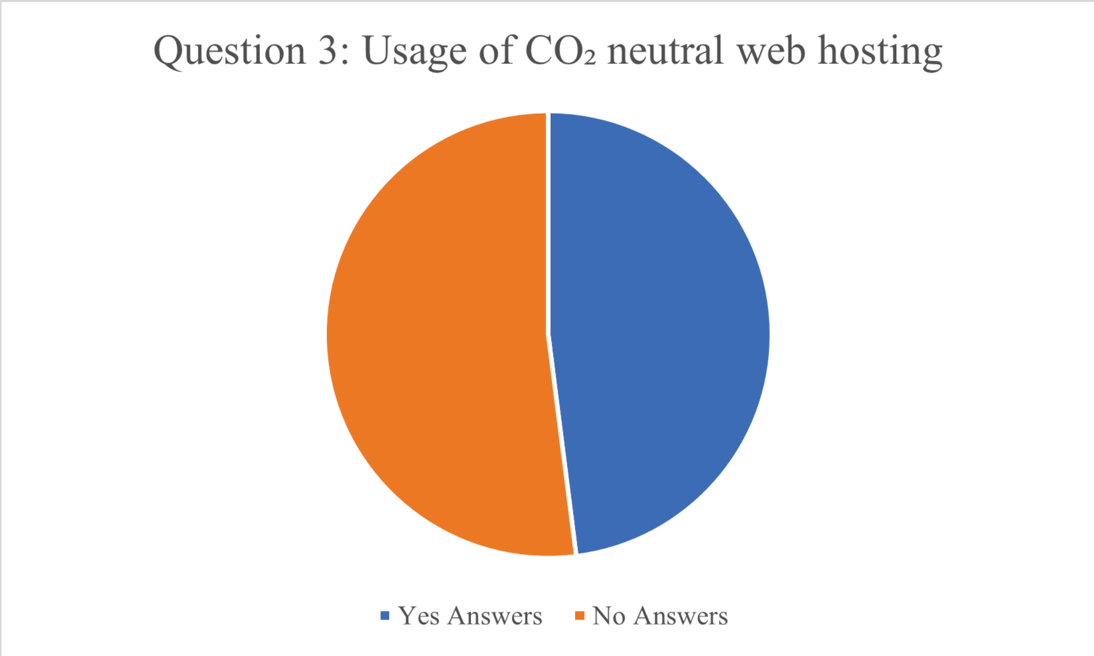

Figure 10 – Question 3 evaluation: total answers

Micro enterprises' budgets did not influence whether they used green hosting. A clear majority of this group indicated that they use green hosting. As shown in Figure 11, employees from micro enterprises are an exception, 66.7% stated that they use CO_2 neutral web hosting for web projects. A total of 40% and 50% of small and large companies, respectively, agreed, while medium-sized companies completely disagreed with the question.

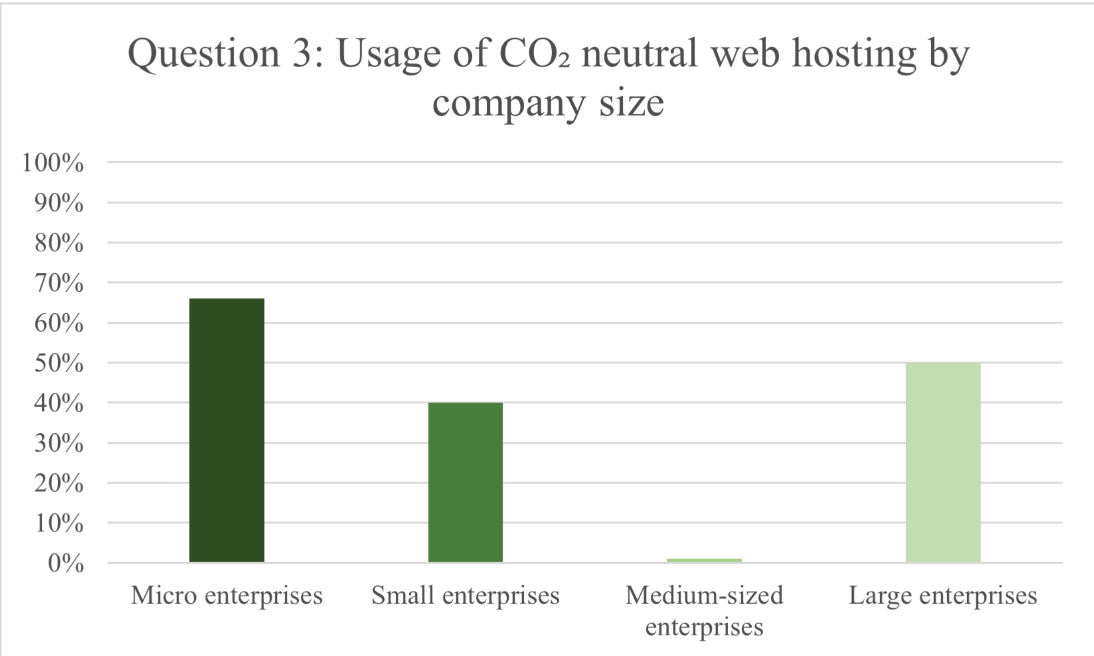

Figure 11 – Question 3 based on company size

3.3.4 Survey Question 4

Question 4 focused on the Likert scale and included several sub-questions concerning the influence of technology and other factors related to sustainability on the web. The paper's research questions 3 to 6 which examined what strategies can be implemented in a web project to make the internet greener, what influence data centres have on CO_2 emissions, what factors other than data centres cause CO_2 emission in the WWW and what influence customers have in relation to a green web applied to the sub-questions of survey question 4, applied to the sub-questions for the survey question 4. However, hypotheses 1, 2 and 3 were also specifically targeted and confirmed.

3.3.5 Question 4.1: Green Web Hosting

Green web hosting was regarded with either indecisive agreement or an undecided response with a positive tendency. With an average rating of 3.5, it ranked second in the importance as a strategy.

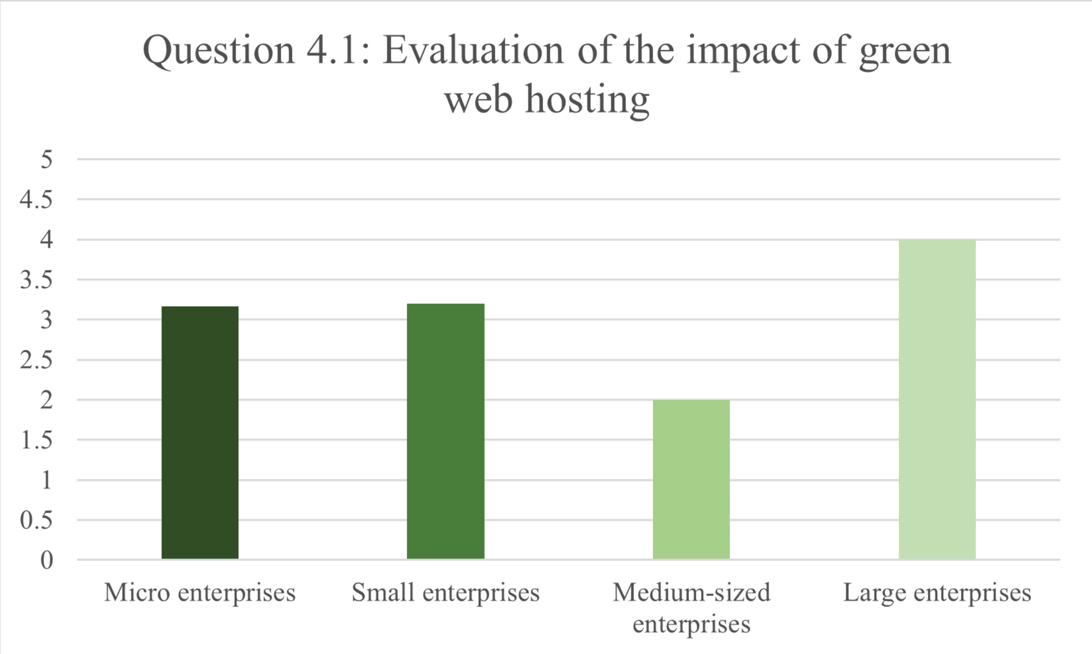

Figure 12 – Evaluation of web hosting as a strategy based on company size

As shown in Figure 12, larger companies clearly rated web hosts as a major influence for energy consumption and emissions, while micro and small companies tended to be indecisive. Only medium-sized companies rejected green web hosting as a strategy. According to Greenwood (2021), 31% of all companies use green hosting. Considering Greenwood's finding, the evaluation indicated that green hosting has become increasingly important. In the optional text responses, four out of 11 persons, or 36.6% of respondents, considered emission-free hosting as an important strategy. Although it cannot be determined whether these individuals were using sustainable hosting, it can be concluded that awareness of this issue has increased.

3.3.6 Question 4.2: Data Centres

Participants undisputedly viewed data centres as the greatest threat to a sustainable web. The participants had an average tendency of 3.88. As shown in Figure 13, only medium sized enterprises showed a clear tendency to disagree (2.0).

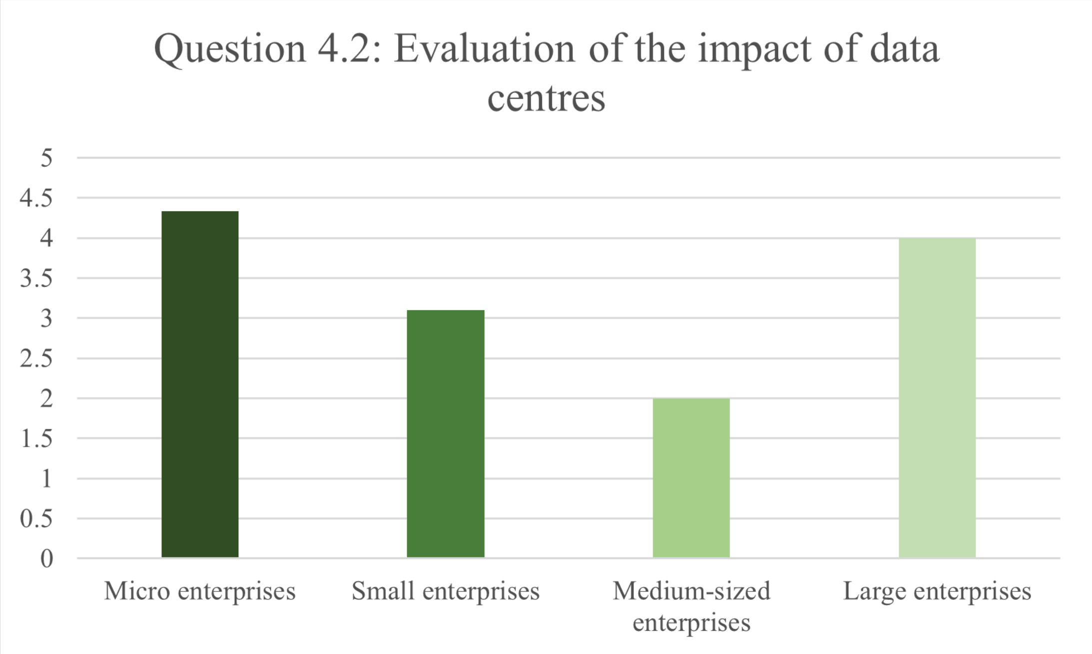

Figure 13 – Evaluation of data centres as a strategy based on company size

The results of this question overlapped with the theoretical aspects, as according to Greenwood (2021), data centres are a major source of global energy demand and create a threat to the UN Framework Convention on Climate Change from the Paris Agreement. Andrae and Elder (2015) indicated that data centres consumed 1.5% of the world's electricity in 2010 and this consumption will increase in the next years. Data centres are only moderately quoted in the text responses. The participants made critical statements, such as that data centres are arguably the greatest energy consumers unless they are green hosted, but there are no alternatives.

3.3.7 Question 4.3: Customer Requirements

Customer requirements received a just below average rating, with the participants having an average tendency of 2.56. No relevant fluctuations due to company size could be identified. As shown in Figure 14, all companies had a consistent attitude towards this issue.

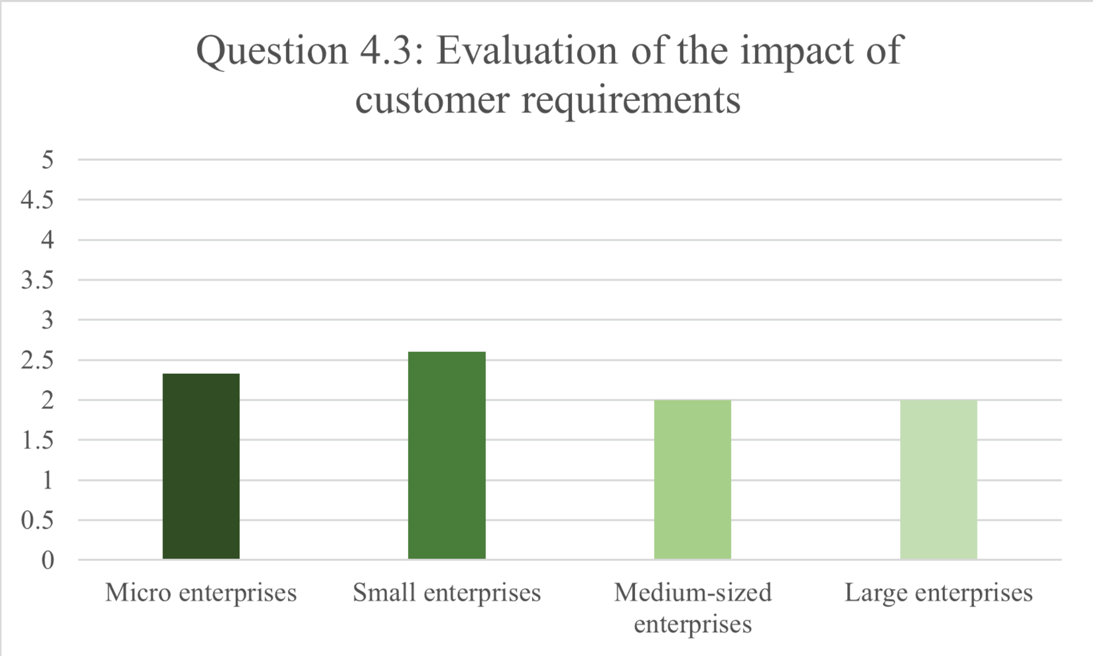

Figure 14 – Evaluation of customer requirements as a strategy based on company size

Greenwood (2021) found that sustainability did not appear on the priority list of clients' requests. He argued that specific client needs should be addressed initially and that sustainable practices could be seen as tools that could be used to complete the project (Greenwood, 2021). The text responses showed that chasing trends and the lack of awareness of those involved in sustainability could negatively impact a web project. This means that customer requirements have priority over sustainable methods.

3.3.8 Question 4.4: UI/UX

UI/UX was rated marginally indecisive, ranking third in terms of importance as a strategy, with an average score of 2.88. UI/UX in this context was narrowed down to the choice of images, videos, fonts, and colours. No relevant deviations based on company size were found. As Figure 15 shows, all companies had an undecided opinion on UI/UX.

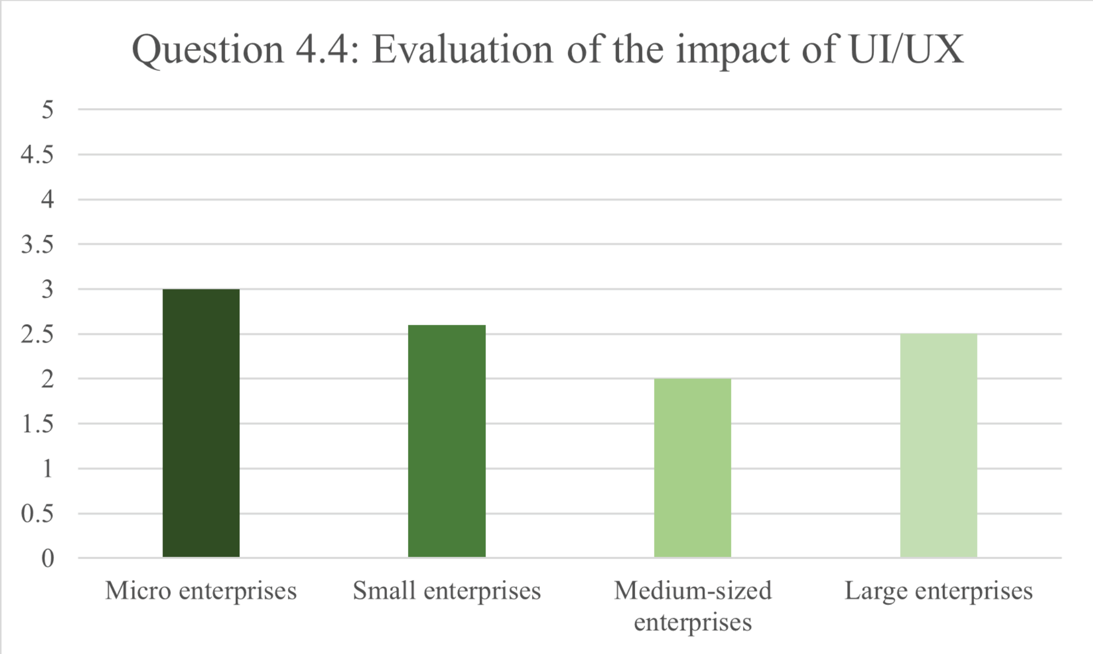

Figure 15 – Evaluation of UI/UX as a strategy based on company size

Although the overall opinion of UI/UX was undecided, the text responses strongly thematised it. The use of system fonts, the optimised use of automatic video playback, the omission of images, and the use of modern file formats were noted.

3.3.9 Question 4.5: Programming Language

Overall, programming languages were not seen as relevant to sustainability. The average score was 2.28, with all company sizes exhibiting similarly disapproving values, as Figure 16 indicates.

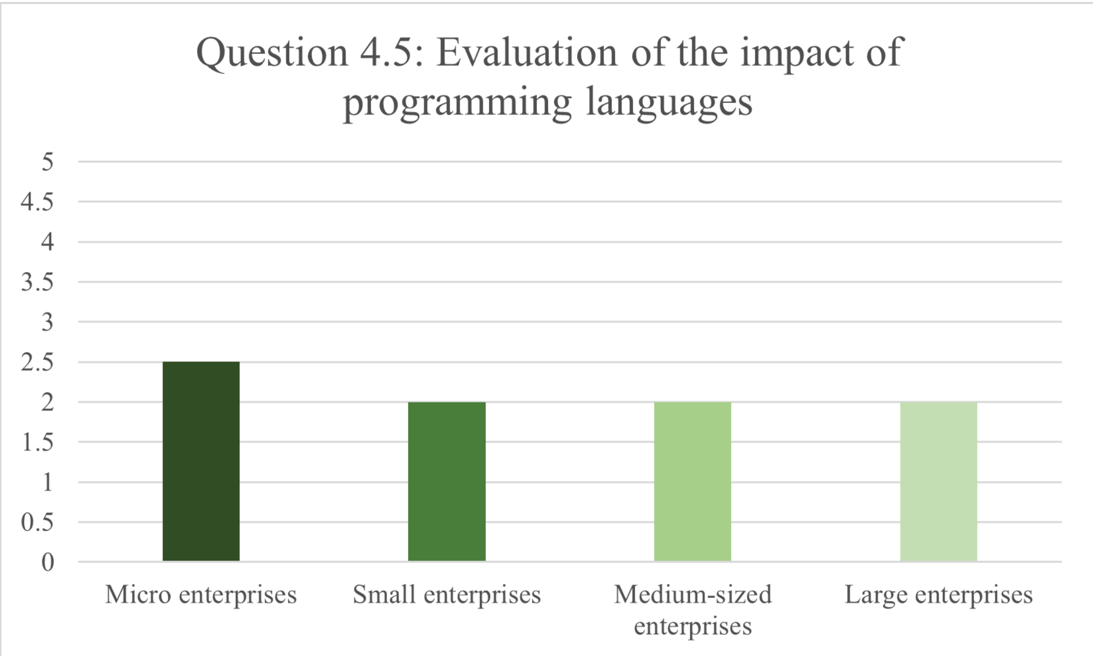

Figure 16 – Evaluation of programming languages as a strategy based on company size

In noting the advantages of code, Greenwood (2021) stated that apart from the reliability, security, and maintainability of well-written code, efficiency is beneficial for programmers. In terms of programming language, efficiency means that a programming language significantly reduces the load on the server. Only two respondents expressed an opinion in the text responses, suggesting question frameworks and using cleaner code without providing further comments or strategies.

3.3.10 Question 4.6: Carbon Offsetting

The purchase of CO_2 compensation was the least popular option. It placed behind programming languages and scored 2.2 on average. Only the largest companies favoured buying CO_2 compensation, with an average rating of 3.5, as shown in Figure 17. Due to their higher budgets, large companies presumably have more financial resources, and therefore this approval arises. This assumption was supported by the text responses of two participants from a small- and medium-sized company, respectively, who stated that budgets directly influence sustainable ways of working.

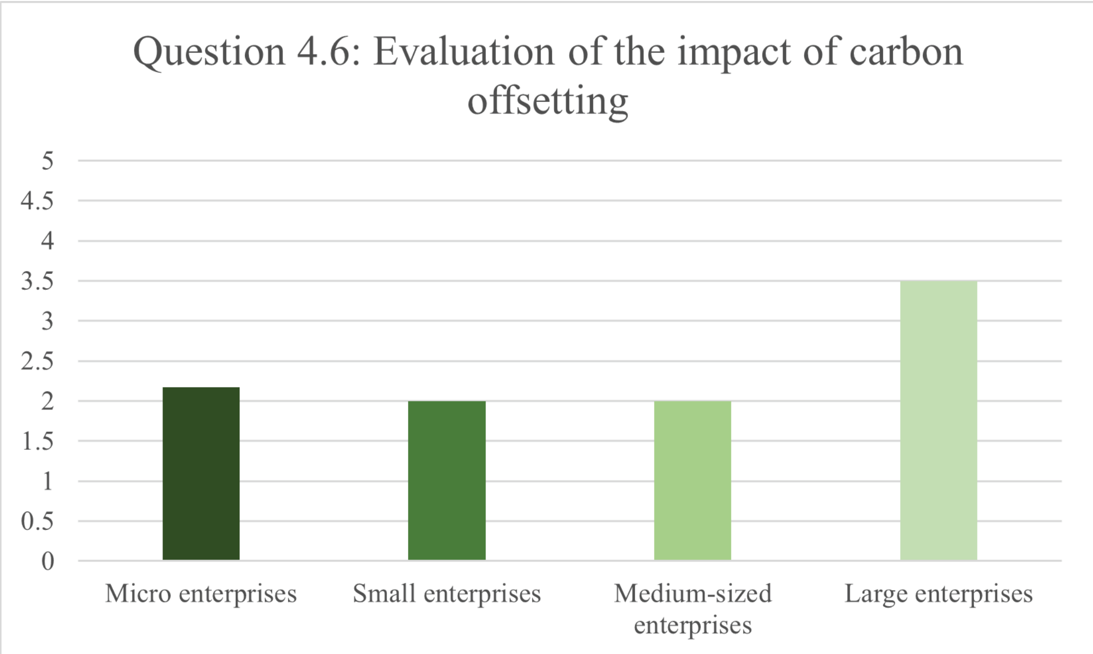

Figure 17 – Evaluation of CO_2 compensation as a strategy based on company size

The respondents from larger companies indicated in the text responses that buying CO_2 neutrality would only provide an additional mechanism, reducing the company's internal emissions needed prioritisation. The other responses were diverse. They ranged from indicating no knowledge of carbon offsetting to arguing that it should only be applied as a last step and that it should not be considered sustainable since it is important to first reduce their consumption and only then compensate.

3.3.11 Question 5: Green Methods

The final Likert scale question addressed the question of whether companies were using green methods. It aimed to provide evidence to confirm the hypotheses and research questions arrived at from survey question 1. On average, this question's answer rate was 2.36, which corresponds to indecisive disagreement.

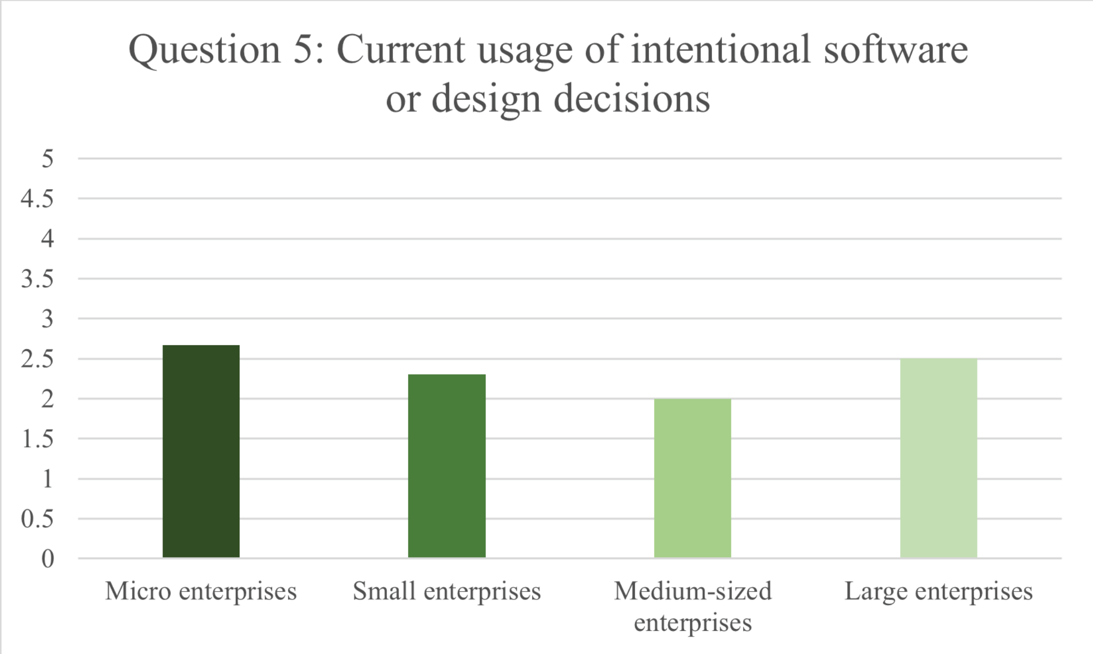

Figure 18 – Green strategies based on company size

In contrast to the first question, differences were noticeable. Micro-sized, medium-sized, and larger companies answered yes to survey question 1 and indicated an opposing attitude. A possible explanation for this discrepancy could be found in the questionnaire. While only yes and no answers were possible for the first question, the Likert scale question provided a more detailed evaluation, as shown in Figure 18.

Regarding the hypothesis, it can be concluded that companies previously emphasised environmentally friendly practices more, as the first question was rated more positively.

4. Strategies

As a result of the theoretical introduction and quantitative analysis, a general technical concept for the implementation of strategies is presented in the following chapter.

4.1 Sustainable Web Design and Web Standards

Since 2013, the median size of a mobile website has increased from 427 KB to 1,900 KB (Bleuer, 2021). Images, videos, and JavaScript were significantly involved in this expansion (Embling, 2019). Sustainable web design principles offer numerous advantages for the environment, as well as for performance and reputation (Ionos, 2022). Ionos (2022) further elaborated that sustainable websites load faster and are more user-friendly because of reduced resource consumption, slim code, and smaller data sizes due to less CSS and JavaScript and compressed images and videos. The resulting faster loading times and lower power consumption lead to more energy savings.

According to Schuster (2021), strategies for a sustainable web can be divided into three categories:

- Minimising a negative carbon footprint
- Maximising a positive footprint
- A combination of the two

4.1.1 Imagery

The survey respondents expressed mixed opinions on the performance of images in the context of sustainable web development. They agree that the reduction or compression of images impacts a website's performance. The average number of images on a web page is 30, with an approximate transfer size of 1 MB (HTTP Archive, 2022). Thus, the average website size is 2,299 KB. Images account for 43.5% of the front-end load and offer considerable potential for savings.

Image compression is a convenient way to save data size on a webpage. This process is referred to either as "lossless", in which the original content is preserved, such as with text or files, or as "lossy", in which the content remains recognisable, such as in the case of image or audio data (Dankmeier, 2001).

Web designers must choose the appropriate image format (Frick, 2016). Frick (2016) also observed that vector graphic formats such as SVG are independent of resolution, scale in dimensions and do not place any additional load on a website. Raster images, such as PNGs or JPGs, or even modern file formats, such as WebP or AVIF, are more suitable than vector graphics for displaying more complex images. WebP and AVIF are both compression formats designed to offer a smaller file size while maintaining quality (Broz, 2022). Greenwood (2021) stated that AVIF offers about 50% smaller files than WebP. Nevertheless, a WebP image is about 26% lighter than the same PNG image. Moreover, a lossy WebP picture is about 25–34% smaller than a JPG version of the same quality (Achilles.H, 2019).

Image compression by removing metadata is often underestimated, but it plays a crucial role in reducing file size. Hidden information (EXIF, IPTC, and XMP) can cause significant data volume in high-quality images (Keuthen, 2021). Keuthen (2021) further explained that almost 90% of a file's size can be saved by deleting metadata from a thumbnail.

Ultimately, the question arises about whether an image needs to be used because omitting an image is the most sustainable approach. Stock photos offer a significant opportunity to save resources, as they are not considered an added value.

4.1.2 Video Footage

The survey indicated that video had a moderate ranking for sustainability on the internet. However, four people stated in the text responses that videography is one of the largest contributors. According to the HTTP Archive (2022), the use of embedded videos on websites has increased significantly since 2015. If a site uses videos, the data transfer increases almost twenty-fold and currently averages 3.5MB (HTTP Archive, 2022). Researchers have stated that 80% of global data traffic consists of video data transmissions (The Shift Project, 2019). The German Federal Environment Agency (Umweltbundesamt) made the following conclusions in 2020 about streaming an HD video:

- The lowest CO_2 impact comes from a fibre optic connection, which on average, leads to only two grams of CO_2 emissions per hour of video streaming.
- A copper cable causes four grams of CO_2 to emit per hour.
- A 3G mobile connection results in 90 grams of CO_2 per hour.
- If data transmission is conducted with a 5G connection, about five grams of CO_2 are emitted per hour.

These calculations do not consider the power consumption of the user device, the rendering process, or the device and location where a video file is uploaded.

Whether videos are self-hosted or embedded via platforms such as Twitch, Vimeo or YouTube plays a subordinate role in sustainability (Schuster, 2021). Schuster (2021) explained that an important aspect of sustainability is to ensure that videos offer exceptional value and that videos are used in the most data-aware way possible. If no video is suitable, the content should be conveyed differently and, therefore, much more sustainably. The simplest approach is to avoid auto-play and background videos (Schuster, 2021). Schuster (2021) noted that video compression must also be

emphasised, and if a download option is available, the user can download the video and watch it several times offline without increasing the load on the server.
Offering transcripts has the advantage of making video content accessible to people who want to but cannot access it. This approach combines greater accessibility with lower environmental impact (Schuster, 2021).

4.1.3 Code

Less code means reduced data transfer and decreased computing power consumption. In 2022, Dziuba created an overview of the three most popular JavaScript web frameworks. Angular was the heaviest, with 143 KB. React followed with 97.5 KB, and Vue.js was the lightest, with only 58.8 KB (Dziuba, 2022). In terms of average website size (2,299 KB), Angular increased the load by 6.2%, React by 4.2%, and Vue by 2.5%. Therefore, a lightweight alternative is recommended if an application is not too large and does not contain sophisticated components. Not only do web frameworks impact a web application's sustainability, but programming language also influences the consistency of the entire website, including the server side.
Although the respondents did not see any relevance in the choice of programming language, a team of six Portuguese researchers showed that the energy efficiency of different programming languages varies significantly. A clear pattern could be identified, with compiled languages boasting the highest energy efficiency (Pereira et al., 2017). Figure 19 shows a direct comparison between all tested programming languages.
On the other hand, popular web programming languages, such as JavaScript or PHP, perform poorly (Greenwood, 2021). Greenwood (2021) found that, if the actual energy consumption is compared, JavaScript is far more efficient than TypeScript or PHP. JavaScript consumes 4.5 joules for an average task, but TypeScript requires 21.5 joules, and PHP consumes 29.3 joules for the same task. In other words, JavaScript consumes 80% less energy than TypeScript and 85% less power than PHP.

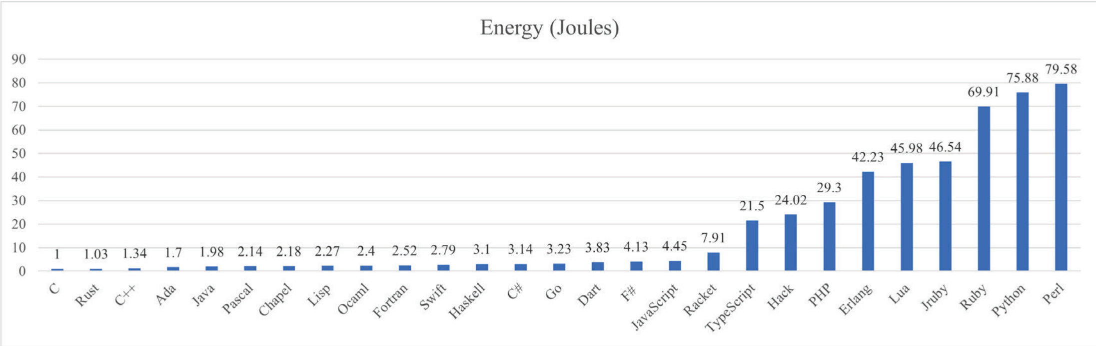

Figure 19 – Overview of programming language and its consumption. Adapted from "Energy Efficiency Across Programming Languages: How Do Energy, Time, and Memory Relate?" by R. Pereira, M. Couto, F. Ribeiro, J. Cunha, J. Fernandes, and J. Saraiva, 2017, in B. Combemale, M. Mernik, and B. Rumpe (Eds.), SLE '17: Proceedings of the 10th ACM SIGPLAN International Conference on Software Language Engineering, *p. 263, Association for Computing Machinery (https://doi.org/10.1145/3136014.3136031).*

JavaScript can be considered energy efficient when it processes algorithmic problems, but it should be used with caution. Often JavaScript solves more advanced problems, such as animations, in the front end, making the website less efficient. CSS can create animated effects with greater efficiency, as less load is placed on the CPU (Greenwood, 2021).

4.1.4 Colour Selection

The evaluation of the text-related questions indicated no predominant attitude towards the selection of colours, as none of the respondents expressed an opinion. Colour affects the energy consumption of a web page in several ways. It impacts the power usage of the user's screen and a website's file size. Designers use colours according to their individual preferences, not according to scientific findings (Issa & Isaias, 2022). Tung (2018) reported that, according to Google, a display is one of the greatest energy consumers, and darker colours on devices with OLED displays significantly reduce power consumption. Schuster (2021) claimed that bright colours consume more power in modern OLED displays than in older CRT monitors. A dark UI can also significantly reduce energy consumption on AMOLED displays (Calero et al., 2021), whereas each pixel of an OLED display is illuminated individually (Schuster, 2021). In contrast, LCD displays illuminate the entire display area in the background and dim it for dark colours (Greenwood, 2021). The amount of energy that OLED displays save depends on the device's settings (Schuster, 2021). Greenwood (2021) specified that black is the most sustainable colour for OLED screens, and blue consumes around 25% more power than green and red tones.

4.1.5 Font Type

Text on the web is the most common way of expressing content. Companies often use custom fonts to showcase their corporate identities. Depending on whether an API for a custom font is used, a font's data traffic can be reduced by different methods or even set to zero. System fonts are already pre-installed on devices; therefore, no data needs to be transferred. Accordingly, they represent the most sustainable option (Schuster, 2021). These fonts are unobtrusive, perform well, and provide a high degree of legibility. A standard font might be a disadvantage because it eliminates part of the branding. Furthermore, texts are displayed differently depending on the operating system and device.

In contrast to system fonts, custom fonts offer individualised styles. This approach can make a web page stand out visually; however, Schuster (2021) argued that web designers should question whether each font is easily readable and thus adds value for the user. Schuster (2021) elaborated that each typeface file can easily generate 200 KB of additional traffic, while this value is around 50–80 KB per file when using fonts from optimised web services (Adobe, Google, and Fonts.com). For an average website size of 2,299 KB, a single custom font generates up to 8.7% more loading time than a system font. Web font providers usually make the source font available through an API, meaning that the font must be loaded from an external data centre potentially located in another country (Greenwood, 2021).

Greenwood (2021) stated that a combination of system fonts and custom fonts is a practical alternative to web fonts and that custom fonts can also be loaded as variable fonts. Variable fonts are designed to support the precise scaling of thickness and tilt, allowing infinite variations of a single font to be rendered from a single font file (Greenwood, 2021).

4.1.6 Green Hosting

Referring to the quantitative survey, a green hosting service is an important step in minimising a negative footprint in terms of GHG emissions. The web consists of an almost inconceivably complex network of the most diverse components, all of which require electricity. Combatting climate change has not merely been undertaken by governments. According to Adams (2021), companies are also changing their behaviour. In particular, the largest technology companies, such as Google, Microsoft, and Amazon, which also offer hosting options, have addressed the environmental impact of their IT and hosting activities. Google claims to be the first company of its

size to run on 100% renewable energy (Adams, 2021). Meanwhile, Microsoft set 2030 as its target for becoming carbon neutral, and Amazon set it at 2040 (Adams, 2021).
In Europe, a wide range of hosting providers already run their data centres with green power. When data is stored on a green host, the climate-neutral footprint per page is reduced significantly (Schuster, 2021). Nevertheless, Schuster (2021) warned that the quality of the electricity varies enormously – from 100% hydroelectric power to carbon offsetting.
Data centres, which can also operate as webhosting services, are expected to improve their power intensity in the near future (Andrae & Elder, 2015). Andrae and Elder (2015) indicated that this factor seems sufficient for coping with the annual growth rate of around 25% for total traffic in data centres. According to Andrae and Elder (2015), data centres will consume about 3%–13% of the world's electricity by 2030, compared to 1.5% in 2010. The trend towards renewable energy use is growing, and it is likely that many efficient data hosts can expand, especially because the expected electrical demand in connection with hosting providers will increase dramatically in the next years, as Figure 20 indicates.

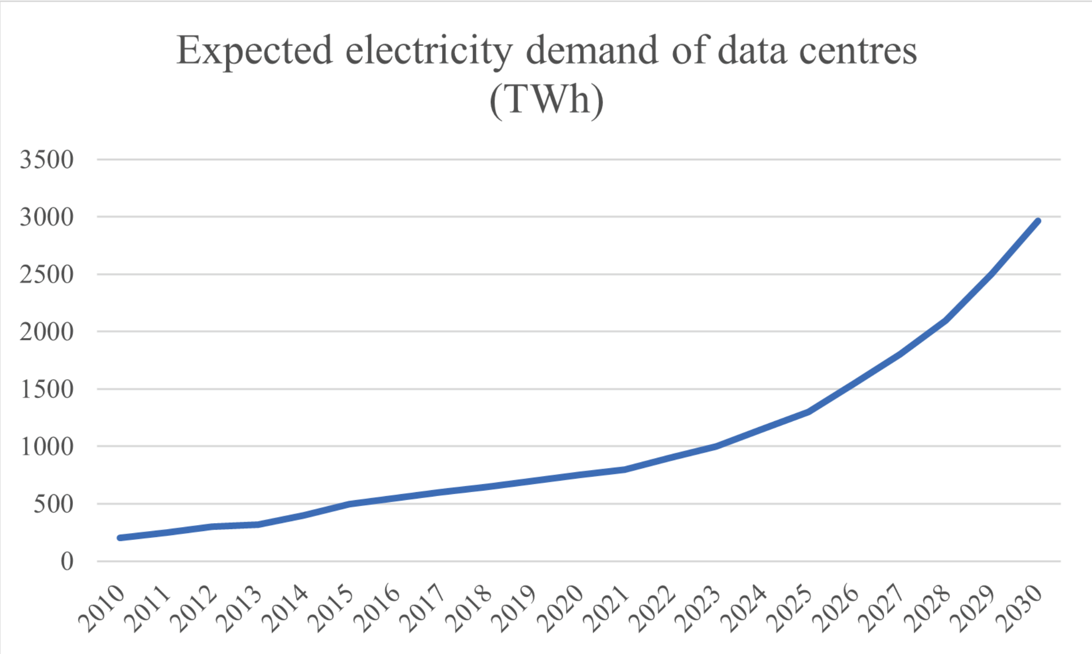

Figure 20 – Expected electricity demand of data centres (TWh). Adapted from "On Global Electricity Usage of Communication Technology: Trends to 2030," A. S. Andrae and T. Elder, 2015, Challenges, 6(1), p. 133 (https://doi.org/10.3390/challe6010117).

The survey and the optional text responses showed that data centres and hosting providers are the main causes of a non-renewable internet. Therefore, the selection of an adequate provider using green sources is an important step in minimising GHG emissions. Schuster (2021) explained that reducing the distance that traffic travels from the data centre to the end device minimises the amount of electricity required and results in faster loading times. For example, if a website's primary target group is located in Europe, a green hosting provider in central Europe should be chosen.

4.1.7 Customer Requests

The survey shows that customer expectations do not have high priority. One respondent specifically stated that customers and budgets are correlated and account for the greatest negative influence on sustainability on the web. The survey confirmed Greenwood's (2021) findings that sustainability is not addressed in customer meetings. Greenwood (2021) also observed that awareness of the concept of sustainability is weak, as individuals engaged in sustainability do not prioritise it. He concluded that the idea of web services being more sustainable resonates, but that low cost and aesthetics take precedence (Greenwood, 2021).

In principle, customer requests do not represent a strategy; nonetheless, they can be classified as a methodology. Customer and user influence is not pronounced, but it can create a framework in which previous strategies can be applied without significant sacrifices. While the product remains the same, the implementation is designed using a sustainable approach, resulting in improved performance and shorter loading times.

4.1.8 Carbon Offset

Carbon offsetting, or greenwashing, is a term used to describe when a company invests more time in advertising its environmental benefits than implementing practices with an actual impact (Frick, 2016). Greenwood (2021) listed five ways to purchase carbon neutrality.

- **In-house renewable energy**: The energy is generated locally and transferred to the same energy grid. This option is best because the web host provides the power supply directly.
- **Financing renewable energy**: Power purchase agreements are concluded with energy companies that prefinance the development of renewable energy sources.
- **Purchasing renewable energy**: The customer purchases sustainable energy sources in the same energy network.
- **Purchasing certificates**: Renewable energy suppliers in more cost-effective countries receive funds to build renewable energy. The financier usually does not profit from this energy.

- **CO_2 Offsetting**: CO_2 offsets corresponding to emission volumes are purchased. The problem is that only offsets are established, and the output remains unsustainable.

5. Conclusion

This bachelor's thesis examines the sustainability of the modern web development according to environmental and social principles.

From the study's results it can be concluded that companies are generally aware of sustainable web development's existence. However, companies do not apply strategies for various reasons, such as the budgetary constraints or customer requirements. As expected, data centres were considered the greatest potential contributor to the goal of an emission-free web. Companies have applied sustainability strategies differently; various approaches exist depending on the size of the firm. In addition to data centres, the main source of an unsustainable system, green hosting is considered an important strategy. Enterprises are aware of the strategies and methods for achieving a green web but do not apply them (yet) in their projects.

The results showed that large companies focus on neutralizing their CO_2 footprint primarily through sustainable practices and further through offsets – whereby offsets are only applied if internal emissions have been reduced. In the survey, large enterprises scored 3.5 points compared to other companies that scored a negative value of 2, in terms of CO_2 offsetting. Green web hosting is a valuable strategy for micro businesses, as they scored 4.33, while small businesses scored 3.1, and large businesses scored 4. Medium-sized businesses, with a score of 2, did not consider green web hosting relevant. Nonetheless, with a general score of 2.36, the respondents indicated that no green strategies are currently applied in projects. A more specific analysis would have to be performed in this case. In this context, an additional analysis could be made regarding gender and age. In addition, the influence of user devices or "product lifecycle emissions" versus sustainable web development, are topics that cannot be elicited from this thesis and could be explored in more detail in future papers on the subject.

Quantitative research and theoretical concepts showed an overall awareness of sustainability on the web and strategies. The study indicated what can positively influence a sustainable web. Methods such as image and video optimisation, programming languages, colour and font selection, and optimisation approaches related to data centres, hosting, and carbon offsetting were examined. In the differentiated text responses, a potential solution for managing images and videos was mentioned, however, it was described to be impractical due to time and cost constraints. In some cases, respondents mentioned choice of font and programming language, both of which are strategies explored in this work and are considered to be positive contributors to sustainable web development. However, in contrast to research, neither of these aspects play a significant role in the view of respondents. This leads to a general undecided opinion of 2.88 Likert points for UI/UX. Data centres and green web hosting, in contrast, were considered more important factors for sustainable web development in the quantitative survey. Respondents agreed with 3.88 and 3.5 respectively. In general, greenwashing was not popular as a strategy among most respondents. On average, people expressed a negative opinion with only 2.2 Likert points.

Climate change will increasingly affect life on Earth in the coming years, and the internet will continue to inescapably impact humanity. Sustainable web development is achievable. The adoption of sustainable strategies and methods is not only a disadvantage but will become a necessity. Targeted strategies and principles can be applied to make a web project clearer in its design and development process. This results in fewer emissions, thereby slowing the advancement of climate change, as well as a better performing project.

6. References

Achilles.H. (2019, November 22). *Image formats comparison - WebP vs JPG vs PNG*. Shareus. https://www.shareus.com/windows/image-formats-comparison-webp-vs-jpg-vs-png.html

Adams, H. (2021, July 20). Google, Amazon, Microsoft, the Cloud - and cutting carbon. *Sustainability*. https://sustainabilitymag.com/sustainability/google-amazon-microsoft-cloud-and-cutting-carbon

Andrae, A. S., & Elder, T. (2015). On global electricity usage of communication technology: Trends to 2030. *Challenges*, *6*(1), 117–157. https://doi.org/10.3390/challe6010117

Bleuer, M. (2021, May 23). Wie das web nachhaltiger werden kann. *Netzwoche*. https://www.netzwoche.ch/news/2021-05-23/wie-das-web-nachhaltiger-werden-kann

Borini, R., & Widmer, P. (2022, June 8). Web3 – die zukunft des internets. *10x10*. https://www.10x10.ch/web3-die-zukunft-des-internets/

Broz, M. (2022, October 21). *Image format comparison (JPEG, PNG, WEBP, & AVIF) – 2023 statistics*. Photutorial. https://photutorial.com/image-format-comparison-statistics/

Brux, O. (2019, July 26). *Nachhaltiges Webdesign - Was ist das eigentlich?* https://oliverbrux.de/blog/nachhaltiges-webdesign-was-ist-das

Bundesamt für Statistik. (2022, August 25). *Kleine und mittlere Unternehmen*. https://www.bfs.admin.ch/bfs/de/home/statistiken/industrie-dienstleistungen/unternehmen-beschaeftigte/wirtschaftsstruktur-unternehmen/kmu.html

Calero, C., Moraga, M., & Piattini, M. (2021). *Software sustainability*. Springer Nature Switzerland.

Collins. (n.d.). Sustainability. In *Collins English dictionary*. Retrieved November 21, 2022, from https://www.collinsdictionary.com/dictionary/english/sustainability

Dankmeier, W. (2001). Datenkompression. In W. Dankmeier (Ed.), *Codierung* (2nd ed.). Professional computing. (pp. 313–364). Vieweg+Teubner Verlag.

Dziuba, A. (2022, November 22). *Angular vs. React vs. Vue.js – Choosing a JavaScript framework for your project in 2023*. Relevant.

https://relevant.software/blog/angular-vs-react-vs-vue-js-choosing-a-javascript-framework-for-your-project/

Ejeke, P. (2022). *Web 3.0 – What is Web3?* Amazon Kindle Direct Publishing.

Embling, J. (2019, April 15). *Are images ruining your website experience?* Essential. https://www.theessential.agency/blog/are-images-ruining-your-website-experience

Erek, K., Schmidt, N.-H., Zarnekow, R., & Kolbe, L. (2009, August 6–9). *Sustainability in information systems: Assortment of current practices in IS organizations* [Conference presentation]. Proceedings of the Fifteenth Americas Conference on Information Systems, San Francisco, CA, United States. https://www.researchgate.net/publication/220893702_Sustainability_in_Information_Systems_Assortment_of_Current_Practices_in_IS_Organizations#read

Europäische Kommission. (n.d.a). *Ganzheitlicher EU-Ansatz für nachhaltige Entwicklung.* Retrieved November 23, 2022, from https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals/eu-holistic-approach-sustainable-development_de

Europäische Kommission. (n.d.b). *Klima- und energiepolitischer Rahmen bis 2030*. Retrieved November 30, 2022, from https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2030-climate-energy-framework_de

Fonial. (n.d.). *Geschichte des internets*. Retrieved November 28, 2022, from https://www.fonial.de/wissen/begriff/geschichte-des-internets/

Frick, T. (2016). *Designing for sustainability*. O'Reilly Media.

Fuchs Media Solutions (Ed.). (n.d.). *Web 2.0 begriffserklärung und definition.* SEO-Analyse. Retrieved October 15, 2022, from https://www.seo-analyse.com/seo-lexikon/w/web-2-0/

Greenpeace. (2017, January 17). *Clicking clean*. https://www.greenpeace.org/international/publication/6826/clicking-clean-2017/

Greenwood, T. (2021). *Nachhaltiges Webdesign*. conopolist Verlag.

Großkortenhaus, M. (2020). Eine kurze geschichte des internets. *HubSpot*. https://blog.hubspot.de/marketing/geschichte-des-internets

Hall, H. (2022, November 30). *Web 2.0 explained: Everything you need to know*. History Computer. https://history-computer.com/web-2-0/

Halsey, M. (2022). *The green IT guide: Ten steps toward sustainable and carbon neutral IT infrastructure*. Springer Science+Business Media New York.

HTTP Archive. (2022, October 1). *Page weight*. https://httparchive.org/reports/page-weight

Indigo, J., & Smart, D. (2022, October 13). *Part IV Chapter 21: Page weight*. Web Almanac. https://almanac.httparchive.org/en/2022/page-weight

Ionos. (2022, March 16). *Nachhaltiges Webdesign: Green Webdesign erklärt*. https://www.ionos.de/digitalguide/websites/webdesign/nachhaltiges-webdesign/

Issa, T., & Isaias, P. (2022). *Sustainable design.* Springer-Verlag London.

Jones, N. (2018, September 13). How to stop data centres from gobbling up the world’s electricity. *Nature*. https://www.nature.com/articles/d41586-018-06610-y

Kenton, W. (2020, November 27). *Quantitative analysis (QA): What It is, how it’s used in finance*. Investopedia. https://www.investopedia.com/terms/q/quantitativeanalysis.asp

Keuthen, K. (2021, April 1). *Bildkomprimierung durch entfernen der metadaten EXIF, IPTC und XMP*. MSR Support. https://www.msr-support.de/bildkomprimierung-durch-entfernen-von-metadaten/

Klatt, R. (2021, October 4). Internet und computer klimaschädlicher als flugverkehr. *Forschung und Wissen*. https://www.forschung-und-wissen.de/nachrichten/umwelt/internet-und-computer-klimaschaedlicher-als-flugverkehr-13375404

McLeod, D. S. (2019, August 3). *Likert scale definition, examples and analysis*. Simply Psychology. https://www.simplypsychology.org/likert-scale.html

Pereira, R., Couto, M., Ribeiro, F., Cunha, J., Fernandes, J., & Saraiva, J. (2017). Energy efficiency across programming languages: How do energy, time, and memory relate? In B. Combemale, M. Mernik, & B. Rumpe (Eds.), *SLE ’17: Proceedings of the 10th ACM SIGPLAN International Conference on Software Language Engineering* (pp. 256–267). Association for Computing Machinery. https://doi.org/10.1145/3136014.3136031

Polyas. (n.d.). *Web 2.0*. Retrieved November 28, 2022, from https://www.polyas.de/wahllexikon/web20

Relevanzmacher Team. (2022, March 8). *Gemeinsame sprache im Web 3.0*. Relevanzmacher. https://relevanzmacher.de/ki/web-3-0/

Schmidt, S. (n.d.). *Grüne webentwicklung*. it bienen web solutions. Retrieved November 24, 2022, from https://www.it-bienen.de/gruene-webentwicklung/

Schuster, G. (2021, November). *18 methoden helfen euch dabei*. https://nachhaltiges-webdesign.jetzt/

Stuck, N. (2019, May 14). *Web 3.0 – Die zukunft des internets in 5 punkten erklärt!* Wolf of SEO. https://wolf-of-seo.de/was-ist/web-3-0/

Teague, J. (2022, July 2). *Part IV Chapter 19: Page weight*. Web Almanac. https://almanac.httparchive.org/en/2021/page-weight

Terra, J. (2022, December 26). *What is Web 1.0, 2.0, and 3.0? Definitions, differences & similarities*. Simplilearn. https://www.simplilearn.com/what-is-web-1-0-web-2-0-and-web-3-0-with-their-difference-article

The Shift Project. (2019, July). *Climate crisis: The unsustainable use of online video*. https://theshiftproject.org/wp-content/uploads/2019/07/Excutive-Summary_EN_The-unsustainable-use-of-online-video.pdf

Tung, L. (2018, November 9). Google: Here's why dark mode massively extends your OLED phone's battery life. *ZDNET*. https://www.zdnet.com/article/google-heres-why-dark-mode-massively-extends-your-oled-phones-battery-life/

Umweltbundesamt. (2020, November 10). *Video-Streaming: Art der datenübertragung entscheidend für klimabilanz*. https://www.umweltbundesamt.de/presse/pressemitteilungen/video-streaming-art-der-datenuebertragung

Wächter, M. (2022, May 6). *Nachhaltige webentwicklung*. Factorial. https://www.factorial.io/de/blog/nachhaltige-webentwicklung

Warzecha, M. (2022, December 1). *Offene & geschlossene fragen: Vergleich, unterschied*. Empirio. https://www.empirio.de/empiriowissen/offene-geschlossene-fragen

Webdesign-Podcast.de. (2012, March 6). *Woher stammt der Begriff Web 2.0*. https://www.webdesign-podcast.de/2012/03/06/woher-stammt-der-begriff-web-2-0/

Witt, H. (2001). Forschungsstrategien bei quantitativer und qualitativer Sozialforschung. *Forum Qualitative Sozialforschung*, *2*(1), Article 8. http://nbn-resolving.de/urn:nbn:de:0114-fqs010189

7. Appendix

7.1 Research Questions and Hypotheses

In the bachelor thesis the author identifies how sustainable web applications can be developed considering environmental, social, and sustainable principles. The following **research questions** arise:

1. How sustainable is the internet in terms of GHG?
2. How do agencies perceive the internet in terms of emissions?
3. What strategies can be implemented in a web project to make the internet greener?
4. What influence do data centres have on CO_2 emissions?
5. What factors other than data centres cause CO_2 emissions in the WWW?
6. What influence do customers have in relation to the green web?

In relation to the research questions, the author intends to provide insights into the following **hypotheses**:

1. Strategies for sustainable web development are applied differently in larger and smaller agencies.
    - Smaller agencies focus more on sustainable approaches due to limited budgets.
    - Larger companies are increasingly adopting greenwashing, due to significant resources.
2. Green web hosting is perceived differently by larger and smaller companies.
3. Agencies are generally interested in sustainability, but neither specifically in a green internet nor in sustainable web development.

7.2 Survey Questions

The survey questions set the basis for polling the companies, agencies, and freelancers to answer the hypotheses and research questions. The survey was accessible under https://www.severinglaser.com and was activated in the period from 24.11.2022 to 12.12.2022.

- **Question 1**: Has your company dealt with sustainability in web projects - in terms of emissions or energy consumption?

- **Question 2**: Does a web application (e.g. Jira, Notion, Miro, etc.) provide more sustainability than traditional methods - is less energy consumed than if e.g. notepad, sketches on paper, calendar notebook, etc. would be used?
- **Question 3**: Does your company use CO_2 neutral web hosting for web projects?
- **Question 4**: On a scale of 1-5 (1= no agreement, 5= full agreement), rate the influence of the following technologies/factors - according to your feeling - on energy consumption and emissions. Move the circular slider to adjust your value.
    - **Question 4.1**: Web hosting
    - **Question 4.2**: Data centres
    - **Question 4.3**: Customer requirements
    - **Question 4.4**: UI/UX (images, video, colour, font)
    - **Question 4.5**: Programming language (JavaScript, PHP, Python etc.)
    - **Question 4.6**: Buying CO_2 compensation («carbon-offsetting»)
- **Question 5**: Does your company use «green methods» (e.g. intentional software or design decisions) for web projects - regardless of the available budget? Move the circular slider to adjust your value. (1= no agreement, 5= full agreement)
- **Question 6 (open text answers)**:
    - **Question 6.1**: What strategies would you recommend to create sustainable web applications?
    - **Question 6.2**: Which factors or people have the greatest negative influence on sustainability on the web? Explain the reasons for your choice.
    - **Question 6.3**: From your point of view, is the internet sustainable in terms of emissions?
    - **Question 6.4**: Describe your position on «carbon-offsetting» as a method for sustainability?

7.3 Text Answers

The text responses are voluntary responses from the participants, in which they can specify their opinion on the given Yes/No and Likert questions. Based on these responses, conclusions can be drawn, and statements can be reinforced. An overview of the anonymous replies can be seen in the table below. The text responses are original excerpts, meaning they have neither been translated, nor checked for spelling errors, nor reviewed for accuracy. If no information on the person or answer was provided, the indicator n/a is used.

Age: 43, **Gender**: male, **Job**: other, **Company size**: > 250
Question 6.1: emissionsfreies Hosting- einfach verständliche UX, mit wenigen Klicks zur Lösung- Dark Mode
Question 6.2: Kunde/Auftraggeber: Budget- Designer: Anspruch an das Design
Question 6.3: nein, davon sind wir noch weit entfernt
Question 6.4: ist OK und nötig, wenn es keine alternative Lösung für eine bestimmte Anforderung gibt- darf aber nicht als "Erlaubnis" für die Anwendung klimaschädlicher Anwendungen/Methoden eingesetzt werden.

Age: n/a, **Gender**: n/a, **Job**: n/a, **Company size**: n/a
Question 6.1: Möglichst effizienten Stack auswählen, der für die Aufgabe geeignet istFrameworks hinterfragen und nur optimiert einsetzenAutoplay-Video weglassenBilder reduziert, in angemessner Größe, gut komprimiert und in modernen Formaten einsetzen
Question 6.2: Webdesigner ohne Blick auf DatenmengeWebentwickler ohne Kenntnis von green software developmentWebsite-Betreibende, die allen möglichen Trends hinterherlaufen.
Question 6.3: nein, nicht per se
Question 6.4: nur als letzter Schritt vernünfitg, wenn die damit finanzierten Projekte tatsächlich einen Effekt haben, nicht nur rechnerisch.DAVOR muss der CO2-Ausstoß deutlich reduziert werden!

Age: 40, **Gender**: female, **Job**: other, **Company size**: < 50
Question 6.1: reduzieren auf das Nötige
Question 6.2: Videos, v. a. Autoplay
Question 6.3: nee
Question 6.4: naja, nicht ganz nachhaltige Lösung

Age: 45, **Gender**: male, **Job**: other, **Company size**: < 50
Question 6.1: n/a

Question 6.2: Vermutlich sind das die Datenzentren. Ohne geht aber auch nicht. Alternativen sind momentan keine in Sicht.
Question 6.3: Nein. Da lässt sich bestimmt mehr machen. Wichtig dabei ist Transparenz über die ganze Wertschöpfungskette.
Question 6.4: n/a

Age: 44, **Gender**: female, **Job**: designer, **Company size**: < 10
Question 6.1: Gute Kommunikation zwischen Designerin und Entwicklerin. Beratung der Auftraggeberinnen, die häufig nicht wissen, dass man daruf Einfluss nehmen kann. Fortbildungen für Designerinnen und Entwicklerinnen.
Question 6.2: Know how kann Nachhaltigkeit im Web meiner Meinung nach am stärksten beeinflussen. Wenn bewusst gestaltet, entwickelt und der Hoster bewusst ausgewählt wird, trägt das positiv bei. Negativ auf die Nachhaltigkeit sind sicherlich Geld/Budgets und Zeit, die oft nicht da sind, um einen Fokus darauf zu legen, Menschen zu bezahlen, die sich damit auskennen und Auftraggeberinnen, die Zeit haben, Datengrößen/Bilder etc. anzupassen.
Question 6.3: nein.
Question 6.4: ? Hier fehlt mir das Wissen, um etwas dazu sagen zu können.

Age: 26, **Gender**: male, **Job**: other, **Company size**: < 50
Question 6.1: Hosting mit möglichst tiefen Emissionen, z.B. mithilfe von serverless Architektur
Question 6.2: Social Media & Streamingplattformen, da diese riesige Datenzentren benötigen, die die Daten speichern und verarbeiten
Question 6.3: Nein
Question 6.4: Finde ich einerseits eine gute Sache, andererseits heuchlerisch. Die Schadstoffe werden ja trotzdem emittiert, die Kompensation lässt diese nicht verschwinden. Aber natürlich trotzdem besser als nichts zu machen.

Age: 32, **Gender**: male, **Job**: other, **Company size**: < 50
Question 6.1: n/a
Question 6.2: n/a
Question 6.3: Ja

Question 6.4: n/a

Age: 25, **Gender**: male, **Job**: coder, **Company size**: < 50
Question 6.1: n/a
Question 6.2: n/a
Question 6.3: propably not in the longterm, depending in which direction the world of technology goes
Question 6.4: n/a

Age: n/a, **Gender**: n/a, **Job**: n/a, **Company size**: n/a
Question 6.1: Die Ersparnisse bei individuellen Personen ist wichtiger.
Question 6.2: n/a
Question 6.3: Ja, weil Informationen gespeichert werden können, welche früher nur mit Büchern oder anderen Mittel gespeichert werden konnten.
Question 6.4: n/a

Age: 43, **Gender**: male, **Job**: other, **Company size**: > 250
Question 6.1: Eigenen Stromverbrauch ermitteln und reduzieren
Question 6.2: Effiziente LogistikVerkauf von qualitativen hochwertigen Artikeln, die lange halten
Question 6.3: ja
Question 6.4: n/a

Age: 47, **Gender**: female, **Job**: designer, **Company size**: < 10
Question 6.1: Keine Videos, kleine Bilder im richtigen Format abgespeichert, Systemfonts, schlanker Code (Wordpress-Templates sind meist per default gross), einfache Userführung, Green Hosting, Dark Mode.
Question 6.2: • Bärenanteil: Videos streamen (Youtube, Netflix, TikTok etc.)• Hosting bei nicht-grünen Providern • Grosse Websites (mehrere MB), die oft und lange genutzt werden.
Question 6.3: Nein. Da müsste man aber genau definieren, was nachhaltig in diesem Zusammenhang bedeutet. Das ist ja ein sehr weiter Begriff.

Question 6.4: Ich würde dies nicht per se als Nchhaltig bezeichnen. Es gilt immer, zuerst zu reduzieren und erst dann zu kompensieren. Leider wird das Kompensieren – da es natürlich einfacher ist als das Reduzieren – von vielen Firmen als nachhaltig bezeichnet, was Greenwashing ist. Kompensatuin kann kurzfristig gemacht werden, bist eine bessere Lösung (Reduzieren) umgesetzt werden lann, sollte jedoch keine langfristige Praxis sein.

Age: 34, **Gender**: male, **Job**: designer, **Company size**: < 10
Question 6.1: n/a
Question 6.2: n/a
Question 6.3: Nein
Question 6.4: n/a

Age: n/a, **Gender**: n/a, **Job**: n/a, **Company size**: n/a
Question 6.1: gute UX für zielgerichtete Userführung; sauberer Code für schnelle Ladezeiten; Datensparsamkeit; mit grüner Energie betriebene Datencenter bei Hostingprovider
Question 6.2: Steaming von Videoinhalten, da dies sehr viel Energie benötigt und wohl die wenigsten Rechenzentren mit nachhaltigem Strom betrieben werden
Question 6.3: "Das Internet" kann man wohl kaum so generell betrachten. Aber ich vermute, es ist deutlich weniger nachhaltig, wie es viele Player in Ihrer Kommunikation propagieren. Dennoch gibt es vorbildliche Pioniere wie zum Beispiel Ecosia.
Question 6.4: Dies sollte lediglich für unvermeidbare Emissionen eine Lösung sein und nicht als Methode für Nachhaltigkeit angesehen werden.