Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Dept. of Information Security and Communication Technology

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Calculating the Carbon Footprint of Digital Services: Toward User Awareness

Master's thesis in Communication Technology and Digital Science
Supervisor: Katrien De Moor
June 2023

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Student: Ørbæk, Anne Seline Jensvold

Problem description:

The environmental challenge we face today is a crucial issue that needs to be addressed immediately. There is a natural cycle of Carbon Dioxide (CO_2) in the atmosphere, and the demand for natural resources, such as oil, is bigger than what the earth can supply. This forces governments to search for the resource underneath the earth's surface, adding CO_2 to the natural carbon cycle, increasing the overall amount of CO_2 in the atmosphere. The term *carbon footprint* has no official definition but is commonly known as the *calculation of how much CO_2 or Greenhouse Gases ($GHGs$) are emitted by human production and consumption.* These emissions have been proven to be the leading cause for *global warming.* The latter term is commonly associated with one of the consequences of the increased level of carbon in the atmosphere, which is leading to higher surface temperatures and other catastrophic natural disasters. However, it is unclear which human activities have the largest impact on the rising levels of CO_2. Previous reports state that some of the human-made $GHGs$ originate from the aviation industry, transportation sector, and deforestation. However, recent reports revealed that the Information and Communication Technology (ICT) sector has a bigger impact on emissions than most are aware of today. While digitization is said to help overcome global warming, the current reports suggest that the ICT sector is also worsening it, thereby making it a paradox. The same reports suggest that different measures can be made to lower an individual's digital footprint, but people can't change their digital habits if they are unaware of the problem.

This project aims to get a better general overview of the negative and positive impacts the ICT sector has on the environment based on previous literature. More specifically, this project will look into digital services commonly used in everyday life (for example, video conferencing, video streaming, and cloud-based storage). To this end, the project aims to investigate what parameters recent reports and available calculators use today to calculate the current impact, as well as their reliability and consistency. In order to map the current user awareness associated with this digital carbon footprint, user studies of digital users will be conducted and analyzed. This will give an insight into how strategies to reduce this impact that can be developed and implemented.

Approved on:	2023-03-22
Main supervisor:	De Moor, Katrien, NTNU
Co-supervisor:	De Moor, Katrien, NTNU

Abstract

In today's society, buzzwords such as the Internet of Things (IoT), cloud computing, Artificial Intelligence (AI), and Virtual Reality (VR) are increasingly prevalent, reflecting the ongoing technological revolution worldwide. While digitalization has gained significant recognition for its positive contributions to social interaction, increased efficiency in multiple sectors, and efforts to combat the climate crisis, it is imperative to address the drawbacks it entails. Recent reports have brought attention to the escalating greenhouse gas emissions resulting from the energy consumption of digital services. This thesis seeks to investigate the methodologies employed in calculating these emissions and explore the level of awareness among digital users regarding this environmental impact. To achieve this, the thesis presents a comprehensive literature study reviewing previous research and assessing existing calculators to explore the quantification models of the digital impact. Additionally, empirical research methods are employed, including a quantitative survey targeting digital users aged 18 and above and qualitative focus group sessions involving children aged 10 to 13.

The findings from the literature study highlight the significant challenges associated with accurately quantifying the emissions from digital services. The absence of a standardized methodology for such calculations undermines the comparability of different sources, given the lack of consistency in reported figures. This lack of standardization is further reflected in the variations observed among calculators, which utilize disparate data sources and consequently yield divergent estimations. Consequently, the credibility of these estimations is compromised, limiting their reliability and hindering comprehensive assessments of the environmental impact of digital services.

The empirical user studies reveal that while digital users generally lack knowledge about the environmental impact of digital technology, they demonstrate an interest in changing their digital habits to reduce their environmental footprint. However, the study also identifies various barriers that hinder behavioral changes, including a lack of knowledge, a sense of powerlessness in making a difference, and that digitalization has transformed into a means of social interaction. Notably, the qualitative focus group sessions with children reveal that they exhibit a greater willingness to change their habits compared to adults, as their digital habits are less deeply ingrained in their lives.

This master thesis provides valuable insights into the methodologies used to quantify the environmental impact of digital services and sheds light on the level of awareness among a sample of 242 digital users. The findings underscore the need for standardized approaches in emissions calculations and emphasize the importance of addressing barriers to behavioral change. Ultimately, this research contributes to a better understanding of the environmental implications of digitalization.

Sammendrag

I dagens samfunn er buzzwords som Internet of Things (IoT), skytjenester, Artificial Intelligence (AI) og Viritual Reality (VR) stadig mer utbredt, noe som gjenspeiler den pågående teknologiske revolusjonen på verdensbasis. Selv om digitaliseringen har fått betydelig anerkjennelse for sine positive bidrag til sosial interaksjon, effektivitet i flere sektorer og innsatsen for å bekjempe klimakrisen, er det nødvendig å adressere de ulemper den medfører. Nylige rapporter har rettet oppmerksomheten mot økende utslipp av drivhusgasser som følge av energiforbruket til digitale tjenester. Denne avhandlingen tar sikte på å undersøke metodene som brukes for å beregne disse utslippene og utforske nivået av bevissthet blant digitale brukere angående denne miljøpåvirkningen. For å oppnå dette presenterer avhandlingen en omfattende litteraturstudie som gjennomgår tidligere forskning og vurderer eksisterende kalkulatorer for å utforske beregningene av den digitale påvirkningen. I tillegg benyttes empiriske forskningsmetoder, inkludert en kvantitativ undersøkelse rettet mot digitale brukere over 18 år og kvalitative fokusgruppesesjoner med barn i alderen 10 til 13 år.

Resultatene fra litteraturstudien fremhever de betydelige utfordringene forbundet med nøyaktig kvantifisering av utslippene fra digitale tjenester. Mangelen på standardiserte metoder for slike beregninger undergraver sammenlignbarheten mellom ulike kilder, gitt mangelen på konsistens i rapporterte tall. Denne mangelen på standardisering gjenspeiles også i variasjonene som observeres blant kalkulatorer, som bruker ulike datakilder og dermed gir forskjellige estimater. Konsekvensen av dette er at troverdigheten til disse estimatene kompromitteres, noe som begrenser påliteligheten deres og hindrer omfattende vurderinger av miljøpåvirkningen fra digitale tjenester.

De empiriske brukerstudiene avslører at selv om digitale brukere generelt sett mangler kunnskap om miljøpåvirkningen fra digital teknologi, viser de interesse for å endre digitale vaner for å redusere sin miljøavtrykk. Imidlertid identifiserer studien også ulike barrierer som hindrer atferdsendringer, inkludert mangel på kunnskap, en følelse av maktesløshet når det gjelder å utgjøre en forskjell og det faktum at digitalisering har blitt en måte å sosialisere seg på. Bemerkelsesverdig viser de kvalitative fokusgruppesesjonene med barn at de er mer villige til å endre vaner sammenlignet med voksne, siden deres digitale vaner er mindre rotfestet i livene deres.

Denne masteroppgaven gir verdifulle innsikter i metodene som brukes til å kvantifisere miljøpåvirkningen av digitale tjenester og belyser bevissthetsnivået blant et utvalg på 242 digitale brukere. Resultatene understreker behovet for standardiserte tilnærminger i utslippsberegninger og legger vekt på betydningen av å adressere barrierer for atferdsendring. På lang sikt bidrar denne forskningen til en bedre forståelse av miljøkonsekvensene av digitalisering.

Preface

This thesis concludes my Master of Science in Communiaction Technology and Digital Security (MTKOM) at the Norwegian University of Science and Technology (NTNU). The topic selection was performed at the end of my 4th year of study and was selected from a list of proposed thesis projects and was suggested by Katrien De Moor. The supervisor for this thesis has been Associate Professor Katrien De Moor from the Department of Information Security and Communication Technology (IIK) at NTNU.

This work builds upon a preliminary project conducted during the fall semester of 2022, ultimately culminating in the writing of this thesis during the spring of 2023 with guidance from my supervisor, Katrien De Moor. I am grateful for her remarkable dedication and support throughout both semesters. Prior familiarity with the subject matter is not necessary, as all the essential background and contextual information are provided. Nonetheless, a general interest in environmental issues and digital habits can be advantageous for readers.

I hope you will enjoy reading this thesis.

Trondheim, June 2023

Anne Ørbæk

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First and foremost, I express my deepest gratitude to my supervisor, Katrien Dee Moor, for her invaluable guidance and encouragement throughout the writing of this thesis. Her expertise and mentorship have been essential in shaping the outcome of this work, and I am truly grateful.

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List of Acronyms

AI Artificial Intelligence.

AR6 Sixth Assessment Report.

C2ES Center for Climate and Energy Emissions.

CO_2 Carbon Dioxide.

GHG Greenhouse Gas.

ICT Information and Communication Technology.

IEA International Energy Agency.

IoT Internet of Things.

IPCC Intergovernmental Panel on Climate Change.

IT Information Technology.

LCA Life Cycle Assessment.

NSD Norwegian Centre for Research Data AS.

NTNU Norwegian University of Science and Technology.

PCE Perceived Consumer Effectiveness.

PUE Power Usage Effectiveness.

REC Renewable Energy Credits.

SDG Sustainable Development Goal.

SEO Search Engine Optimization.

SPSS IBM SPSS Statistics.

UN United Nations.

UNEP United Nations Environment Programme.

UNFCCC United Nations Framework Convention on Climate Change.

VR Virtual Reality.

WCED World Commission on Environment and Development.

Chapter 1
Introduction

In today's reality, there is a noticeable excitement surrounding the emergence of new technologies. Terms such as Internet of Things (IoT), cloud computing, Artificial Intelligence (AI), and Virtual Reality (VR) have become buzzwords, representing the technological revolution that is currently underway. However, recent reports show concerns regarding the increasing CO_2 emissions associated with digitalization. The combination of digitalization and climate change is an underexplored field and therefore receives little attention. In light of digitalization's increasing impact on the environment, this issue must be addressed.

In recent decades, human activities have been responsible for intensifying climate change and contributing to the phenomenon known as global warming. The term global warming has no universal definition; however, the Oxford Dictionary defines it as "*a gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of carbon dioxide and other pollutants*" [Oxf]. This process can be understood as follows: as Greenhouse Gass (GHGs) are released into the atmosphere, they trap heat, leading to a general increase in temperature and subsequent alteration in global climate patterns [MZ+21].

Previous research highlights the connection between technological advancements and environmental sustainability [EBB20]. However, this relationship is complex, and its directionality is not always uniform, depending upon the circumstances. Numerous researchers emphasize the potential positive impacts of technology, including Information and Communication Technology (ICT), on sustainability. Conversely, others draw attention to the environmental drawbacks associated with Information Technology (IT), such as excessive energy consumption, accelerated depletion of natural resources, and greenhouse gas emissions. They emphasize the need to mitigate these adverse effects [EBB20].

Overall, the motivation for this thesis stems from the pressing need to understand and address the digital carbon footprint and to empower individuals with the

knowledge and awareness necessary to make sustainable choices in their digital activities. By examining the calculations and assessing user awareness, this research aims to promote a more environmentally conscious society.

The scope of this thesis is limited to examining the calculations behind the digital carbon footprint and assessing the level of awareness among individuals. It focuses on digital users and includes a specific demographic of pupils aged 10-13 for the qualitative study.

1.1 Research Questions

The primary objective of this thesis is to investigate previous calculations involved in quantifying the digital carbon footprint and assess the level of awareness among individuals in the present context. In pursuit of this goal, the following research questions have been formulated:

RQ1 How is the digital carbon footprint calculated today, and to what extent are these calculations documented?

RQ2 Are digital users aware of their digital carbon footprint, and are they willing to change their digital behavior to decrease their footprint?

To address RQ1, a literature review will be conducted, examining previous studies related to the topic. This review will provide a foundation of knowledge and insights into the calculations involved in quantifying the digital carbon footprint. To address RQ2, two distinct empirical user studies will be conducted. The first study will involve the distribution of a quantitative user survey to individuals who actively engage with digital technologies. This survey will gather quantitative data to analyze the level of awareness among users regarding their digital carbon footprint. The second study will involve a qualitative focus group session specifically targeting pupils aged 10-13. This session aims to gain deeper insights into the perceptions and attitudes of younger individuals toward their digital carbon footprint. The qualitative data obtained from this focus group will be analyzed to provide a richer understanding of the awareness levels among this particular demographic.

1.2 Structure of This Thesis

This master thesis is structured as follows: Chapter 2 will provide an in-depth analysis of the background and related research on the calculations of the environmental impact within the ICT sector, along with an exploration of previous studies conducted on digital users. Following, Chapter 3 will outline the methodology employed in this

study. Moving forward, Chapter 4 will present the results derived from both the literature review and the empirical user studies. Furthermore, Chapter 5 will discuss these findings encountered, where a short description of the study's limitations will also be provided. Lastly, Chapter 6 will present the concluding remarks drawn from the research, accompanied by suggestions for future work.

Chapter 2
Background and Related Work

This chapter presents the extensive literature review carried out as part of this thesis. It begins by presenting a comprehensive overview and definition of global warming as a phenomenon in Section 2.1. The historical context and current initiatives addressing global warming are briefly examined. Secondly, the focus shifts to the ICT sector, where key information relating to the sector and its energy consumption is assessed in Section 2.2. This section also addresses the current understanding of how digitalization contributes to the fight against climate change, considering the latest developments and perspectives. Furthermore, a review of the literature on the environmental impact associated with the ICT sector is presented. In addition to this a review of currently accessible calculators and their accompanying documentation, which is seen in Section 2.3 The objective is not to provide an exhaustive overview of all previous studies and current calculators, but rather to gain insights into the perspectives and documentation that is accessible. This will allow a comprehensive understanding of the sector's environmental impact, allowing for a more informed analysis of its sustainability practices. Lastly, in Section 2.4, the literature review investigates previous user studies that have explored user awareness and their willingness to change habits in the context of environmental sustainability.

Throughout this chapter, an academic approach is maintained to examine relevant literature thoroughly. The review incorporates a range of scholarly sources, enabling a comprehensive understanding of the topic and facilitating the development of the research framework for this thesis.

2.1 Global Warming

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Society and the United Nations Environment Programme with the aim of providing a clear scientific view on climate change and its potential impacts on the environment and society [SUL]. In their latest report, the IPCC Sixth

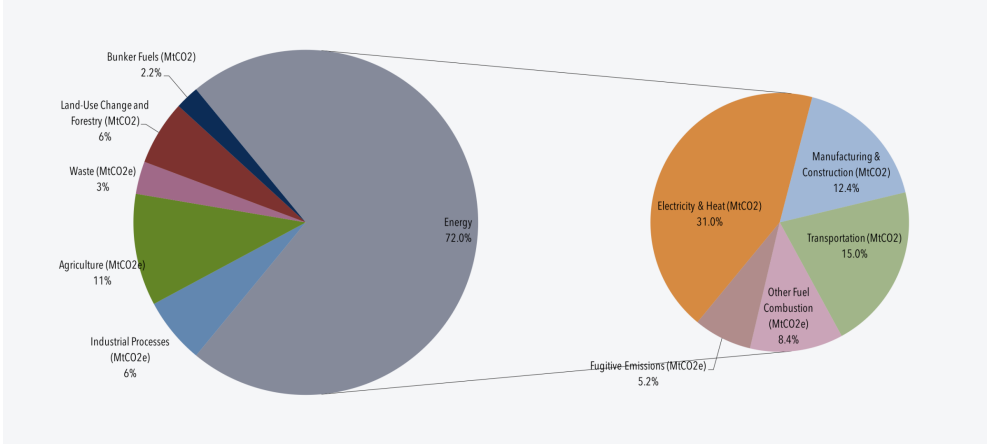


Figure 2.1: This figure, based on the research conducted by the Center for Climate and Energy Emissions [C2ES], presents a chart that depicts the proportion of GHGs attributed to human activities. The figure provides a visual representation of the contribution of human-made GHGs to the overall GHGs emissions.

Assessment Report (AR6) [MZ+21], it is emphasized that our current consumption patterns and practices that contribute to GHG emissions have a negative impact on the environment and are not sustainable. Therefore, it is crucial that we take action and make changes to our habits.

When quantifying the amount of GHGs emitted, the concept of "*carbon footprint*" is frequently used. Although it lacks a precise definition [WM08], it is generally understood as the estimation of the amount of CO_2 or other GHGs released from human activities related to production and consumption. In 2017, the Center for Climate and Energy Emissions (C2ES) published a chart illustrating which proportion of GHGs are human-made, which can be seen in Figure 2.1. This chart showed that in 2017 the majority (72%) of human-made GHG emissions were solely from energy production where electricity and heating were the main sources [C2ES].

2.1.1 History of Initiatives

Global warming is not a new phenomenon; as early as 1896, Swedish scientist Svante Arrhenius (1859-1927)[RCC97] recognized the potential for increased levels of CO_2 in the atmosphere to influence the Earth's surface temperature through the greenhouse effect. His first article about this possible human-made global temperature change was published in 1896 in a Swedish paper, where he referred to the phenomenon as *"hot house"*. His work primarily focused on the increase of CO_2 in the atmosphere and how this affected the surface temperatures. He was one of the first scientists to discover the correlation between increasing levels of CO_2 and the greenhouse

effect, which is now associated with global warming. The consequences of global warming encompass various aspects, such as climate change and occurrence of natural disasters. These include, but are not limited to, rising sea levels, more frequent natural disasters such as earthquakes, hurricanes, and severe wildfires, as well as general climate change [MZ+21].

It wasn't until 1972 that global warming was addressed further in a formal matter [Jac07]. The United Nations (UN) Conference on the Human Environment in Stockholm in 1972 was the first world conference to make the environment a major issue [UNc]. During the conference, a declaration was adopted, The Stockholm Declaration, focusing on principles for the protection and improvement of the human environment, in addition to an action plan, Action Plan for the Human Environment, that provided recommendations for global warming initiatives. In a specific section addressing the identification and regulation of pollutants, the declaration brought attention to the issue of climate change for the first time. It warned governments to consider the potential consequences of activities that might contribute to climate change and urged them to assess the magnitude of climate effects [Jac07]. The major outcome of this conference was the establishment of United Nations Environment Programme (UNEP), which has become the leading environmental authority in the UN [UNc].

A decade later, in 1983, the Brundtland Commission was created, named after Gro Harlem Brundtland, former Prime Minister of Norway [UN07]. The commission was founded to further examine the relationship between labor practices, economic development, and environmental protection. A few years later, in 1987, Brundtland, along with the commission, published the "Brundtland Report", now referred to as "Our Common Future", where the phrases "*sustainability*" and "*sustainable development*" were introduced to the general public. The latter phrase was defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*".This was a pivotal moment in the shift towards a more sustainable future and served as a catalyst for environmentally conscious decision-making.

The Brundtland report starts off by stating that "*What is needed now is a new era of economic growth – growth that is forceful and at the same time socially and environmentally sustainable*" [UN07]. Later, the UN defined three dimensions of sustainable development: economic growth, environmental protection, and social inclusion. This is what the Sustainable Development Goals (SDGs) is based on, which is a global call of action to take to improve the lives and prospects of everyone; every UN Member State adopted this in 2015 [UNb]. This includes 17 goals, where *affordable and clean energy* and *climate action* are two. Recent reports, such as a paper published in 2021 by Mondejar et al. [MAD+21] suggest that in order to reach

these 17 goals, digitalization is essential, especially the use of IoT. The highlights from the text include that digitalization will both capitalize on sustainable development as well as being a guide to actions to face climate change and protect biodiversity. They also state that IoT is an essential tool for sustainable food production and planet health, AI can optimize energy production and water treatment, and innovative technologies can provide equity access to services and increase well-being [MAD+21]. In other words, their report insinuates that although digitalization is not a direct goal for the UN, digitalization and technology are essential to achieve some of their main goals.

Further, in 1992, nations joined an international agreement, the United Nations Framework Convention on Climate Change (UNFCCC), a global collaboration to foster collective efforts to mitigate average global warming and address the substantial climate change while also adapting to its unavoidable impacts [UNd]. Five years later, they adopted the Kyoto Protocol, which enhanced the convention by imposing legally binding emission reduction targets for 37 developing countries. Currently, there are 196 parties to the convention and 192 parties to the Kyoto Protocol.

The Paris Agreement, formed in 2015 and signed in 2016, was also built on the UNFCCC [UNa]. The Paris Agreement is a significant international agreement aimed at combating climate change and accelerating actions for a sustainable low-carbon future. It brings all nations together to undertake efforts to fight climate change and adapt to its effect, focusing on supporting developing countries. The agreement's primary goal is to limit the global temperature increase, in addition to enhancing countries' capacity to address climate change impacts, as well as aligning financial flows with low-emission and climate-resilient pathways. To achieve these goals, the Paris Agreement emphasizes the deployment of financial resources, technology transfer, capacity-building, and transparent reporting of emissions and implementation efforts. After the signing of the agreement in 2016, more countries have joined in on the agreement [UNa].

All these initiatives have contributed to raising awareness and forcing governments, as well as the general population, to take action to decrease emissions to fight climate change. Commonly known ways to reduce emissions are to limit fuel-based transportation, reduce waste, reduce energy consumption at home, and switch to more renewable energy sources [Nat]. Furthermore, there exists a prevailing inclination to expedite the ongoing technological revolution that is currently unfolding. This effort aims to contribute to reducing emissions by improving process efficiency, which leads to the reduction of energy demand, thereby reducing the associated emissions. However, varying perspectives exist regarding this technological development. According to some sources, another sector contributing to global warming is the ICT sector. The Shift Project, a nonprofit with an objective to limit climate change and

economic dependency on fossil fuels, reported in 2019 that the ICT sector stands for more global emissions than the aviation sector [Fer19] [FBW+21]. It is therefore concerning that this topic has received minimal attention from global emissions reduction initiatives. This critical aspect will be further explored in Section 2.2.

2.2 Environmental Impact of ICT

Accurately calculating the environmental impact of the ICT sector, also referred to as the *digigtal carbon footprint*, which refers to the GHG emissions associated with digital activities and infrastructure, is a complex task. Today some different reports and articles address claims they know how to calculate the impact accurately; however, they are often contradictory, and the facts can vary. Nevertheless, there are certain common key considerations and areas within the network that have a significantly higher impact. Two main areas need to be considered, as Belkir et al. suggested, electronic devices and infrastructure facilities [BE18]. In addition, Morley et al. suggest that network and data center consumption is growing [MWH18]. They reported that the primary contributors to energy consumption throughout the lifecycle of tablets and smartphones are networks and data centers, comprising a substantial major of the total energy usage, estimated to be at least 90%, which also includes the manufacturing and charging process, a fact they retrieved from the book by Hischier et al. on ICT Innovations for Sustainability [HCSA15]. With this in mind, a deeper look into different calculations of the impact will be examined. The goal is not to review an exhaustive amount of literature, but rather to gain a general understanding of the field in order to examine connections and differences.

2.2.1 Related Work

Despite the global focus on reducing GHGs emissions in accordance with the Paris Agreement, the ICT industry has received limited attention as a contributor to such emissions [BE18] [Fer19]. In fact, it is often applauded for enabling efficiencies that help reduce the environmental footprint of other industry sectors. The ICT sector is today viewed as a positive tool for limiting emissions, examples being video conferencing, which has helped reduce traveling; monitoring technologies that help optimize energy consumption; and production optimization, which has increased efficiency and decreased energy demand in manufacturing processes. These are all well-known examples of how the ICT sector is actively contributing to emission reduction; however, this is only one facet of the situation. In reality, this situation has two sides, where the opposing side is being overshadowed by the positive one [MWH18] [BE18].

Define which refers to the greenhouse gas emissions associated with digital activities and infrastructure

In 2018, Belkir and Elmeligi posted an article assessing the ICT sector global emission footprint [BE18]. Their objective was to estimate the footprint of the ICT sector, consisting of mainly two main categories, electronic devices, such as smartphones, tablets, and laptops, and infrastructure facilities, such as data centers, communication networks, and power and cooling equipment. To calculate this, they looked at four different parameters: the production energy, the useful life of the component, the use phase energy, and the active installed base from 2007 onwards. In Table 2.1, their calculations for smartphones and tablets are presented [BE18]. They estimated that the total impact of emissions associated with the ICT sector was equivalent to 3.0% - 3.6% of all global GHGs.

Another report on the calculation of the emissions associated with the ICT sector was a 2021 study by Freitag et al. where they address the different stages that need to be included when calculating the impact [FBW+21]. They refer to three different stages: embodied emissions, use phase emissions, and end-of-life emissions. Embodies emissions refer to the GHG emissions released during the extraction of raw materials, the manufacturing process, and the transportation of the product. These emissions are generated before the product is put into use. The use phase emissions are the emissions that occur during the actual use of the product, with results from energy consumption and maintenance activities throughout its lifespan. The third stage refers to the end-of-life emissions that are generated after the disposal of the product. This includes emissions from waste treatment, recycling processes, or any other activities associated with its final disposal. They estimate that all these stages of everything within the ICT sector is equivalent to 1.8 % -2.8% of all GHG emissions [FBW+21]. They also address the possibility that every calculation underestimates the impact, leading to the belief that the impact might be as high as 2.1% - 3.9%.

	Useful Life (years)	Production Energy (kg CO_2)	Use Phase Energy (kg CO_2/year)	Lifecycle Annual Footprint (kg CO_2/year)
Tablets	3 / 8	80 / 116	4.5 / 5.25	14.5 / 43.9
Smartphones	2 / 2	40 / 80	4.5 / 5.25	124.5 / 45.3

Table 2.1: The values presented in the table represent the minimum and maximum estimate for Useful Life, Production Energy, Use Phase Energy, and Lifecycle Annual Footprint. The data used for this table is retrieved by Belkhir et al. [BE18].

In 2020, when Suski [SPF20] calculated the impact of video streaming, she set up boundaries, see Figure 2.2, to make the computation easier. These boundaries are based on Preist et al.'s article on the interaction design of YouTube from 2019 [PSS19]. It is important to emphasize here that the focus is on something much more limited than the aforementioned.

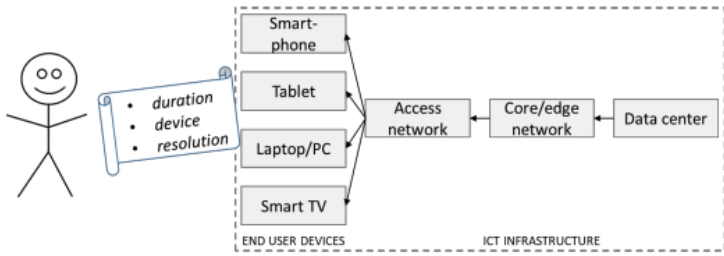


Figure 2.2: This figure illustrates the defined boundaries used for calculating the environmental impact of video streaming used by Suki et al. [SPF20]. The boundaries represent the specific aspects and factors taken into account when estimating the overall impact.

In June of 2022, Sharma and Dash published a paper describing the relationship between digitalization and CO_2 emission [SD22]. As seen in Figure 2.3, a big portion of the emissions comes from electricity usage, which they think is due to digitalization. In their research, Sharma et al. discuss various digitalization concepts contributing to emissions. These include search engines, music and video streaming, internet usage through mobile apps, cloud computing, and blockchain and cryptocurrency technologies. Their findings reveal that the internet is responsible for the most significant percentage of carbon emissions associated with digitalization. Accessing digital services through the internet requires electricity both on the user's end and from the services' servers. The continuous operation of servers to ensure content accessibility contributes to the substantial electricity consumption of the internet. The researchers assert that digital technologies account for 4% of global GHGs, with their energy consumption increasing by 9% every year. They also report that an hour of video conferencing emits approximately 57 grams of carbon, highlighting the significant carbon emissions resulting from the global increase in video conferencing after the 2019 - 2022 covid pandemic [SD22].

Another issue Sharma et al. shine light upon is that of the emissions related to search engines. According to Jens Gröger [SJ19], a single query emits 1.45g CO_2 [SD22], assuming an average of 50 searches per person daily, this amounts to approximately 26kg of CO_2 emissions per year per person. They also refer to The Shift Project, which will be further looked into in Subsection 2.2.2, when saying that they discovered that 80% of data moves through the internet in the form of images. Further, their report indicated that 60% of the global data transfer was downloaded videos. The researchers also discuss cloud computing, which involves storing data in remote computers for convenient access from any location [SD22] [AAM20]. In 2020, Agarwal et al. [AAM20] published a paper on how the internet is becoming a significant contributor to global warming. One of their findings in this research is

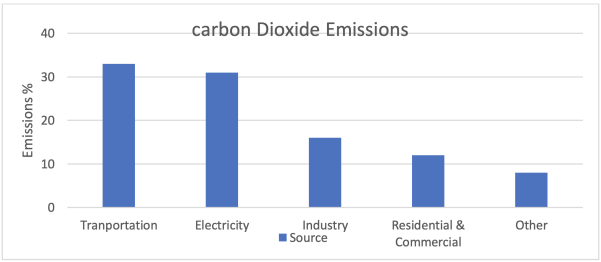


Figure 2.3: This figure illustrates the key factors or sectors that contribute to CO_2 emissions. Among these sectors are transportation, electricity generation, industrial activities, residential and commercial sectors, and other miscellaneous sources [SD22].

that 20mg of CO_2 is generated every second someone uses a simple website. They also state that the annual carbon footprint of the internet is the same as the aviation industry. Richard Bull also mentions this claim in his article from 2015 [Bul15], where at that time, the aviation emissions were on the same level as the ICT sector at 2%.

In a report by Elgaaied-Gambier et al. from 2020, they highlight that despite data centers and internet companies' efforts to reduce their carbon footprint through technological advancements and increased efficiency, there could be unintended consequences, a phenomenon that can be understood through the lens of the "Jevons paradox" [EBB20]. The Jevons paradox is an economic theory that posits that as the efficiency of production increases, the corresponding demand also rises [Alc05]. Figure 2.4 illustrates this concept by depicting the relationship between price and quantity. The figure demonstrates that although the cost per product may decrease, the overall demand increases, resulting in a similar total cost of production. This principle can be applied to the ICT sector as well, where the pursuit of greater efficiency and digitalization in technology is expected to reduce emissions. However, the escalating demand for various technologies may hinder the achievement of this goal.

2.2.2 Initiatives

The Shift Project

In a report posted in 2019, The Shift Project reported that the ICT sector stands for approximately 3.7% of global emissions [Fer19]. The Shift Project is a French think tank that advocates for the shift to a post-carbon economy. As a non-profit organization committed to serving the general interest through scientific objectivity, it is dedicated to informing and influencing the debate on energy transition in Europe. Multiple studies have based their calculations on The Shift Project's claims, it is

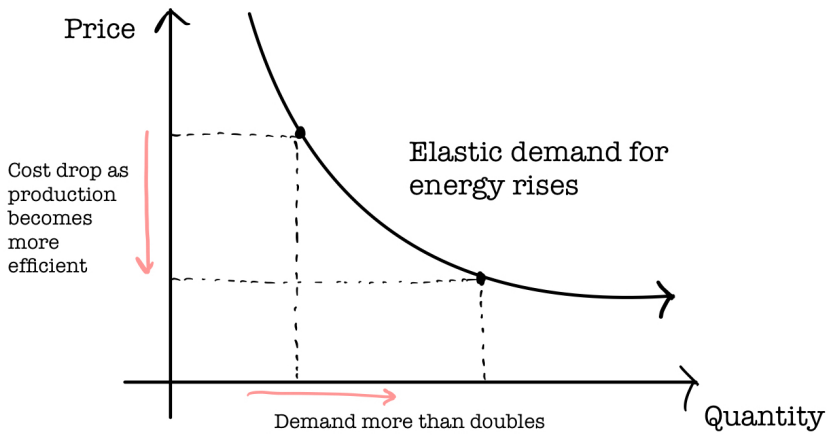


Figure 2.4: The figure depicts the concept of the Jevons Paradox, as described in the paper authored by Elgaaied-Gambier et al. [EBB20]. In the figure, a graphical representation showcases the relationship between price and quantity.

therefore important to take a closer look at their documentation of the calculation. To evaluate the impact the ICT sector has, The Shift Project has a documented methodology for identifying the characterization of the environmental footprint of the digital ecosystem [Fer19]. They focus on various factors, such as energy consumption, GHG emission, consumption of critical metallic raw materials, and the volume of ore moved for raw material extraction. They represent the digital ecosystem in two main categories; digital equipment and digital actions. In their analysis, digital equipment includes smartphones, laptop computers, data centers, connected TVs, and internet access routers. The selection of digital actions performed by digital equipment is in their report two activities, sending emails and watching a video online. They also present their assumption in calculating the footprint; overall, they state that for each digital equipment and action, they use the average number based on statistical studies on current uses worldwide. They identify the characterization of the two actions; "*sending an email*" is characterized by a duration of 5 minutes for the use of the device and a data transmission size of 1 MB, which includes any attachments, "*watching a video online*" involves a device operating time of 10 minutes and a transmitted data size of 170 MB for a video in 1080p quality. Based on the presented scope of the calculation, they presented the claim that watching a video online on "*the cloud*" is equivalent to the energy consumption of using a smartphone for ten consecutive days [Fer19].

DIMPACT

DIMPACT (Digital Impact) was established to address the uncertainties surrounding the emissions associated with digital media and entertainment products, aiming to enhance transparency in the value chain processes involved in processing, transmitting, and consuming digital content [JP22] [DIM22]. In collaboration with the University of Bristol's Computer Science Department, the DIMPACT tool was developed, leveraging their prior work with prominent entities like the BBC and the Guardian. Initially tailored to specific companies, this work was expanded into a generalized framework applicable to other digital media organizations. They aim to develop a tool that provides more accurate measurements of the footprint of digital services. Instead of relying on outdated sources that many calculators are based on, they seek to use realistic values from today's society, taking into account the advancements that have made processes more efficient and resulted in lower emissions. Furthermore, DIMPACT aims to estimate how these emissions will evolve in the future. Their objective is to provide companies that are questioned about their digital footprint with a more precise estimation of their emissions [DIM22].

To calculate the impact, DIMPACT defined the scope for the publishing module, which consists of three categories. They want to use a bottom-up structure and have defined the categories into back-end infrastructure processes (data centers), network transmission, and end-user devices. In addition, DIMPACT stipulates that the minimum requirement is to include the emissions generated during the use phase of each process. The consideration of "*embodied emissions*," which pertain to the emissions originating from the extraction of raw materials, manufacturing, transportation, and installation of equipment necessary for digital content viewing and delivery, is optional. Nonetheless, the tool offers the flexibility to incorporate embodied emissions if reliable data is accessible [DIM22].

2.2.3 Data Centers

Several studies discussed earlier suggest that data centers, within the ICT sector, exhibit the highest energy demand, thus making them the predominant contributor to its overall impact. Positioning them as the primary driver of its overall impact. Therefore, addressing data centers becomes crucial as the initial step toward reducing the sector's overall environmental footprint.

A website can lower its footprint by switching to green hosting providers. Tom Greenwood wrote an article on the Wholegrain Digital website discussing how to move over to a green provider [Gre20a]. He explains how data centers require energy both for the computers running and storing the data, but also for the extensive air condition system for cooling down the computers. It, therefore, makes a huge difference whether or not a data center is run on renewable energy.

Cloud Datacenters	Coal		Nuclear		Clean	
	2012	2016	2012	2016	2012	2016
Amazon	34%	30%	30%	26%	14%	17%
Apple	55%	5%	28%	5%	15%	83%
Facebook	39%	15%	13%	9%	36%	67%
Google	29%	15%	15%	10%	39%	56%
HP	50%	27%	14%	5%	19%	50%
IBM	50%	27%	12%	15%	12%	29%
Microsoft	39%	31%	26%	10%	14%	32%
Oracle	49%	36%	17%	25%	7%	8%
Salesforce	34%	16%	31%	15%	4%	43%

Figure 2.5: This figure presents a comparison of major cloud data center companies and their distribution of coal-generated, nuclear, and clean-run data centers from the year 2012 compared to 2016 [Rad17].

In their report, Belkhir et al. also address that to lower the emissions associated with ICT data centers should be prioritized to become sustainable, as they see data centers to be the main contributor to the impact [BE18]. First and foremost, they suggest that all new data centers should be required to run on 100% renewable energy sources and that existing ones should gradually shift towards renewable energy. They informed that both Google, which is the largest data center operator in the world and Facebook both declared in 2017 that their data centers would be run on 100% renewable sources [BE18] [FBW+21]. Facebook provides an outstanding example of a solution adopted by major companies. They have relocated a portion of their data centers to Sweden, where the cooler climate compared to the United States helps reduce the energy consumption required for cooling the systems [SD22].

In Radus' report from 2017 [Rad17], a table of the different cloud data centers and their energy sources are presented; see Figure 2.5. This is a little outdated source, but still, it is interesting to see which companies take this seriously and which don't. Today the energy sources used might look a bit different. In the article by Elgaaied-Gambier et al., they also bring up that various big companies (GAFA, i.e., Google, Amazon, Facebook, Apple) have adopted a 100% renewable energy commitment, thereby promising a zero-emission policy [EBB20]. Agarwal et al. [AAM20] also support the claim that the big companies are taking actions to lower their carbon footprint; in their report from 2020 they stated that Google has invested roughly one billion dollars in renewable energy methods. When comparing Google's data centers to ordinary ones, the centers are more efficient and utilize about 50% less energy [AAM20].

On the other hand, in an article from 2020 by Itten et al. [IHA+20] on digital transformation, they refer to the project "DigiSUFF" presented by Regula Keller [KSI19]. The latter shows the situation (at that point) of the Swiss youth's use of digital media. In this project, they discovered that 78% of the ecological impact

comes from user devices, while data centers stand for 15%. This leads them to believe that the best thing a digital user can do to lower the impact is to reduce the number of devices, limit screen time, as well as prolong their lifetime.

Additionally, a study done by Jiang in 2021 [JVK21] suggests that according to the ICT sector, the use of devices stands for 20% of the energy consumption, data centers are responsible for 19%, networks account for 16%, and computers 17%, and are the main sources of energy consumption. This indicates that the research is built upon various sources, all of which have independently found that digital devices and data centers have a significant environmental impact and consume substantial amounts of energy. However, with the utilization of distinct sources in the two papers, variations in the reported numbers for the environmental impact arise.

DIMPACT also supports this claim that it is the user devices that produce the most emissions in the ICT sector. In their methodology paper [DIM22], they highlight that the most significant contributor to the impact is the user devices, with networks and data centers closely trailing behind. However, the figure presented demonstrates that the ratio between embodied emissions and use-phase emissions varies among the three components. User devices exhibit a balanced 50-50 ratio, whereas data centers and networks exhibit a higher proportion of emissions during the use phase.

With this in mind, a deeper look into different website carbon calculators will now be conducted.

2.3 Website Carbon Calculators Available Today

Today, multiple website carbon calculators have emerged, offering to estimate the carbon footprint associated with individual websites. The motivations driving the development of these calculators vary, ranging from assisting website hosts to reduce their footprint to enabling digital users to access these calculations with the aim of enhancing their awareness of the carbon footprint generated by their digital behavior.

This section will examine some of these calculators. Among these are; "*Original Website Carbon Calculator*" [Dig], "*Green Pixie*" [Pix], "*Karma Metrix*" [Mat], and "*Ecograder*" [Miga]. To start off, an experiment was conducted, where the same URL was put into each of these calculators to see what their estimation was; this is seen in Table 2.2. Upon initial examination, the table presented reveals distinct calculations for the same websites, indicating variations in the scope of these calculations across the four sources. In order to gain a comprehensive understanding of these variations, a dive into the accompanying documentation for each source will now be undertaken.

The creators behind "*Website Carbon Calculator*" is *Wholegrain Digital*, a WordPress agency established in 2007 by Tom and Vineeta Greenwood [Gre20b]. According

Website	Website Carbon Calculator	Ecograder	Green Pixie	Karma Metrix (yearly - 120.000 page views)
Ntnu.no	3.58g CO_2	1.63g CO_2	3.66g CO_2	1041kg CO_2
Google.com	0.04g CO_2	0.35g CO_2	0.23g CO_2	Not identified
Facebook.com	0.16 CO_2	0.09g CO_2	0.53g CO_2	69kg CO_2

Table 2.2: This table provides a summary of CO_2 emission per page view across three different websites using four calculators [Dig] [Pix] [Mat] [Miga].

to Greenwood, the carbon calculator primarily serve as an estimator rather than providing a precise measurement of CO_2 emissions for websites. Due to the inherent complexities involved in accurately quantifying website emissions, it is nearly impossible, if not entirely impossible, to obtain exact measurements. Assumptions are, therefore, necessary to facilitate a practical approach. These include the website, user behavior, devices, infrastructure, and power supply [Gre20b]. The objective is to capture a representative scenario with a reasonable level of accuracy. When documenting their calculations, they define their scope to include: data transfer over the wire, energy intensity of web data, the energy source used by the data center, carbon intensity of electricity, and website traffic. They refer to *Sustainable Web Design* [SWD] for further information about their methodology.

Sustainable Web Design is a website created by *Wholegrain Digital* [Gre20b], and *Mightybytes* [Migb], in collaboration with the *Green Web Foundation* [Fou]. They aim to establish a standardized methodology for estimating carbon emissions from digital products. *Mightybytes* is also the founder of the *Ecograder* calculator and uses the methodology from *Sustainable Web Design*. They have well-documented the method of their calculations on their website. They show that they have divided the system segments into four parts, which different weights on the calculations; consumer device use (52%), network use (14%), data center use (15%), and hardware production (19%) [SWD]. These weights are based on a study from 2020 conducted by Anders Andrae [And20]. Further, the rest of their numbers in the calculations are also based on the study by Andrae. Given this shared methodology between the *Website Carbon Calculator* and *Ecograder*, one would expect similar estimations from both tools. However, as demonstrated in Table 2.2, notable discrepancies exist in the calculated emissions.

Green Pixie is a website carbon calculator focusing explicitly on cloud emissions data. Their methodology enhanced a customer's cloud Cost and Usage Report file by incorporating additional columns that capture emissions metrics. The calculations performed by *Green Pixie* encompass various components, computation, storage, memory, networking, and embodied emissions. They highlight continuously improving

the methodology to ensure the most reliable and up-to-date data possible. Apart from the aforementioned aspects, their methodology is not further documented.

The last calculator examined, the *Karma Metrix Assessment* evaluates website efficiency by considering various factors related to energy efficiency [Mat]. These factors include the weight of components, caching techniques, code processing demands, HTTP calls, and hardware resources. The assessment aims to provide comprehensive insights for optimizing energy consumption in website design and development. Their calculation of CO_2 emissions uses a proprietary algorithm considering the number of website page views. This calculated value is then compared to the CO_2 emissions produced by the median website with an equivalent number of visits [Mat]. Besides this, a defined methodology is not provided.

In addition to pure calculators, there are also related services that aim to trigger carbon footprint reduction linked to online activities. As many of the mentioned websites over, the abovementioned *Ecograder*, in addition to offering to calculate the impact of a specific number, also provides tips on how to lower emissions related to a website [Miga]. These strategies include optimizing page weights by removing code and properly sizing images, enhancing the user experience to improve efficiency and minimize emissions associated with end-user device usage, and selecting green hosting options. These approaches contribute to a more sustainable web ecosystem with reduced carbon emissions and increased energy efficiency. This information is presented with the intention of providing guidance and motivation to website owners, encouraging them to reduce their digital carbon footprint actively. This allows website owners to contribute to the overall mitigation of the environmental impact associated with digital services.

Finally, Yoast is a website that assists clients with Search Engine Optimization (SEO), which encompasses the science and art of getting pages to rank higher in search engines like Google [Yoa]. Through their blogpost, Yoast posts different blog posts to help their customers with their SEO. In April 2023, they published a post called *The carbon footprint of your website and how to reduce it*, focusing on the environmental impact of online activities.

Within this blog post, Yoast highlights the significant influence of online traffic on carbon emissions, drawing upon insights from the Shift Project [Fer19]. They highlight that digital technology is responsible for roughly 4% of GHG emissions. They explain that each interaction with websites requires electricity and the effect of multiple steps involved in a website request. They further identify additional electricity factors, such as the role of data centers in website hosting and bot traffic, which is the non-human traffic to a website or an app. To back up their statements, Yoast presents different carbon footprint calculators, such as the Website Carbon

Calculator and the Green Web Foundation. Moreover, the blog post includes a section about the strategies for reducing a website's carbon footprint. Here they provide actions for website owners seeking to minimize their environmental impact. Overall, their websites shed light on the environmental implications of website operations and offer valuable guidance for reducing the carbon footprint associated with online activities [Yoa].

Merely comprehending the calculations of digital impact falls short in driving substantial change among the general population. To effectively tackle the environmental consequences of digital technologies, user consciousness, and involvement are pivotal. It is imperative to narrow the divide between awareness and action by cultivating a deeper understanding among users regarding their own digital behaviors and the resultant environmental effects. Through the promotion of user awareness and the provision of easily accessible information, we can empower individuals to make informed decisions and actively participate in diminishing the environmental footprint of the ICT sector.

2.4 User Perspective and Awareness

Metaphors play a powerful role in shaping our understanding and conceptualization of complex concepts. By examining the impact of metaphors on how individuals perceive the internet, we can gain valuable insights into the broader implications for their attitudes and behaviors regarding digital impact. Furthermore, this section explores previous user studies that have investigated people's attitudes toward the environmental and societal impact of digital technologies. Understanding user perspectives and attitudes is crucial for developing effective strategies to address the digital impact and promote more sustainable practices

2.4.1 Metaphors

In Borning et al.'s paper on the invisible materiality of ICT, they point out what impact the metaphors we use, such as "*The Cloud*," has on people's perception of ICT and how it affects their comprehension of what "*The Internet*" is [BFL20].

Some of their ideas for what can be done is to increase the visibility of some aspects of the truth. They suggest that the metaphors we now use should shift to include a perspective of materiality without being overly prescriptive. Figure 2.6 is an image they present of a typical illustration of cloud computing. They suggest that to enhance the descriptive nature of the metaphor "*The Cloud*," they propose including hardware-associated images to provide a clearer representation. Another suggestion they make is to train the new generation and target the interface designers, software engineers, hardware engineers, and other education fields in ICT related

fields. Understanding the mental models people have on information technologies, both their personal devices and the networking infrastructure and servers [BFL20].

Similar to Borning et al.'s research, Bull called data centers for "*the invisible footprint of ICT needs*" [Bul15]. He continues to say that the fact that data centers are located far away contributes to altering people's perception of their energy consumption because it is "*out of sight, out of mind*" [Bul15]. Yet, the paper also sheds light on the fact that it is easy to forget the energy consumption of the physical devices we possess. It is emphasized that even simple actions like turning off a computer overnight can reduce energy consumption. Bull then mentioned Brown et al.'s research [BBFE12] indicating that user behavior alone can account for the wastage of up to 30% of energy.

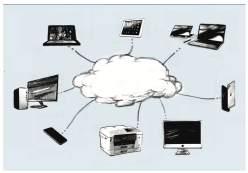


Figure 2.6: This figure depicts a typical illustration of cloud computing, utilizing a metaphor of a cloud in the center [BFL20].

In a study conducted by Gnanasekaran et al. [GFH+21], described later in Section 2.4.2, they interviewed some students at NTNU and asked them questions related to their awareness and understanding of digital carbon footprint. One of the participants, a 25-year-old female, highlighted the lack of technological understanding might be a reason for not grasping the impact, stating: "*that's why maybe you are more unaware of your digital consumption [...], it's not something tangible*" [GFH+21]. This supports the assumption that Borning, Freidman, and Logler had on the invisible materiality that affects the comprehension of digital services that can lead to an invisible truth [BFL20].

2.4.2 Previous User Studies

There are a few previous user studies related to digital carbon footprint and the attitude digital users have toward the topic. They have some contradicting results, which makes it challenging to compare the results; however, they do uncover different aspects and perspectives, which together shed light on various facets of the issue.

A study conducted by Kim et al. in 2005 [KC05] explored what factors influence people to make environmentally friendly purchases and how those factors are related to each other. The three different factors they look at are collectivism, which is the idea of working together for a common good, environmental concern, and Perceived Consumer Effectiveness (PCE), which refers to how much people believe their actions can make a difference. The method they used was a self-administered survey distributed to students enrolled at a Midwestern university in America with a total of 304 students, with an age range of 18 to 29 years old, participating. They

discovered that individuals with collectivistic values tend to hold stronger beliefs about their effectiveness as consumers (PCE) and that their actions can make a difference, which leads to more green buying behavior. However, environmental concerns directly influence green purchase behavior [KC05].

In 2009, Chetty et al. posted an article that focused on home computer power management [CBMJ09]. It is important to state this study was conducted when stationary computers were more widespread than today. The researchers observed 20 households and their power management behavior regarding their home computers. The study revealed that even though there was a potential for lowering the electricity bill, the savings weren't significant enough to motivate the users to change their behavior. The inconvenience of turning the computer off and the long boot-up time were not noteworthy enough for the user to choose their convenience over the economic and environmental benefits [CBMJ09]. They quickly noticed that they didn't turn the computer off after use, even though this would potentially lower the electricity bill, however, these economic and environmental savings were too small to motivate the users to change behaviors.

In 2020 Elgaaied-Gambier et al. studied user behavior regarding consumers' self-attribution of responsibility [EBB20]. To investigate the underlying factors influencing internet users' adoption of environmentally friendly online behavior, they carried out three user studies, consisting of one exploratory study and two quantitative studies. The studies encompassed a diverse participant pool of female and male individuals aged between 21 and 61 years.

The exploratory study, face-to-face semi-structured interviews conducted on 17 participants, aimed to map the consumers' reactions to the environmental impact of internet usage, which overall showed a low level of awareness, and although the participants showed interest in the subject, they didn't feel a responsibility to improve the matter. However, most of the participants showed a willingness to learn more. The other two studies aimed to understand what promotes or hinders people's self-attribution of responsibility to adopt green behavior [EBB20].

The first of the two studies was a survey they distributed to a panel of French consumers where they aimed to map perceived sacrifice associated with behavior change, how they perceived the severity of the environmental threat associated with each practice and self-attribution of responsibility. Based on their findings, the researchers reached two contrasting conclusions. Firstly, when individuals are aware of the gravity of the outcomes resulting from their online behavior, they are more inclined to support the notion of personal responsibility. However, their endorsement of such responsibility is hindered by the perceived sacrifices associated with modifying their online behavior [EBB20].

The objective of the second quantitative user study was to present a comprehensive framework that elucidates the impact of sacrifice and severity within the context of cognitive dissonance. This study revealed that if internet users perceived pro-environmental online actions as less practical and less functional than their usual online behavior, a change would be associated with significant sacrifice and effort. For instance, consumers may engage in self-persuasion by considering the proposed solution irrelevant. Consequently, if they perceive the alternative behavior as burdensome, they are more likely to express skepticism toward the solution, leading to a negative impact on their self-attribution of responsibility [EBB20].

An exploratory study conducted at NTNU by Gnanasekaran et al. [GFH+21] in 2021 also explored user awareness related to pro-environmental friendly user behavior. Semi-structured interviews were utilized to map "*(1) the extent to which today's digital natives are aware of their digital carbon footprint, (2) what could motivate them to reduce this footprint, and (3) the compromises they might be willing to make in reducing it*" [GFH+21].

Their findings suggest a lack of awareness among digital natives regarding the environmental impact of digital applications and services, both in general and their individual user behavior. Most participants exhibited limited knowledge on this subject, and the lack of awareness was attributed to a lack of public information and societal consciousness surrounding the topic. Additionally, the study revealed a lack of understanding regarding the environmental implications of underlying technological processes and infrastructure, as they are not readily visible, as also indicated in multiple of the studies discussed previously [GFH+21] [Bul15] [BFL20].

Regarding the motivation to adopt environmentally friendly digital habits and reduce one's digital carbon footprint, the results indicate several indirect factors, including a desire for personal well-being. However, the motivations for digital technology may also inadvertently contribute to unsustainable consumption habits, creating conflicting roles. Furthermore, the findings suggest a certain willingness to make compromises in adopting pro-environmental digital behaviors. However, this willingness is not unconditional and depends on factors such as alignment with other personal goals and the perceived sacrifice and effort involved. Additionally, the ability to visualize or perceive the meaningfulness and impact of individual choices, such as planting a tree per search, seems to be crucial in triggering a sense of individual responsibility and agency to take action [GFH+21].

The background chapter highlights the complexity of calculating the environmental impact of the ICT sector. Previous research reveals variations in estimations due to discrepancies in data sources, scopes, and parameters. Additionally, the absence of a standardized method for website carbon calculators further complicates the

assessment. User studies indicate a lack of knowledge on the subject, underscoring the significance of metaphors in comprehending complex concepts. The upcoming section centers on the methodology, examining various approaches to enhance understanding. By employing diverse research methods, this study aims to contribute to existing knowledge.

Highlights from Chapter 2

- Global warming poses an imminent threat to humanity, demanding immediate attention and proactive measures for mitigation.
- Initiatives and international agreements have been undertaken to address global warming and propose strategies for its mitigation. Among these efforts, the concept of digitalization is presented as means to overcome the issue without mentioning its drawbacks.
- Previous studies investigating the environmental impact of the ICT sector have reveled estimates ranging from 1.8 - 4% of all global GHG emissions. The variation in estimation can be attributed to differences in the data sources utilized and variations in the definition and scope of the calculations.
- There are several website carbon calculators available today, yet, they yield varying calculations for the environmental impact of the same website.
- Previous user studies revealed that individuals express a sense of responsibility to reduce their carbon footprint, including modifying their digital habits. However, these studies also identified barriers that pose challenges that limit their ability to adopt digital sustainable practices.

Chapter 3
Methodology

This thesis endeavors to explore the definition of environmental impact calculations in the ICT sector established by previous research and assess the level of societal awareness on this issue. The following chapter outlines the methodology utilized in this thesis to address the research questions presented in Chapter 1. Firstly, Section 3.1 describes the methodology used to gather perspectives and insights into how different sources calculate the environmental emissions from the ICT sector to address Research Question 1.

The user awareness data is collected through empirical user studies, specifically a mixed-method approach of quantitative and qualitative methods carried out on two different sample groups, as seen in Table 3.1. The first sample group (S1) consists of digital users over 18, for which a qualitative cross-sectional user survey was distributed (section 3.2). The second sample (S2) consists of young pupils attending primary school aged 10 to 13 years, where focus groups were organized (section 3.3).

3.1 Literature Study

The literature review involved a thorough analysis of various papers, which were categorized into five distinct groups. These five groups were as follows; previous user studies, previous research on ICTs emissions, current actionable measures, website emission calculators, and generally global emissions. Concurrently, summaries of

	Survey	Focus group	Number of participants
S1	x		242
S2		x	5

Table 3.1: This table provides an overview of the two samples included in the study. S1 represents the participants of the survey, while S2 represents the participants of the focus groups.

each paper were composed so that it would be easier to go back and review the literature. This systematic approach helped structure and organize the literature enabling a clear definition of the specific topics that needed further exploration.

To acquire relevant literature, a combination of methods was employed. Keywords used in Google Scholar in the search for literature were, amongst others, *global warming*, *ICT*, *climate impact of ICT*, *cloud services*, and *carbon footprint calculator*. The collected literature formed a baseline for the review, and cited literature was further examined. After gathering a baseline of the different topics, a review of the cited literature was conducted. Noteworthy facts mentioned in the texts prompted further investigation into the respective sources, adding credibility and depth to the research. The findings of this literature review on global warming and the environmental impact of the ICT sector are presented in Chapter 2, Section 2.1 and 2.2. Further, an examination of website carbon calculators was conducted. the objective was to assess and evaluate the methodologies employed by these calculators to calculate the carbon footprint of websites. These findings are presented in Chapter 2, Section 2.3.

In addition, the literature review encompassed gathering information on the design of user surveys and the conduct of focus group sessions. This exploration aimed to acquire valuable insights and best practices in order to ensure the effectiveness of the empirical research conducted in this study. The subsequent section provides a detailed elaboration on the methodologies employed for designing user surveys and facilitating focus group sessions, offering a comprehensive guide for implementing these research techniques.

3.2 Quantitative User Studies

A quantitative user survey was conducted, where the audience was digital users over 18 years old. The survey was sent out anonymously and the main recruitment platform was Facebook and personal network. Initially, the intention was to conduct follow-up interviews with some of the participants, which is why an option to leave their personal information was initially provided. In order to ensure the privacy and security of participants' personal information, an application to *Sikt* (formerly Norwegian Centre for Research Data AS (NSD)), a service provider that offers privacy services for research to educational and research institutions, was necessary. This application can be viewed in Appendix B. However, due to a prolonged approval process, which would have delayed the research too much, it was decided to distribute the survey anonymously, which doesn't require formal authorization. This approach ensured that the data collection process could proceed as intended. The survey was created in *Nettskjema.no*, a tool approved by *Sikt* for conducting surveys. The completed survey can be found in Appendix A.

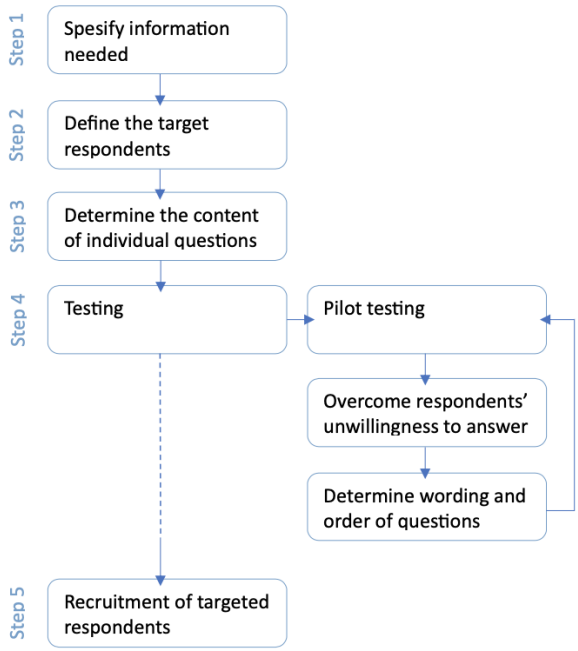


Figure 3.1: This figure illustrates the design cycle adopted for the survey conducted in this study.

3.2.1 Design Cycle

Before forming the design cycle, I conducted a literature study to gather insights and inspiration for its development, as mentioned in Subsection 3.1. A paper written by Taherdoost in 2022 [Tah22] and a book written by Creswell on research design [CC03] were frequently used for this and it helped form the design cycle. The finalized cycle can be seen in figure 3.1.

Step 1 - Specify Information Needed

In the first stage of the cycle, the research questions were used to specify the information needed, specifically RQ2, as described in section 1.1. The relevant topics were divided into eight sections, as seen in table 3.2. Sections 1, 2, and 3 were intended to map their personalia, both in the sense of age, gender, and occupation, but also their relationship with climate change and whether they feel responsible or not, and if they think digitalization is contributing to solving the climate crisis. Section 4, 5, and 6 aims to assess participants' digital habits and their perception of

Section	Topic
1	Personalia
2	Personal relationship to the climate crisis
3	Digitalization and the climate crisis
4	Material impact
5	Personal digital habits
6	Digital services environmental impact
7	Willingness to change digital habits
8	Conclusion

Table 3.2: This table provides an overview of the eight sections of the survey, including their respective section numbers and names.

the potential environmental impact associated with these habits. Section 7 is meant to test if the participants are willing to change their habits to more environmentally friendly actions, while section 8 was a feedback section. The construction of each section is described below.

Step 2 - Define Target Respondents

The subsequent phase in the cycle involved identifying the targeted audience for the survey, which is a crucial step as it established the groundwork for its implementation. Initially, the intended group consisted of the general public; however, a convenience sampling approach was used, a method in which a sample is taken from a group that is easy to reach, without any further inclusion data [SAGE]. Various channels were utilized to reach individuals, including personal networks and Facebook. The reachable audience primarily comprised IT students, employers in the IT sector, and personal Facebook networks. It can be assumed that IT students and employees might show interest in participating in the survey due to their familiarity with technology and a potential desire to improve their digital habits, considering their frequent use of technology. In addition, posting the survey to a climate activist group became relevant because they might be willing to change their habits before other segments of the population are willing to do so.

Step 3 - Determine the Content of Individual Questions

When developing the survey questions, previous user studies were examined to find questions that had already been tested as their parameters were already proven accurate, adding credibility to this survey. In addition, some new questions were developed to add to the existing research. The questions reused from previous studies were gathered from two studies, Kim et al. on *Antecedents of green purchase behavior: An examination of collectivism, environmental concern, and PCE* [KC05], and

Construct	Measures
Perceived Consumer Effectiveness (PCE)	I can protect the environment by buying products that are friendly to the environment.
	There is not much that I can do about the environment (R).
	I feel capable of helping solve the environment problems.
Environmental Concerns	I am extremely worried about the state of the world's environment and what it will mean for my future.
	Mankind is severely abusing the environment.
	The balance of nature is very robust and isn't easily upset (R).
	Humans must live in harmony with nature in order to survive.
Green Purchase Behavior	I make a special effort to buy paper and plastic products that are made from recycled materials.
	I have switched products for ecological reasons.
	When I have a choice between two equal products, I purchase the one less harmful to other people and the environment.
	I have avoided buying a product because it had potentially harmful environmental effects.

Table 3.3: This table presents an overview of the questions that have been reused from the previous study by Kim et al. [KC05].

Elgaaied-Gambiers et al.'s report on *Cutting the Internet's Environmental Footprint* [EBB20]. From the study done by Kim et al., the retrieved questions represent three different test categories, environmental concerns, PCE, and green purchase behavior; the questions can be seen in Table 3.3. These questions were used in Section 2, *Personal relationship to the climate crisis*. The paper, described in Section 2.4.2, discusses the parameters used [KC05]. Questions from Elgaaied-Gambiers et al.'s report related to *familiarity with practice* were used to map digital habits and willingness to alter current habits. These questions were used in Sections 5 and 7 *Personal digital habits* and *Willingenss to change digital habits*. In Section 5, they were asked what actions they take today that are considered digitally environmentally friendly; in Section 7, the same set of actions was presented with the aim of determining the number of individuals who are open to continuing to take pro-environmental measures, and who are willing to modify their habits.

I also self-constructed some questions in line with the research questions to provide more precise answers. This included questions related to material impact and digital behavior. The material impact part asked questions related to the number of devices, how many of them they inherited, and what they do with the devices once done with them. The questions in the survey were a mix of structured and unstructured questions or so-called quasi-structured surveys [Tah22]. Unstructured questions are open-ended questions where the respondents can answer with their own words, while

structured questions are closed-ended and answers are pre-determined. The eight sections as shown in table 3.2 will be further elaborated below.

The first section of the survey is intended to map the characteristics of the participants to use in the analyses. In this section, I mapped factors such as age, occupation, education, and gender. Later I used this information to cross-examine the results of these factors.

The second section aimed to map the participant's relationship to the climate crisis and what actions they take today to lower their carbon footprint. In this section, I used the pre-tested questions from the paper by Kim et al. [KC05]. These questions aimed to map if they felt responsible or were motivated to help save the planet from the climate crisis. In the last question of this section, the participants were provided with an unstructured question where they could describe additional actions they undertook to decrease their environmental impact. The objective of this was to stimulate participants' reflection on their present-day behaviors and map their level of awareness regarding the individual carbon footprint.

In the third section, the participants were asked to answer structured questions related to which degree they thought digitalization had a negative or positive impact on the environment. On a scale from strongly disagree to strongly agree, participants were asked to respond to questions such as "*Digital technology contributes to solving the climate crisis*", "*Digitalization contributes to optimizing the production of goods, thereby reducing the associated emissions*", and "*It's better to have a one-hour digital Teams or Zoom meeting than to drive for 10 minutes by car*". In this context, the objective was not to elicit the correct answer from the participants but rather to prompt them to contemplate the question and respond based on their current knowledge and individual perspectives.

In the fourth section, the participant's material impact was mapped. This included the number of digital devices they possess, how many of these were bought second-hand or inherited, and what they do with their devices after they are done using them. The process of creating digital devices has a significant impact on the environment, stemming from emissions generated during manufacturing and the use of rare materials in the devices, as described in section 2.2. After utilizing a device, it is a common practice for individuals to simply store it in a drawer without much thought, or alternatively, they may misplace it and find themself needing a replacement. I intended to investigate the participants' typical behaviors in these scenarios.

A series of questions related to the participant's digital habits were asked in the fifth section. The intention was to map what they primarily use digital services for, their average screen time, and what actions they take that are *environmentally*

friendly according to Elgaaied-Gambiers et al. [EBB20]. In Elgaaied-Gambier et al.'s study, a list of environmentally friendly actions was listed, and the participants were asked if they were familiar with them. These actions were listed in the survey, and the participants were asked to check off which of these they do today.

In the sixth section, the objective was to assess the participants' perception of digital services' environmental impact. The aim was to investigate the difference between different age groups and/or climate activists. Additionally, I opted to get the participants' level of optimism, pessimism, or knowledge gaps regarding the environmental consequences of digital technology.

In the last section of relevant questions, the list of actions from Elgaaied-Gambier et al.'s study was presented again, and the participants were asked to check off for which action they were willing to do in the future. The goal for this section was to cross-examine the question in section five with the answers in this section to see if they thought they would change their habits after conducting the survey. As a wrap-up and part of the conclusion section, the possibility to leave a comment or feedback was given.

3.2.2 Testing

Pilot-testing

Once the survey was completed, a pilot test was conducted with three students to assess the duration and comprehensibility of the survey. This was necessary to evaluate and refine the survey instrument. During the test, I encouraged participants to verbalize their thoughts, allowing me to pick up moments of confusion or misunderstanding. In addition, after they were finished, I requested their feedback on the quality of the questions, specifically asking them to indicate whether or not a question was well-designed and easy to understand. However, I didn't give them any tips while they were doing the survey; this was to get a more accurate estimate of the duration. I decided that a more in-depth iteration of reflection was necessary, this was done in the second iteration, and a third iteration was conducted to get a realistic estimate of the duration. This approach allowed me to gather valuable insights for improving the survey.

Upon analysis of the pilot tests, it was revealed that the survey was excessively lengthy, making it clear that removing certain questions was necessary. Specifically, the participants indicated that questions related to their perception of the CO_2 emissions and electricity consumption associated with certain websites were hard to answer due to their lack of knowledge on the topic. The decision to delete these questions was made to avoid receiving potentially inaccurate or speculative information, which isn't valuable information in this thesis.

Second Iteration

The next step involved conducting a new test of the revised version of the survey on a fresh set of participants to examine whether or not this was understandable; two individuals in my personal network participated in this iteration. The participants gave feedback that most of the questions were understandable; however, some were difficult and confusing. This led to further adjustments to the sequence and wording of the questions. Additionally, a subset of questions was consolidated to reduce the length. In this iteration, the participants were again encouraged to think out loud and engage in discussions and reflections regarding specific questions. More questions were removed, specifically related to their relationship with the climate crisis. I determined that the sequence of questions from Kim's study [KC05] was sufficient enough to map this. This meant that the definitive length of the survey was not yet determined, and the survey was not yet ready to be sent to Sikt for approval.

Third Iteration

This iteration aimed to assess the duration of the survey; two individuals in my family participated in this iteration. The participants answered the questions alone while being timed. The goal was to get the survey to be 10 minutes long, to reduce the risk of participants not wanting to complete the survey. However, during this iteration, it was revealed that one of the participants spent approximately 13 minutes, which was more than the desired time limit. After completing the survey, a walk-through of the questions was done where the participants talked about their experiences. As a result, the questions retrieved by Elgaaied-Gambier et al. [EBB20] were converted from "*in what degree do agree or disagree to this statement?*" to "*check of for which actions you take*". In addition, it was revealed that multiple questions addressed similar aspects, essentially requesting the same information. This resulted in these redundant questions being consolidated into a single question encompassing the relevant content, this was done to a few questions in section 4, material impact. As a result, this revision led to a sufficiently concise survey, which was then prepared for submission and approval by Sikt.

3.2.3 Recruitment of Sample 1 (S1)

Initially, the survey on the digital platform *Nettskjema.no* was distributed to acquaintances of the researcher. After receiving positive feedback, I further distributed it to a broader audience by posting it on my Facebook page to people I've met over the past years. This audience consists of young students and employed adults in all age groups, creating a diverse representation of age groups and knowledge levels. In addition, my parents, who are both employed in the IT sector, distributed the survey to coworkers, which meant I could recruit more of the intended target audience. After four days, I received 115 responses and decided to post the survey on a climate

activist Facebook page to recruit them as well. The group is called "*Folkeoppgjøret mot folkeoppgjøret mot klimahysteriet*", which translated to English is: "*People's movement against the people's movement against the heightened concern for climate crisis*". This proved to be effective, and after ten more days, I received 242 responses. Subsequently, I closed the survey and commenced the analysis of the collected data.

3.2.4 Data Analysis

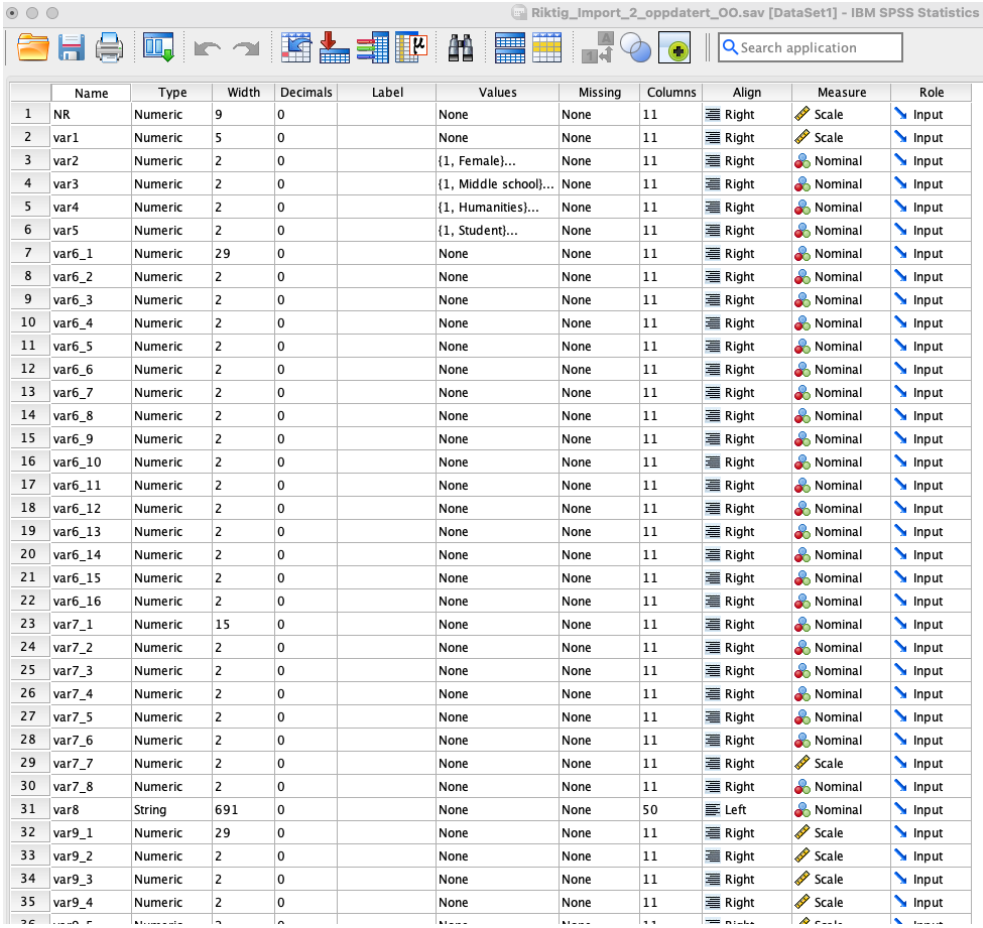
When analyzing the survey, different tools were utilized. Excel and IBM SPSS Statistics (SPSS) were essential for analyzing and structuring the results. Excel was used to visualize the results in figures and diagrams. SPSS, as shown in Figure 3.2, can be used for mathematical analysis, and tests such as reliability (Cronbach alpha), Chi-Square, Mann-Whitney, Spearman, and Kruskal-Wallis tests were conducted. The Chi-Square tests can be used to map the distribution of the answers, the Man-Witney test is utilized to compare two independent groups, the Kruskal-Wallis test may be used to compare more than two distinct groups, while a Spearman test can be used to map if there was any correlation between different answers [Fie18]. The intention was to conduct these tests on the gathered data; however, due to time constraints, Excel was used to visualize the results and became the primary tool.

3.3 Qualitative User Studies

The second part of my user studies was conducting focus groups with pupils in primary school. The motivation behind this was to see if they had a different look at the topic and whether they had some creative solutions to tackling the environmental issue related to the ICT sector. In addition to getting an insight into the future generation's attitude toward the topic. Conducting focus groups with children allows for capturing their unique perspectives, innovative ideas, and valuable insights, which are frequently overlooked in user research [KKK01]. This method also provides children a platform to express their experiences and thoughts, offering researchers a deeper understanding of their viewpoints.

3.3.1 Designing the Focus Group Guide

When designing the focus group session, tips from Kennedy et al.'s article on considerations in children's focus groups were followed [KKK01]. They stated that it is essential to divide the session into four parts, beginning, opening, discussion, and wrap-up. The beginning should consist of introducing ground rules, names, and the introduction to the topic. The opening should focus on some easy-to-answer questions that indicate that there are no right or wrong answers; in addition, they should both be on the topic and something they can relate to; in this thesis, questions like *What's your favorite app?* were used. The discussion part should include an activity



	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	NR	Numeric	9	0		None	None	11	Right	Scale	Input
2	var1	Numeric	5	0		None	None	11	Right	Scale	Input
3	var2	Numeric	2	0		{1, Female}...	None	11	Right	Nominal	Input
4	var3	Numeric	2	0		{1, Middle school}...	None	11	Right	Nominal	Input
5	var4	Numeric	2	0		{1, Humanities}...	None	11	Right	Nominal	Input
6	var5	Numeric	2	0		{1, Student}...	None	11	Right	Nominal	Input
7	var6_1	Numeric	29	0		None	None	11	Right	Nominal	Input
8	var6_2	Numeric	2	0		None	None	11	Right	Nominal	Input
9	var6_3	Numeric	2	0		None	None	11	Right	Nominal	Input
10	var6_4	Numeric	2	0		None	None	11	Right	Nominal	Input
11	var6_5	Numeric	2	0		None	None	11	Right	Nominal	Input
12	var6_6	Numeric	2	0		None	None	11	Right	Nominal	Input
13	var6_7	Numeric	2	0		None	None	11	Right	Nominal	Input
14	var6_8	Numeric	2	0		None	None	11	Right	Nominal	Input
15	var6_9	Numeric	2	0		None	None	11	Right	Nominal	Input
16	var6_10	Numeric	2	0		None	None	11	Right	Nominal	Input
17	var6_11	Numeric	2	0		None	None	11	Right	Nominal	Input
18	var6_12	Numeric	2	0		None	None	11	Right	Nominal	Input
19	var6_13	Numeric	2	0		None	None	11	Right	Nominal	Input
20	var6_14	Numeric	2	0		None	None	11	Right	Nominal	Input
21	var6_15	Numeric	2	0		None	None	11	Right	Nominal	Input
22	var6_16	Numeric	2	0		None	None	11	Right	Nominal	Input
23	var7_1	Numeric	15	0		None	None	11	Right	Nominal	Input
24	var7_2	Numeric	2	0		None	None	11	Right	Nominal	Input
25	var7_3	Numeric	2	0		None	None	11	Right	Nominal	Input
26	var7_4	Numeric	2	0		None	None	11	Right	Nominal	Input
27	var7_5	Numeric	2	0		None	None	11	Right	Nominal	Input
28	var7_6	Numeric	2	0		None	None	11	Right	Nominal	Input
29	var7_7	Numeric	2	0		None	None	11	Right	Scale	Input
30	var7_8	Numeric	2	0		None	None	11	Right	Nominal	Input
31	var8	String	691	0		None	None	50	Left	Nominal	Input
32	var9_1	Numeric	29	0		None	None	11	Right	Scale	Input
33	var9_2	Numeric	2	0		None	None	11	Right	Scale	Input
34	var9_3	Numeric	2	0		None	None	11	Right	Scale	Input
35	var9_4	Numeric	2	0		None	None	11	Right	Scale	Input

Figure 3.2: This figure is a screenshot from the SPSS program where all the variables serve as inputs.

while answering, such as drawing or looking at pictures; this way, the discussion is less formal. While answering, it is essential for the interviewer to include everyone, and a round-robin approach can be fruitful [KKK01]. For the wrap-up, Kennedy et al. suggest that the interviewer provides a summary of the session without offering participants to add any further comments, as children may not possess the developmental capacity to provide a comprehensive analysis [KKK01]. In the original focus group guide, the question: "*is there anything you'd like to add?*", was listed in the wrap-up. However, after reading this material, I decided to omit this question. I was also aware of the wording used during the session and to keep examples relatable to them. The completed focus group guide is shown in Appendix C.

3.3.2 Recruitment of Sample 2 (S2)

I sent a request to a primary school in Oslo that I had existing connections with. I believed having a personal relationship with the staff would facilitate a faster response. Prior to receiving approval from *Sikt*, I sent out the request to initiate the process, with the understanding that the actual session couldn't take place until the approval and receiving parental approval from the participants. As soon as I got the approval, I started planning my visit. The school got parental approval from 4 parents, allowing me to conduct a focus group, now referred to as Focus Group 1, with four female pupils within the age range of ten to twelve, see an overview of S1 in figure 3.3. The intention was to complete two focus groups; however, the second focus group was changed to an interview, hereby referred to as Interview 1, with a 13-year-old female in 8th grade recruited in my network due to prolonged approval time.

3.3.3 Conduction Session

The session for Focus Group 1 was done at Korsvoll Skole in Oslo. They were kind enough to let me visit their school and talk to a few of their pupils. I talked to four pupils, as depicted in figure 3.3, referred to as Focus Group 1. Within this sample, three pupils were in the 5th grade; aged ten (P1 and P3) and eleven (P2), and one was in the 6th grade, aged twelve (P4). When I arrived at the school, the administration welcomed me and led me to a classroom at my own disposal. While waiting for the pupils to arrive, I arranged a table in the center of the classroom in a formation that allowed everyone to see me and each other. The setup of the session is illustrated in figure 3.4. To record the session, the *Nettskjema Diktafon* app was utilized; this secure tool allows recording through the mobile app, which is then securely transmitted to *Nettskjema.no* while also storing the recording encrypted on the mobile device.

Before starting the session and recording, I introduced myself and told them about the project they are now participating in. As Kennedy et al. [KKK01] suggested, seven ground rules were set:

1. You can pass whenever you do not want to answer a question.
2. Take time to think before answering.
3. Let me know if I do not understand you or if you do not understand me.
4. There is no right or wrong answer. You can say whatever you want to.
5. I will not tell anyone else what you say.
6. One by one, take turns talking.
7. No teasing the others.

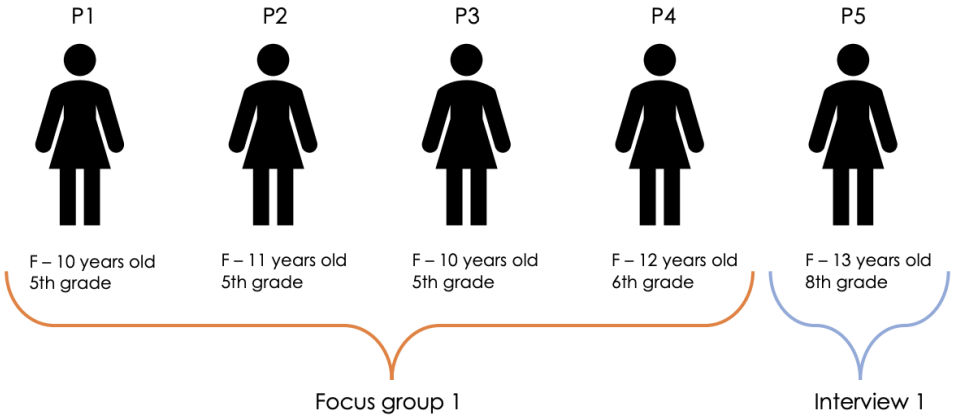


Figure 3.3: This figure provides an overview of group sample 2, which includes both participants in Focus Group 1 and one participant in Interview 1.

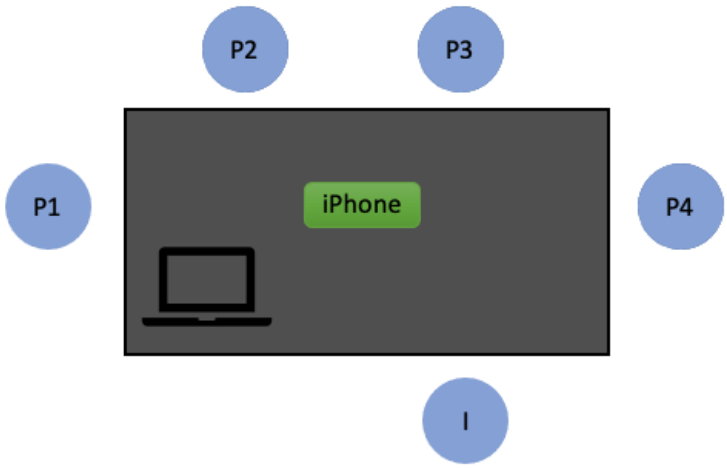


Figure 3.4: This figure presents an overview of the focus group setup, consisting of four pupil participants ("P1" to "P4") and the interviewer ("I").

Then the pupils were asked to confirm again that I had their permission to record the session. To start off the session, the pupils were asked to write down their name, age, and favorite app. We then discussed these apps, why they liked them, and their hobbies and activities outside school. Before going into more serious topics, the words *digital service* and *digital device* were established, explaining that a service is, for instance, an app and a digital device is, for instance, a phone. While presenting these terms, I ensured that everyone understood by allowing them to ask follow-up questions, as these terms remained relevant throughout the rest of the session. Additionally, we quickly established a round-robin structure when talking, fostering a respectful environment where each participant had the opportunity to be heard.

We discussed topics like their digital habits, what devices they possessed, and whether or not their parents gave them a screen time limit. We also talked about their relationship with global warming and what climate change actions they take to reduce their footprint. I proceeded to elaborate on digital services and devices' effects on the environment, focusing on the electricity consumption associated with digital services. To illustrate this concept, I presented an image of a data center and encouraged them to envision it as a "*giant computer that stores all their favorite TV shows, chats, and apps*". I explained that this computer, that's situated far away, has to send this data to their personal device whenever they watch a video or use social media platforms. Although they might not grasp the technical details involved in this process, the key takeaway they comprehended was that every online activity they engage in requires energy, which isn't always sourced from renewable sources, leading to a negative environmental impact.

The discussion part followed right after presenting this information, capturing the pupil's interest and evoking numerous questions and reflections. They were then asked to share their thoughts on potential actions and strategies to raise awareness. They actively participated by offering their ideas and concerns about our digital habits and reflecting on how this discussion might inspire them to make changes. As we concluded the discussion, we delved into their perspectives on the session and what they found most intriguing. Despite the recommendation from Kennedy et al. [KKK01] to not ask questions like *is there anything you'd like to add?* in the wrap-up, their evident knowledge and reflective skills made this question feel natural, providing them with an opportunity to share their thoughts of the session and their key takeaways.

As mentioned earlier, the school encountered difficulties in recruiting additional pupils for the study. Fortunately, a 13-year-old female from my personal network generously volunteered to participate in an interview. Consequently, the second focus group had to be transformed into an interview format at short notice, referred to

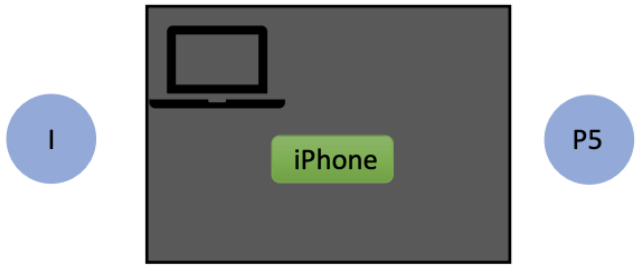


Figure 3.5: This figure presents an overview of Interview 1 setup, consisting of a pupil participant ("P5") and the interviewer ("I").

as Interview 1, see Figure 3.5. Nevertheless, the structure of the session remained consistent with that of Focus Group 1, with the same ground rules presented and the discussion following a similar topic flow.

3.3.4 Ethical Considerations

There are ethical considerations to be taken into account when using children in a research project [Str22]. For this thesis, the consent for the pupil's participation was obtained through their caretakers, who were given an information and consent form with information about the thesis, the data collection, and the guide for the session, see Appendix D. These forms were distributed to the parents by the staff at the elementary school and to P5's parents, the female participating in Interview 1. The pupils were provided with the opportunity to give verbal consent, and they were informed of their right to withdraw their consent at any point during the study. Prior to recording the session, participants of both Focus Group 1 and Interview 1 were given a detailed explanation of the project and its objectives. They were asked to provide verbal consent, acknowledging their understanding of the project's scope and their voluntary participation. Additionally, it was explicitly communicated that participants had the freedom to discontinue their involvement in the project at any time, without the need to provide a reason.

Highlights from Chapter 3

- A literature study was conducted to gain insight into previous research on the environmental impact of the ICT sector and previous user studies.
- Empirical user studies were utilized to gain insight into digital users' awareness of the impact and attitudes to changing digital habits.

Chapter 4
Results

This chapter will provide an overview of the results obtained from the quantitative user survey and qualitative focus group sessions. First, the finding from the user survey will be presented in Section 4.1. Following that, Section 4.2 will present the findings from the quantitative focus group session, beginning with Focus Group 1 and followed by the presentation of Interview 1. These results will be further discussed in chapter 5.

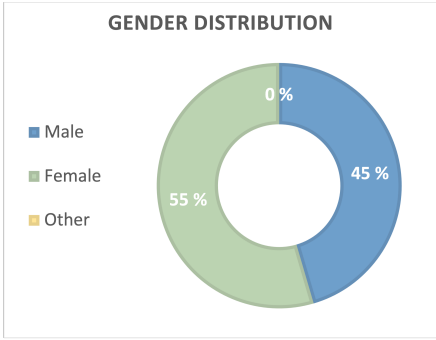
4.1 Survey

In this section, the findings from the survey will be presented. Each subsection represents the different sections of the survey, and the various findings are presented using graphs generated from Excel, along with the results of the statistical tests. These findings will be further discussed in chapter 5.

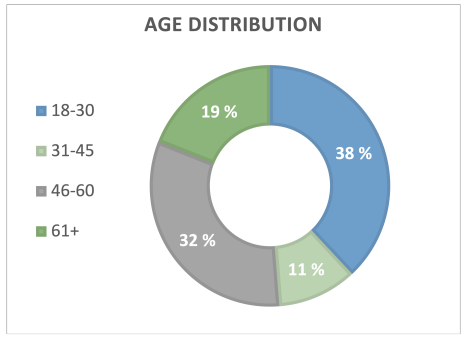
4.1.1 Demography

A total of 242 individuals responded to the survey, encompassing a diverse range of participants. Of the sample, there were 55% female and 45% male participants, ranging from students aged 18 to retired adults aged 85; see Figure 4.1 where the gender and age distribution are presented. The figure shows that the majority of the respondents (38%) are 18 to 30 years old and 46 to 60 years old (32%), while 11% are 31 to 45 and 19% are 61 or older. The respondents included both students and employed professionals with a broad specter of different study fields, as seen in Figure 4.2. The students represented 32% of the participants, while 53% were employed adults, where 43% worked in the private or public sector, and 12% of the participants were retired.

The distribution of education level is depicted in figure 4.3. Among the participants, 4% hold or are currently completing a Ph.D., 50% of the participants have completed or are currently pursuing their master's degree, 34% have completed or

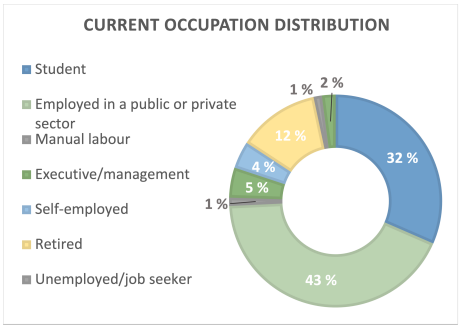


(a) Gender Distribution.

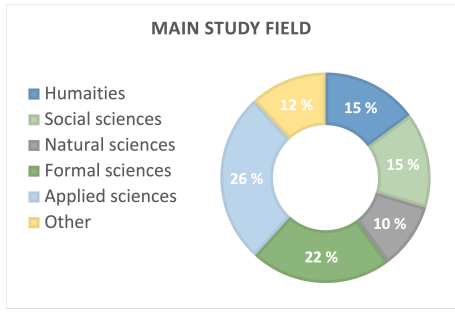


(b) Age distribution.

Figure 4.1: This figure illustrates the personalia distribution from the survey. Figure 4.1(a) showed the gender distribution of the participants and Figure 4.1(b) shows the age distribution.



(a) Occupation distribution.



(b) Main study field distribution.

Figure 4.2: This figure illustrates the current occupation distribution (a) and main study field distribution (b).

are currently pursuing their bachelor's degree, 11% have completed higher secondary school, while 1% or two people's highest education level is lower secondary school. In this thesis, a Norwegian school system is used as a reference. The lower secondary school refers to completing the first ten years of school, while upper secondary school refers to the 13th year, the final year before commencing higher education in Norway. These statistics indicate that the participants constitute a sample of the population with a higher level of education.

4.1.2 Relationship to the Climate Crisis

In the second section of the survey, several questions were asked to map the participant's relationships and attitudes toward the climate crisis. They needed to answer in the scale presented in Table 4.1. When presenting the results, the scale has

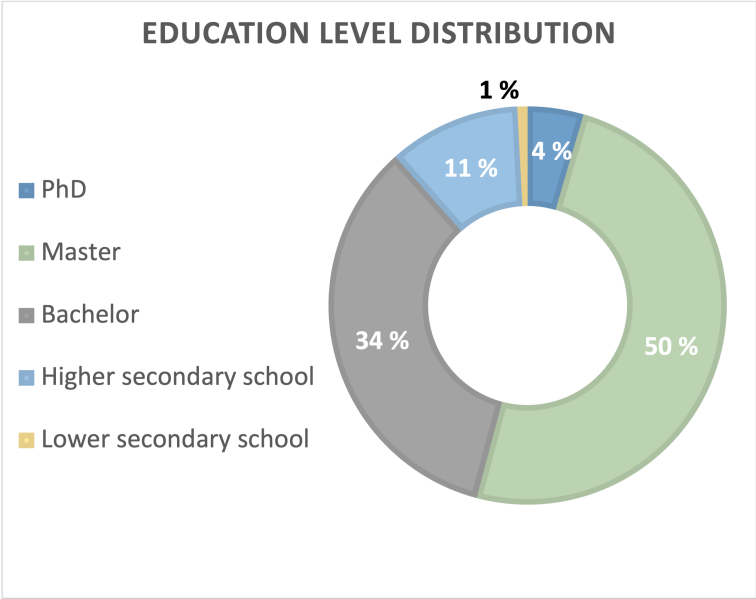


Figure 4.3: This figure presents the education field distribution among the participants.

shifted so the results are more clearly presented; see Table 4.1 for the new scale. The questions consisted of, as explained in Section 3.2.1, a combination of the pre-tested parameters in Kim et al.'s study [KC05] and some new added questions to gain further insights; these are presented in Figure 4.4. This sample demonstrates a widespread environmental concern and awareness of the current global situation. More than 90% of the participants acknowledged that human activities contribute to the climate crisis. Furthermore, over 80% of the participants answered that they were concerned about the situation today, while only ten people (4%) strongly disagreed with being concerned. Further, 83% of the sample agrees or agrees strongly that they feel responsible for solving the climate crisis; however, 87% answered that they either agree or strongly agree that politicians and large companies are responsible for facilitating environmentally friendly choices.

Next, the participants were asked structured questions where they checked off what environmentally friendly measures they take part in today; the distribution is shown in figure 4.5. A significant majority of 96% of the participants reported actively recycling their trash, and 81% expressed mindfulness regarding their electricity usage in their living space, showing a conscious effort to conserve energy. Further, 80% stated that they eat plant-based meals at least three times a week. 37% of the participants use an electric car, a notable contribution to reducing carbon emissions, and 40% expressed their support for environmentally friendly organizations. Subsequently, the

New scale	Equivalent in old scale
Strongly disagree	Strongly disagree + disagree
Disagree	Slightly disagree
Neutral	Neutral
Agree	Slightly agree
Strongly agree	Strongly agree + agree

Table 4.1: This table presents the transition from the scale utilized in the survey to the scale employed for presenting the findings.

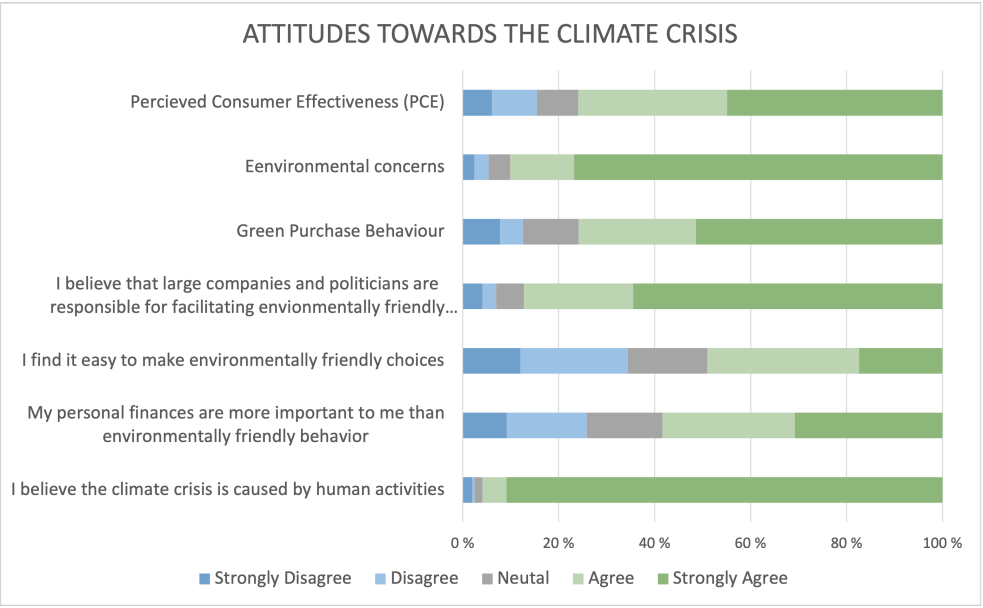


Figure 4.4: This figure presents the results of attitudes the participants has towards the climate crisis.

respondents were asked an unstructured question about what other measures they use today. Some frequently answered measures were buying used clothes, opting for train travel instead of flying, choosing to walk instead of using fuel-based transportation when possible, choosing to be vegetarian or vegan, using a bicycle instead of a car, and purchasing second-hand goods. Some less frequently mentioned responses included statements such as "*I shop foods that are in season*" (Female 35), "*limit water use*" (Female 35), and "*I will contribute by pursuing a good education that can make a difference by developing new energy-efficient systems*" (Male 21).

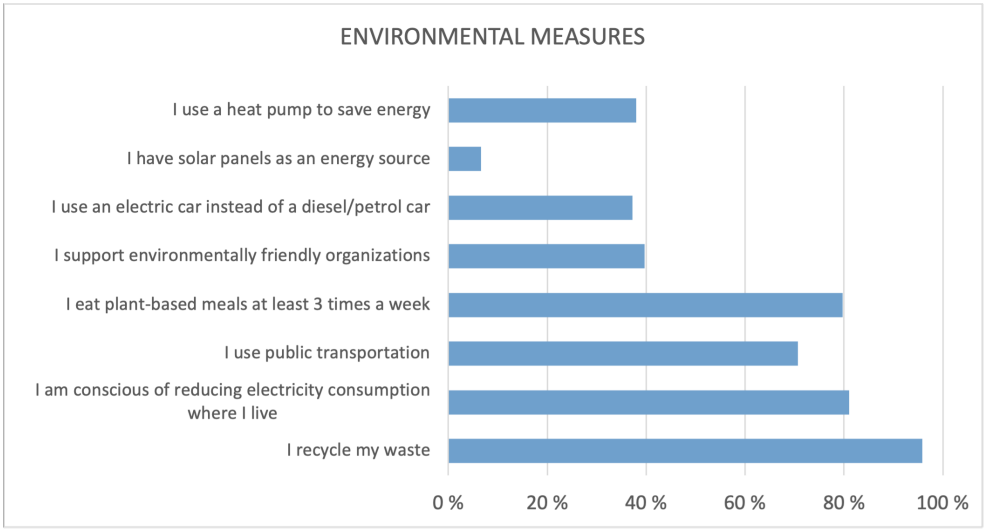


Figure 4.5: This figure presents the results of environment-friendly measures the participants take part in today.

4.1.3 Digitalization and the Climate Crisis

In section three of the survey, the participants were again asked to react to different statements concerning their perception of digitalization and the climate crisis on a scale from strongly agree to strongly disagree. Figure 4.6 presents this distribution. 63% of the participants agree or strongly agree to the statement "*Digital technology is helping to address the climate crisis*" while 90% disagree or strongly disagree with the statement "*The production of digital devices has no negative impact on the environment.*" 66% of the participants are neutral to the statement "*It is better for the environment to live stream TV programs from a digital platform than to watch traditional linear TV*," meaning that most of the participants don't have a strong opinion related to this matter. Further, 91% of the participants strongly agree that "*It is better to have a digital Teams or Zoom meeting than to fly to another city*," while 41% strongly agree to "*It is better to have a digital Teams or Zoom meeting than to drive for 10 minutes by car.*" 73% of the participants believe that "*Digitizing contributes to the development of renewable processes.*"

4.1.4 Material Impact

In the fourth section about the material impact, there were some structured questions and one unstructured question allowing an open response. In the first question, the participants were asked to check which digital devices they possessed. Of the participants, 99.5% possessed a smartphone, 93% a PC/Mac, 51% an AppleTV or

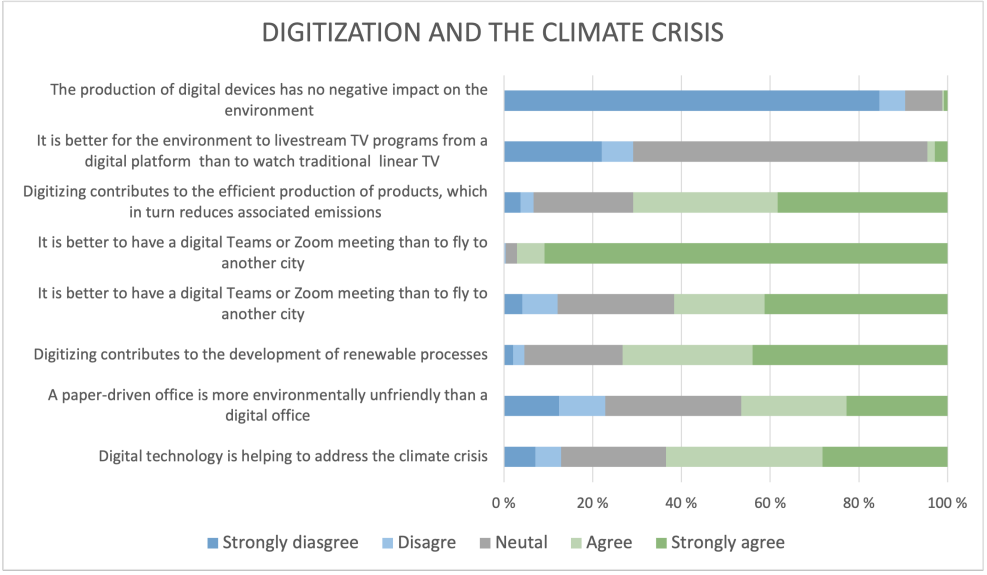


Figure 4.6: This figure visualizes the participants' perspectives on digitalization and its relationship to the climate crisis.

Chromecast, and 72% a TV. In addition to this, 50% possessed a computer monitor, 36% an iPad, and 23% had a digital watch with the ability to access WiFi or a wireless network. An open-ended follow-up question was asked where they could list what other devices they possessed, some of the answers were Playstation, Kindle, Robot Vacuum, Google Home, and VR-headset.

Another follow-up question to the initial one was: "*How many of these have you inherited or bought used*?". The distribution is shown in Figure 4.8, which reveals that 51% answered "none", 24% answered one device, 22% answered two to three devices, and 2.5% answered between three to 14 devices. Only one person, a 45-year-old male, answered that he had inherited or bought 15 or more devices used.

The last question of this section aimed to map what the participants do with their device after they were done using it, they were allowed to check off multiple answers. The answers are presented in figure 4.9. This revealed that under 1% throw the device away in a regular trash can, 6% report losing their device, 49% recycle them, 43% give them away, and 33% return them to the store. Notably, a substantial 57% of the participants indicated putting the device in a drawer somewhere.

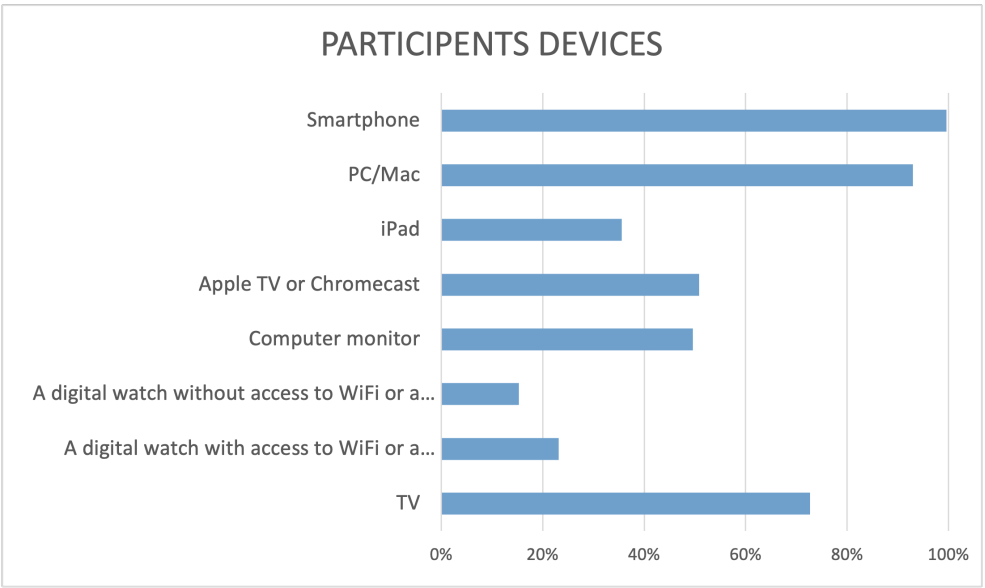


Figure 4.7: This figure shows the results of which digital devices the participants possess.

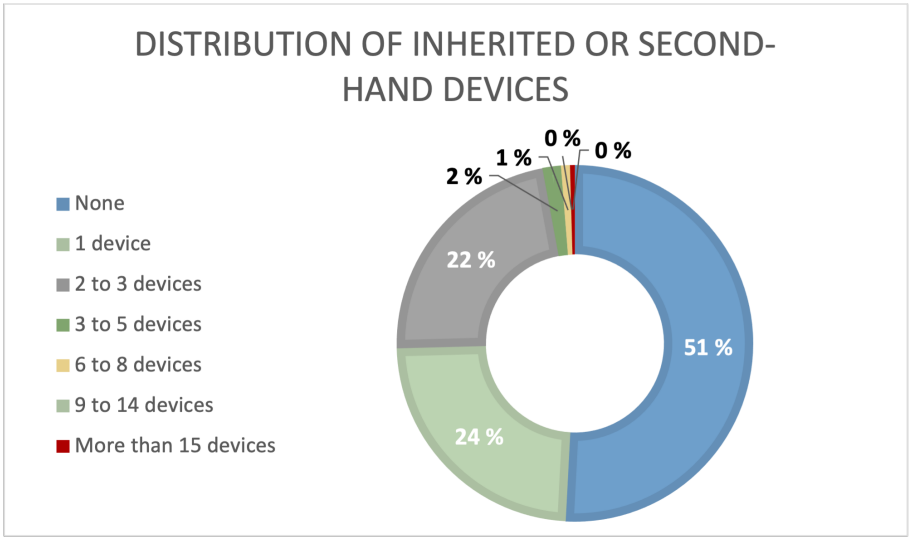


Figure 4.8: This figure presents the distribution of the number of devices that participants have inherited or purchased second-hand.

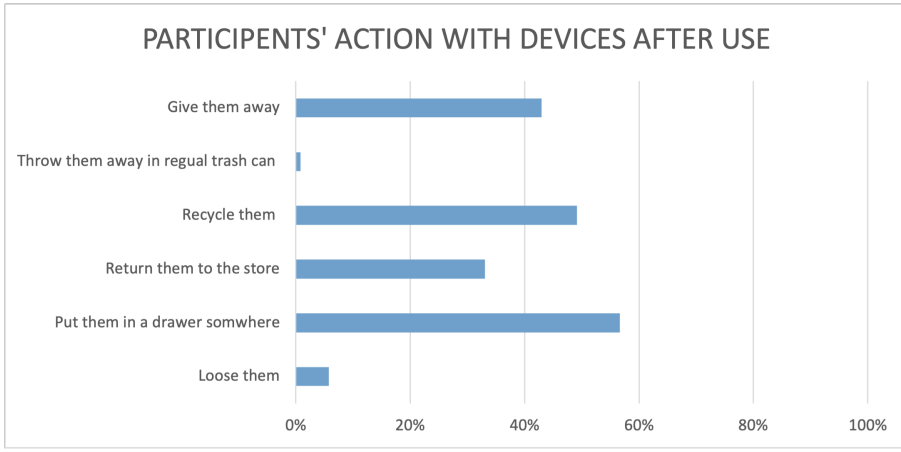


Figure 4.9: This figure displays the actions taken by participants with their devices after use.

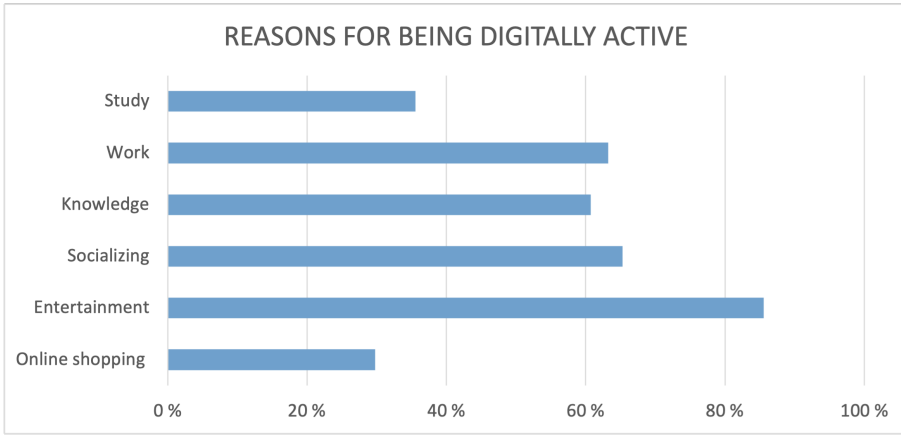


Figure 4.10: This figure displays the results of participants' responses to the question, "What are your main reasons for being digitally active?.

4.1.5 Personal Digital Habits

In the fifth section, the participants were asked to answer questions related to their digital habits. The first question was "*What are the main reasons for you to be digitally active*?," and they were allowed to cross off multiple answers. The two most answered reasons were to socialize and for entertainment. This is presented in Figure 4.10. An open-ended question followed where they were given the opportunity to list more reasons besides the ones listed in the previous question. A few people gave examples such as volunteer work, political engagement, planning, and time filler.

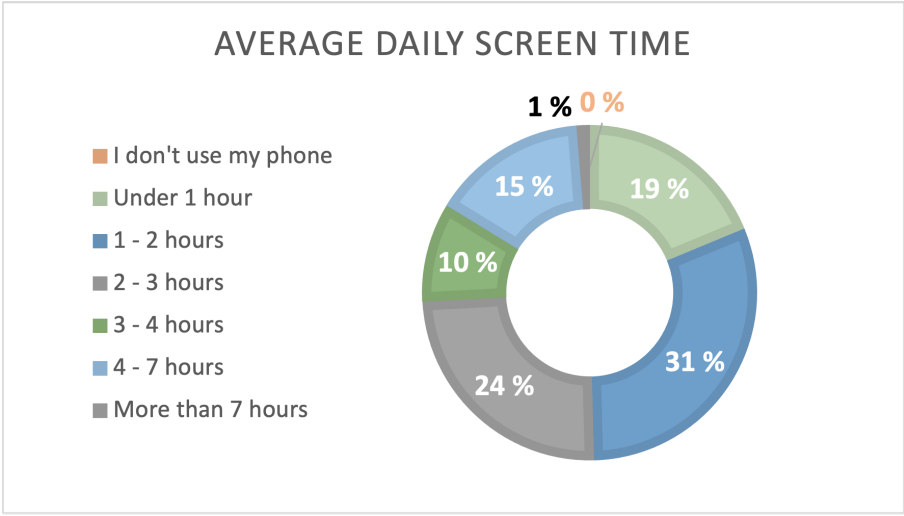


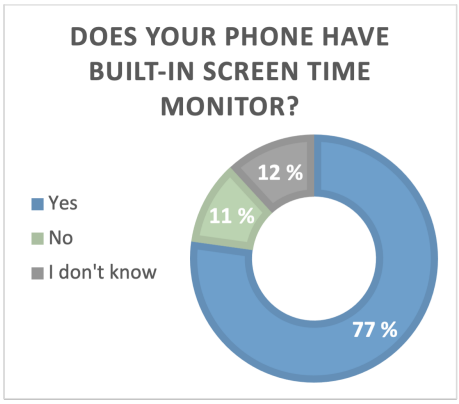
Figure 4.11: This figure presents the distribution of participants' self-reported average daily screen time.

The next question was "*How many hours of screen time do you have on average on your mobile phone in a day*". They were only able to check for one alternative, and the distribution is shown in Figure 4.11. 19% reported spending under one hour on their phone, 31% stated that they spend one to two hours, 24% spent two to three hours, 10% three to four hours, and 15% spent between four and seven hours on their phone. Three people (1%) answered that they spend more than seven hours on their phone, while no participant selected the "I don't use my phone" option.

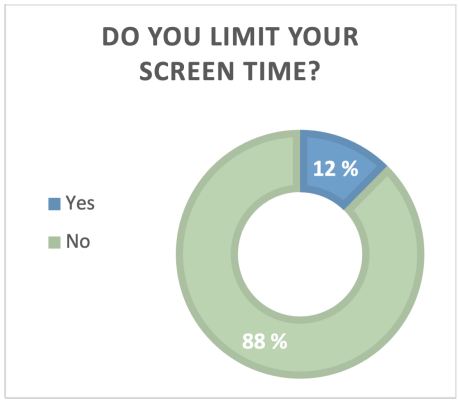
A related question followed where participants could list an app they considered their most frequently used. The responses varied significantly, although the prevailing choices included Facebook, Instagram, and Snapchat. Less frequently mentioned applications encompassed online newspapers, Safari, and Spotify.

Considering the participants' average screen time, a trichotomous question was used to gather information on their awareness of a built-in function on their phones that monitors their screen time. A trichotomous question offers respondents three response options, a clear "yes" and "no," in addition to an option to indicate uncertainty with "I don't know." The question was "*Does your phone have a built-in function that monitors your screen time?*." 77% of the participants answered "yes," 11% answered "no," while 12% answered, "I don't know," as illustrated in Figure 4.12a. This indicates that the majority of the respondents are familiar with the concept.

A follow-up question was then presented inquiring whether they used this function



(a) Built-in monitor function.



(b) Utilization of screen time monitoring.

Figure 4.12: This figure displays the responses of participants regarding their utilization of built-in monitor functions.

to lower their screen time, and if so, how. Merely 12% of the participants answered that they utilize this service. The few respondents who actively utilize these features mentioned practices such as night mode and abstaining from phone usage during nighttime. Others employ app time limits, requiring a passcode to regain access after a predetermined period. Some rely on their iPhones' built-in screen monitoring app to track their screen time. Several individuals have activated the *gray screen* function, rendering the display grayscale to discourage prolonged usage. A few respondents mentioned utilizing the *OneSec* app, which introduces a three-second delay upon opening an app, providing insights into usage frequency and prompting users to decide whether to proceed or exit. On the other hand, some individuals confessed that they had disabled these features due to feelings of guilt surrounding excessive screen time.

The next few questions were related to digital streaming services. Figure 4.13 illustrates how many hours the respondents spend watching different streaming services on average daily. Among the participants, 18% claim they don't engage in digital streaming, while 36% reported watching less than one hour, 26% indicated they watch one to two hours, 5% answered they stream for three to six hours daily, while 3% answers they stream more than six hours on a digital platform each day. In relation to this, they were then asked to check off which steaming service they had access to; this can be seen in Figure 4.14. This question revealed that 80% had access to Netflix, 61% had access to HBO Max, 42% had access to Viaplay, 41% had access to Disney+, 37% had access to TV2 Play, and less than 20% had access to Amazon Prime, Apple TV+ or Discovery+. This leaves the most popular streaming services to be Netflix and HBO Max.

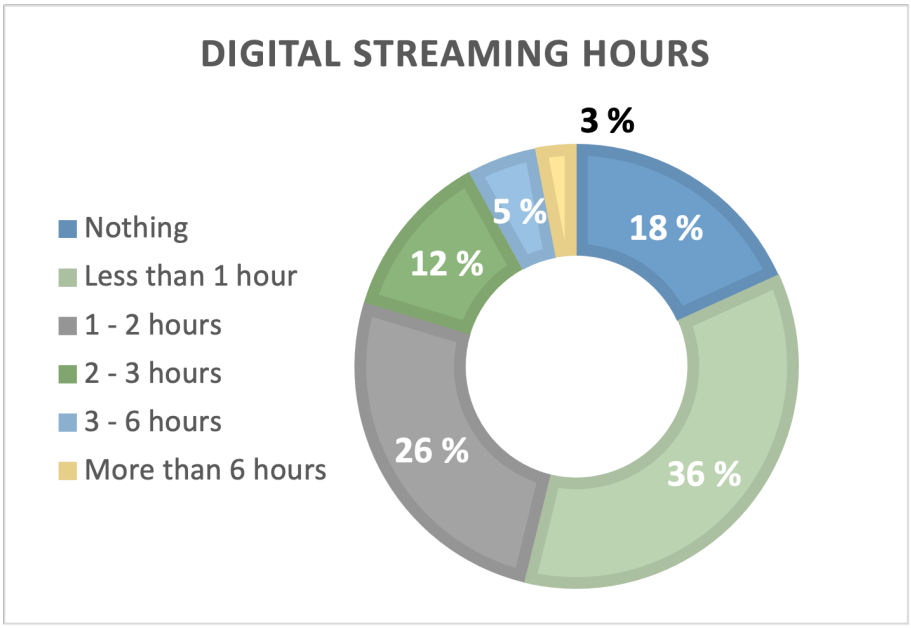


Figure 4.13: This figure presents the average number of hours participants reported spending on streaming digital services.

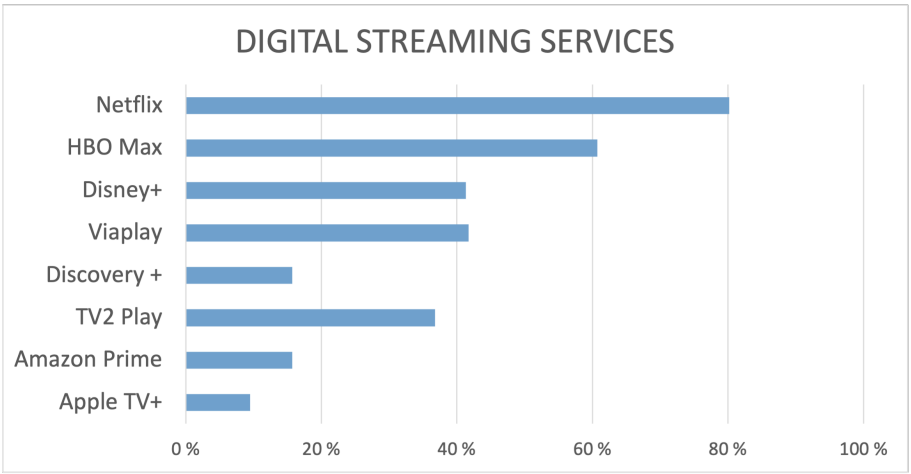


Figure 4.14: This figure displays the digital streaming services that participants reported having access to.

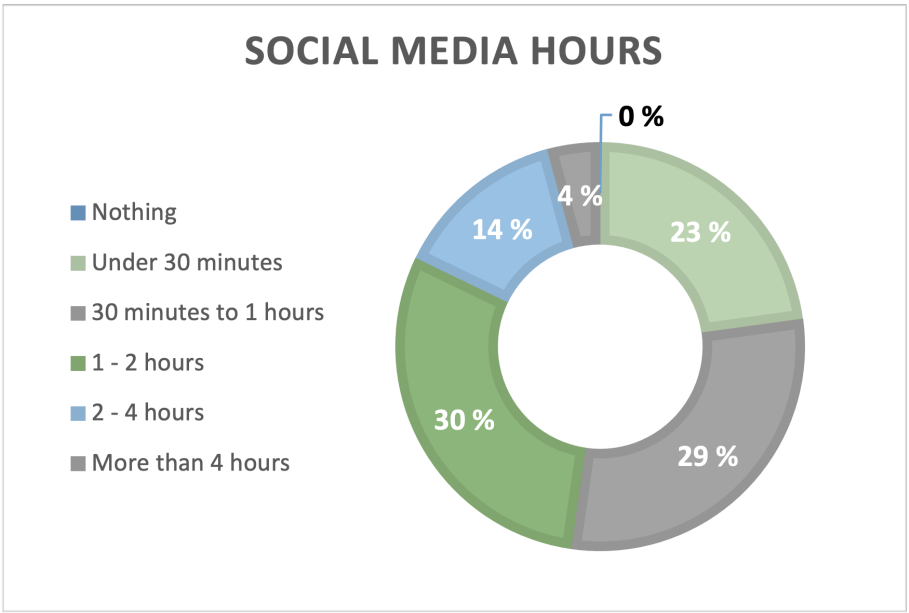


Figure 4.15: This figure illustrates the distribution of participants' time spent on various social media platforms.

In addition, the participants were asked about their daily usage of social media platforms. The results, shown in Figure 4.15, show that 23% of the participants reported that they spent under 30 minutes, 29% stated between 30 minutes and an hour, 30% indicated between one and two hours, while 14% reported between two to four hours. Only 4% said more than four hours, and no participants reported spending no time on social media.

Following, the participants were asked what cloud services they use, and they were allowed to check off multiple answers, the results are shown in Figure 4.16. It is important to acknowledge that an error occurred during the creation of the survey, as Google Drive and Microsoft OneDrive were intended to be presented as two distinct alternatives. However, 73% of the participants reported that they use Google Drive or Microsoft OneDrive, 47% said they use iCloud, 27% had access to DropBox, and less than 1% used Box. An open-ended question followed where they could list other cloud services they used. The most frequent answers included Jottacloud, Min Sky (Telenor), and Telia Sky.

Another related question explored whether participants stored the same content on two or more different cloud services. The results showed that 23% of the participants answered "yes," 39% claimed they don't do this, and 38% indicated that they don't know, see Figure 4.17 for the visual representation of these findings.

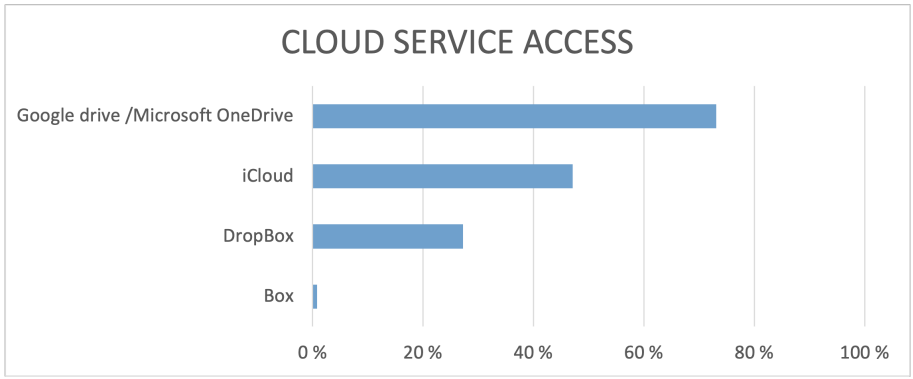


Figure 4.16: This figure presents the distribution of cloud services accessed by the participants.

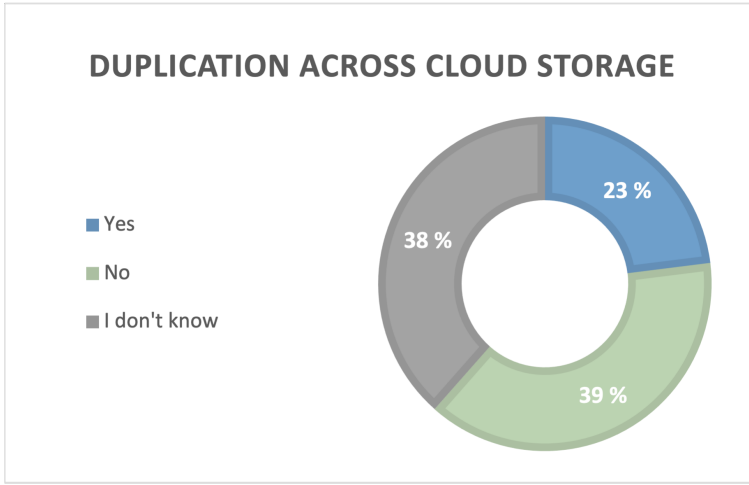


Figure 4.17: This figure presents the responses of the participants regarding the duplication of content across multiple cloud storage services.

In the final question of this section, participants were presented with statements Elgaaied-Gambier et al. [EBB20], and they were asked to check off which actions they currently engage in. The results are displayed in Figure 4.18. The actions that are most commonly practiced include deleting older emails (57% of participants), keeping website tabs open until completely finished with them (52%), and bookmarking frequently used websites (50%). The less frequently observed actions are; watching videos in low to medium quality instead of HD (5%), compressing attachments before downloading them, using an environmentally friendly search engine like Ecosia, and opting for sustainable online storage options are less frequently observed, with the last three with fewer than 2% of participants reporting these behaviors.

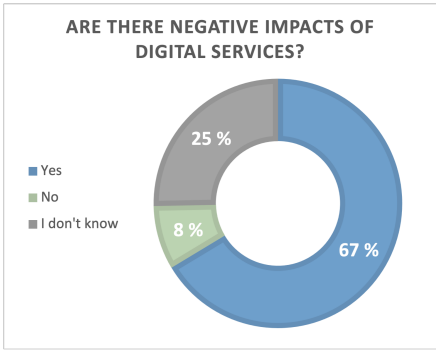
4.1.6 Digital Services Environmental Impact

The next set of questions was related to what perception the participants had about digital services' environmental impact. The first question was if they thought their use of digital services harmed the environment. As Figure 4.19a illustrates, 67% of the participants answered "yes", 8% said "no", while 25% expressed that they didn't know. Further, they were asked whether the aviation sector has a greater negative impact than the ICT sector. Of the participants, 46% answered that they thought the aviation sector had a bigger impact, 27% answered that the ICT sector, in fact, had a greater impact, while 27% said they didn't know. This is shown in Figure 4.19b.

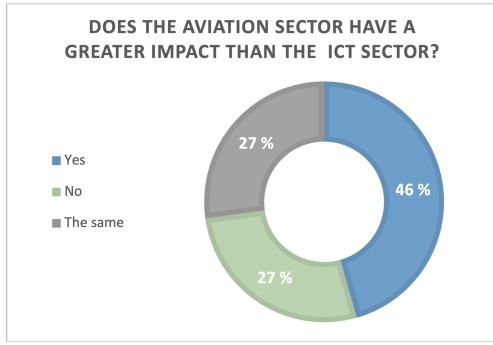
The next question was again a set of statements where the participants were asked to rate to what degree they agreed to the statement, the same scale as shown in Table 4.1. The statements were related to the environmental impact of the ICT sector, as seen in Figure 4.20. Among the participants, a significant majority of 77% agreed that data centers have substantial emissions and exert negative impacts on the environment, and 20% agree or strongly agree that if they are powered by renewable energy, it poses no threat to the environment. Only 8% of the participants agree or strongly agree that it is easy to calculate the environmental impact of digital services. 71% of the participants agree or strongly agree that the increased emissions from digital services are a problem, while 49% agree or strongly agree that the rising emissions associated with digital services will affect their life negatively in the future.

The last question of the sixth section was to map whether the participants thought there was a more environmentally friendly search engine than Google available today. In Figure 4.21, it is shown that 82% of the participants thought there was indeed a more environmentally friendly option, while 18% said no. 12 participants didn't respond to the question.

Figure 4.18: This figure displays the responses of the participants regarding the environmentally friendly actions they currently undertake.



(a) Perception of digital service's environmental impact.



(b) Aviation sectors impact greater than ICT sector.

Figure 4.19: This figure presents the participants' perception of the environmental impact of their digital service usage (a) and the participants' perceptions regarding the environmental impact of the aviation sector compared to the ICT sector(b).

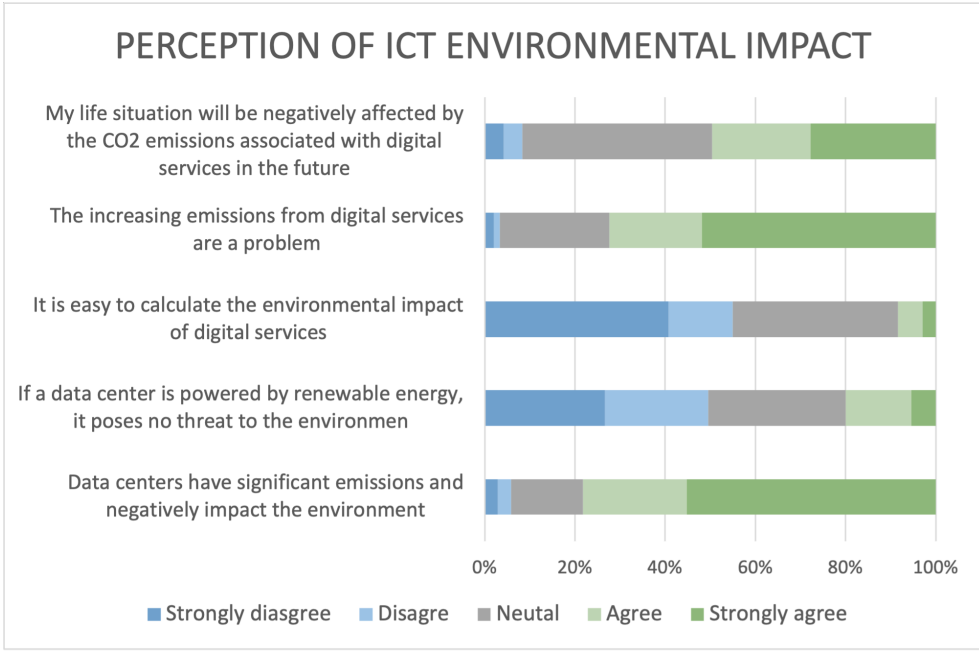


Figure 4.20: This figure presents the participants' reactions to the statements regarding the environmental impact of the ICT sector.

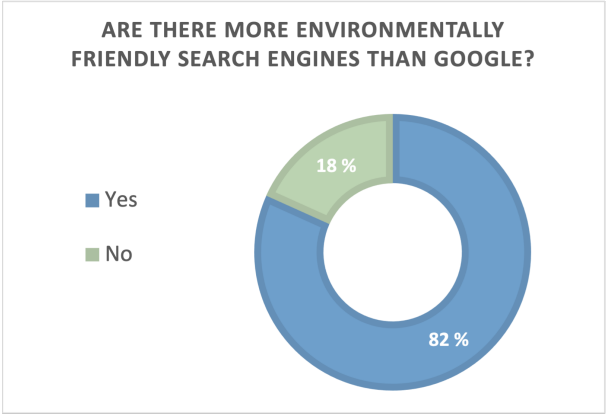


Figure 4.21: This figure presents the distribution of responses among the participants regarding their perception of whether there are search engines more environmentally friendly than Google.

4.1.7 Willingness to Change Digital Habits

In this particular section of the survey, participants were presented with a set of actions identical to those outlined in Subsection 4.1.5, as depicted in Figure 4.18. They were then instructed to indicate their willingness to undertake these actions in the future by checking off the respective boxes, the result is shown in Figure 4.22. In Figure 4.23, a comparison of the two figures is shown side by side. Among the actions presented, the majority of the participants expressed their willingness to delete older emails (88%), recycle their phones (82%), and completely shut down their computers (81%). The actions that received less enthusiasm were using an environmentally friendly search engine, such as Ecosia (37%), using a sustainable online storage option (34%), and watching videos in low to medium quality instead of HD (29%). These findings suggest that overall, there is an increased willingness to change habits, although the less conducted actions remain the same.

Barriers for Changing Habits

An open-ended question followed where the participants were encouraged to leave a comment about what barriers they see that would prohibit them from changing their digital behavior. There were 68 individuals who left a comment, providing a large variety of opinions. Thirty-one participants identified a lack of knowledge as their main barrier to changing their digital habits, expressing a desire for more information or a need for further knowledge. They also expressed the difficulty of obtaining information about the challenge of reducing their digital carbon footprint and identifying actionable steps to mitigate it.

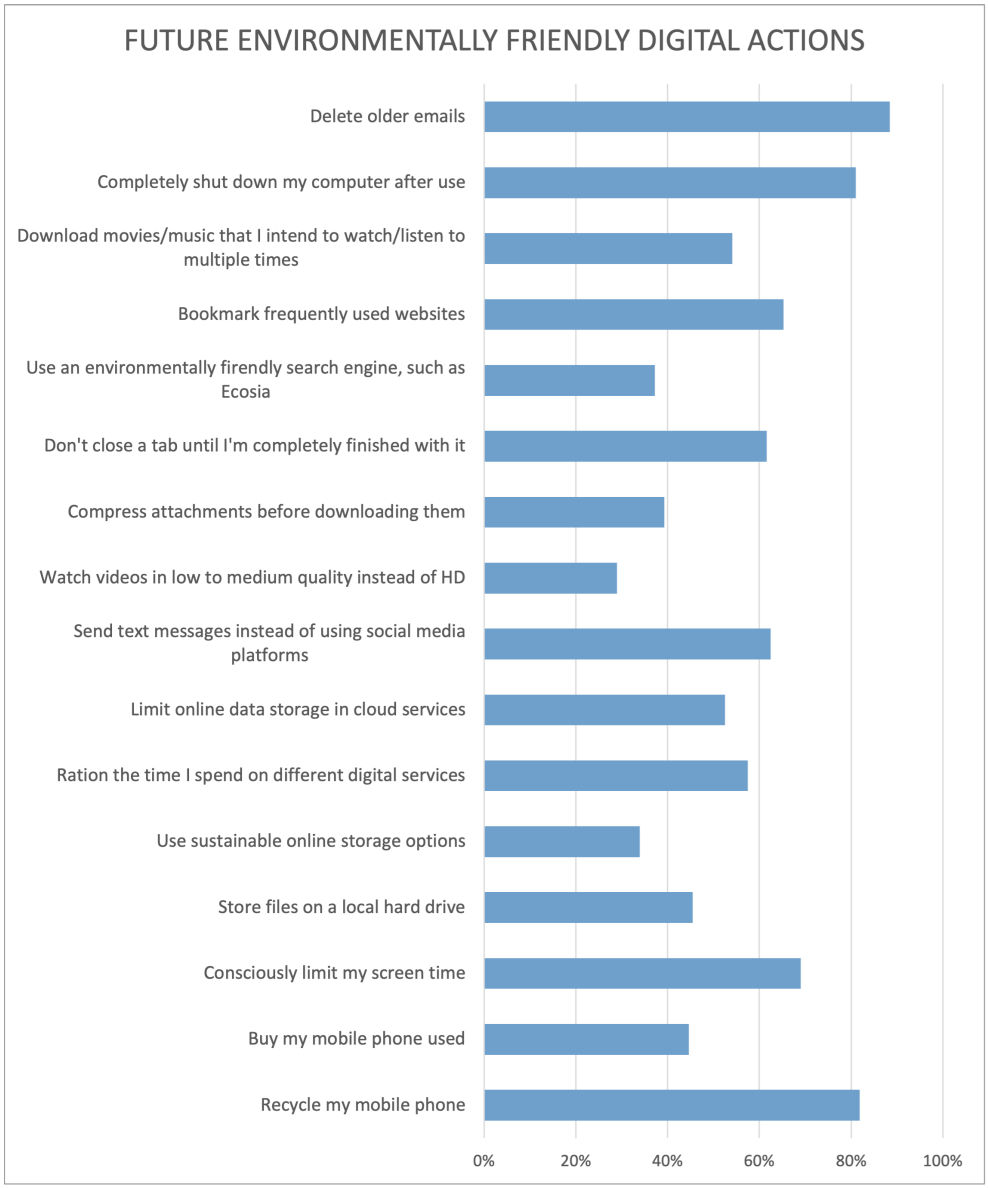


Figure 4.22: This figure represents the participants' responses regarding their willingness to take specific environmentally friendly digital actions in the future.

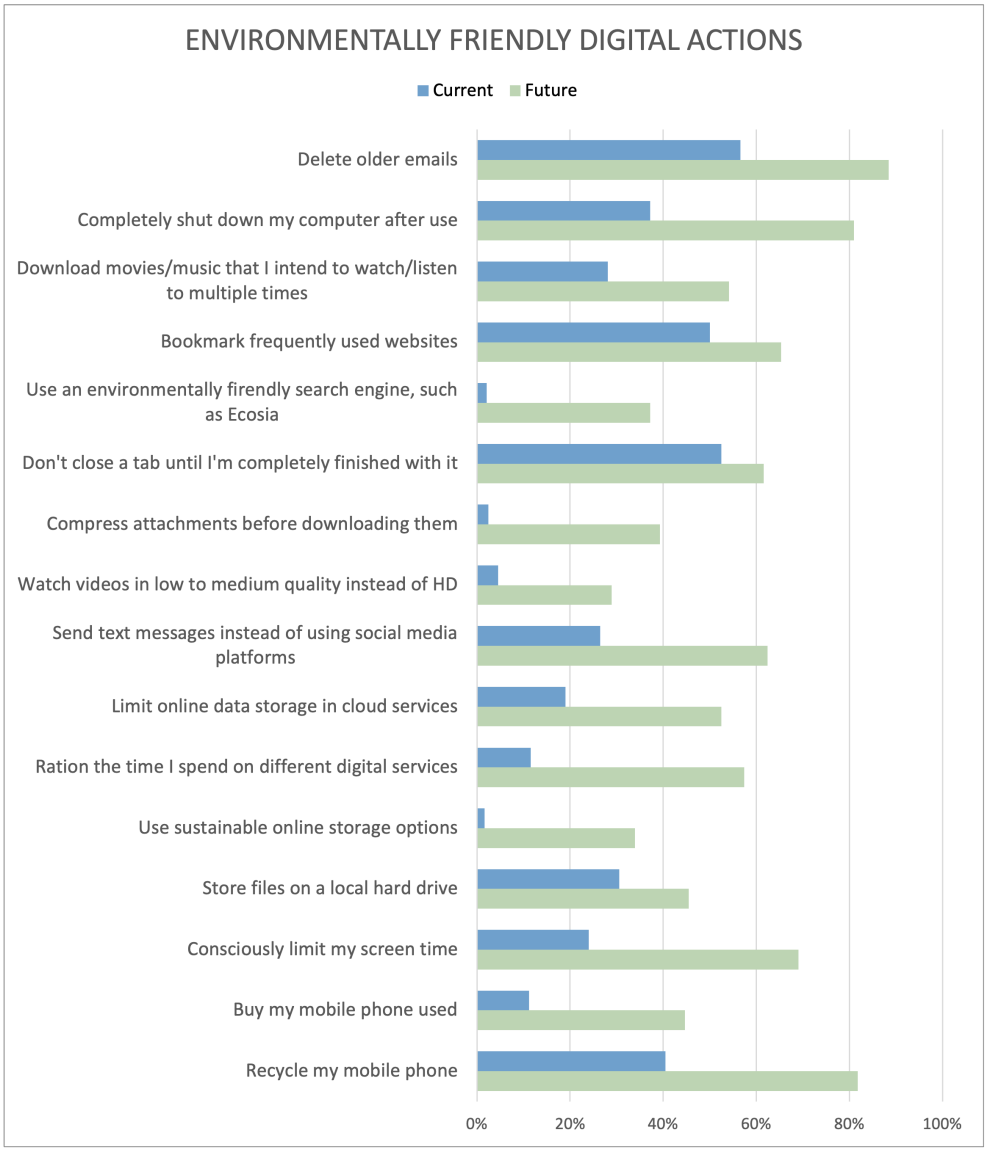


Figure 4.23: This figure presents the participants' responses comparing the two questions of environmentally friendly digital actions from Figure 4.18 and Figure 4.22.

The most frequent answer was related to "*Lack of knowledge*," which individuals from all age groups expressed. Another common response was the feeling of not having the ability to make an impact.

> "*The feeling of being a drop in a vast ocean*" - Male 49.

> "*Demotivating when it doesn't have much impact*" - Female 25.

> "*Changing personal habits becomes less effective when the fundamental systems need to be altered*" - Male 45.

Some of the participants expressed various psychological factors.

> "*Laziness*" - Male 67.

> "[...]*addiction*" - Male 50.

> "*The mentioned measures impact my comfort of living*" - Male 30.

> "[...] *Habits are so well integrated into my life that I rarely think about them*" - Male 24.

> "*My only social life is through the internet, I am disabled and have no other options*" - Female 64.

Others expressed concerns about the financial aspects. Many believe that sustainable options often are more expensive.

> "*Cost* [...] *good environmental choices becomes challenging without the financial resources to make those choices*" - Male 25.

> "[...] *fear of making a bad used purchase and fear of spending a lot of money on something that becomes outdated or breaks*" - Female 27.

> "[...]*the less sustainable options are usually more accessible and user-friendly*" - Female 19.

Yet others highlighted the practical aspects of utilizing cloud services and storing all old emails. As a result, this ensures constant accessibility and effortless navigation whenever they require access to previous information.

> "*I find it difficult to delete older emails because they are helpful for references and memories*" - Female 45.

> "[...] *data/files that must be shared with colleagues. This makes it difficult to move away from cloud services and makes tidying up time-consuming*" - Male 43.

Some others referred to the overwhelming feeling associated with climate change and everything happening with technology without even noticing it.

> "[...] *the most significant barrier is that the climate crisis is so overwhelming that it becomes harder to make good choices. Another barrier is that our leaders (politicians) don't take this seriously enough, which kills the motivation to take significant actions as individuals*" - Male 50.

> "[...] *there is so much happening without one being aware of it or noticing it, for example, when Gmail automatically filters emails into categories like "promotions". They become somewhat invisible, and suddenly there are thousands of emails stored somewhere*" - Female 27.

> "*I think it would be more effective if we had legislation that compelled us to live more environmentally friendly*" - Female 57.

Lastly, some people expressed that they were under the impression that digitalization is helping fight climate change and not worsening it.

> "[...] *we hear a lot about video quality improving and becoming so good. Therefore, it feels strange to lower the quality when all we hear otherwise is positive, and it is portrayed as a good thing*" - Female 25.

> "*I'm under the impression that the efficiency gained from digital tools outweighs the environmental issues*" - Male 28.

The next question asked was whether participants took any supplementary measures to the actions mentioned today to reduce their digital carbon footprint. Surprisingly, some participants demonstrated a certain level of awareness and described conscious decisions based on this knowledge. Some of the participants indicated other sustainable habits they have learned they could do.

> "[...] *turn off Bluetooth when it is not needed*" - Female 27.

> "*I stopped sending GIFs after learning about their carbon footprint*" - Female 19.

> "*I have shut down two websites I owned in the past year*" - Male 57.

A 47-year-old male mentioned that he "*compensates with carbon offsets*," emphasizing that some individuals utilize financial resources to reduce their carbon footprint. A 26-year-old female participant commented that she had "*checked off things I have done without knowing they were more environmentally friendly.*" This response reflects a positive outcome, suggesting that individuals may engage in environmentally friendly habits even without being consciously aware of their impact.

Another participant pointed out how the main focus in society affects what he personally focuses on.

> "*I'm trying to follow the advice given, but so far I feel like it hasn't been a major focus for me. The focus has been more on the energy consumption of cryptocurrencies, and recently there has perhaps been a bit more focus on the enormous resources that AI consumes*" - Male 49.

4.1.8 Concluding Remarks

In the last section of the survey, the participants were given the opportunity to leave a comment or feedback if they wanted. Some of the participants used this opportunity to address again that they wish they had more knowledge.

> "*It would be very satisfying to include a "solution" or fact box about carbon footprint and resource consumption in the survey - at the end.*" - Male 62.

> "*More information should be provided on how to save electricity when using cloud storage and similar services*" - Male 25.

Other participants expressed that the survey contributed to raising their awareness.

> "*Until now, I haven't really thought much about my digital footprint, but hopefully, I will become more conscious of it in the future*" - Female 23.

> "*I don't quite know how much things matter! It was nice to have a list of actions to do!*" - Female 26.

> "*Raising awareness is important. Thank you!*" - Female 52.

> "*Many people are completely unaware of the environmental impact of digital services. It's great that you are shining a spotlight on this issue*" - Female 54.

> "*I may need to look into what I can do about my digital footprint if it is indeed a problem. I thought digital usage was environmentally friendly*" - Female 71.

Others pointed out again that the responsibility lies with the big companies and not individual humans.

> "*The services we use need to become better at making it easy to make sustainable choices* [...] *and should be developed with consideration for their carbon footprint*" - Male 27.

> "*I fail to see the point of deleting emails when Equinor releases three billion tons of CO2 before lunch*" - Male 29.

> "*Regarding the environmental movement, it is important to consider financial motivations. The climate is constantly changing and will continue to do so. Humans cannot change it. Regarding the environment, Norway is one of the cleanest countries in the world. Anyone who claims otherwise probably hasn't traveled much*" - Male 70.

A 24-year-old male shared some very reflective thoughts and concerns. He expressed that although he lacked knowledge regarding the extent of the digital

environmental impact, he emphasized the need for significant changes to address unhealthy consumer habits.

> "*A little light went on for me when a lecturer said that one Google search could heat 12 cups of coffee. I don't know if it is 100% accurate, but I am willing to believe it is in the ballpark of a reasonable estimate. Google is a search engine in an unimaginably large network called the Internet. I see it as a problem that people lose sight of how much energy they use with the digital tools they use nowadays.*" - Male 24.

> "*I don't have a solution, especially because it is easier to complain and criticize than to fix the problems we face. Nevertheless, I believe many people (including myself) should have a reality check on how much energy digital technologies consume and their effect on the environment.*"
> - Male 24.

Another young male shared a joke retrieved from ChatGPT:

> "*Here's a joke from ChatGPT on your topic: Why did the mobile phone feel so lonely? Because the owner had deleted all the apps that kept it busy and reduced its digital footprint!*" - Male 23.

One participant left a comment expressing that she believed that a paper-based educational system is better than a digital one.

> "*The digitalization of schools is neither environmentally friendly nor beneficial for learning. Paper books can be reused and recycled, which is not the case with the electricity consumed during screen time*"
> - Female 23.

> "*I believe the solutions lie in renewable resources and clean energy production. I think we will be stuck in a rut if the solution is for everyone to become Luddites and, in a way, turn their backs on technological progress*"
> - Male 49.

Lastly, the participants were provided with an opportunity to leave comments, and for the most part, they took this opportunity to leave positive feedback and express gratitude for the awareness they gained from this survey.

"*I felt guilty for how little I actually do. Good luck!!*" - Female 57.

"*The survey made me more conscious of the choices I make in my everyday life*" - Female 25.

"*It was an interesting survey that made me think more about my digital footprint*" - Female 23.

"*Great that you're writing a paper on this. Awareness is crucial. Otherwise, there won't be any change*" - Female 58.

Highlights from Section 4.1

- On average the participants felt a responsibility to limit their environmental footprint.
- The participants spend on average one to three hours on their phone.
- Few of the participants use screen time monitoring to lower their screen time.
- The participants showed a willingness to change habits to more environmentally-friendly alternatives.
- Barriers such as lack of knowledge, difficulty to make the *correct* environmentally-friendly actions, and the feeling of not having an impact as an individual were common.
- Many believed that politicians had a responsibility to facilitate environmentally-friendly choices.

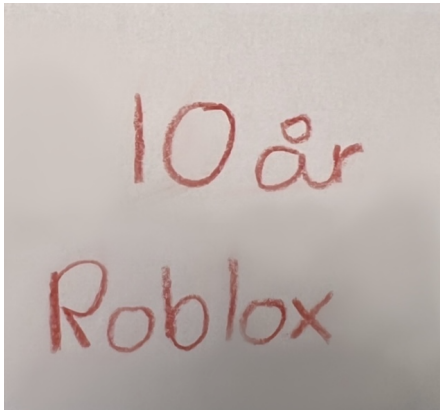
4.2 Focus Groups

This section will present the results from the focus group sessions. Overall the conducted focus group indicates that children are more interested and engaged in solving the problems than the adults who responded to the survey. The children were more eager to expand their knowledge on the subject matter and actively spread more awareness. During the discussion with Focus Group 1, a thought-provoking question was raised regarding the apparent familiarity surrounding the environmental impact of the aviation sector, contrasted with a relative lack of knowledge regarding the potentially higher carbon footprint associated with digital services[Fer19], P4 responded:

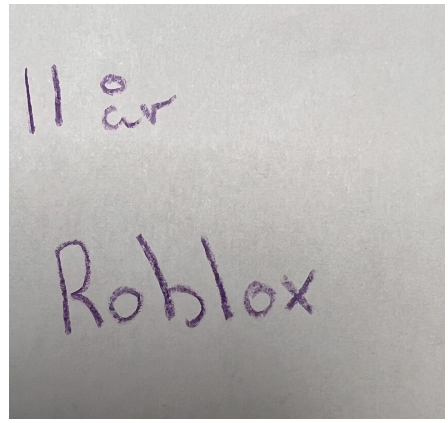
> "*I knew almost nothing about this. I hadn't really thought about it, so I was a bit surprised. One should probably say like, use your phone less [...] that would help, right?*" - P4, 12 years.

4.2.1 Focus Group 1

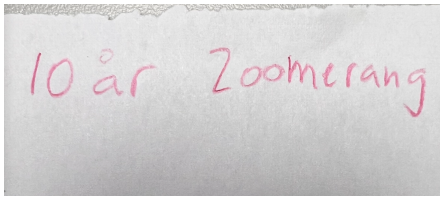
When first explaining why digital services can have a negative impact on the environment, they were asked what their immediate thoughts were, and without thinking about it, one participant responded: "*I maybe think that I should reduce my screen time, perhaps?*" (P3, 10 years).



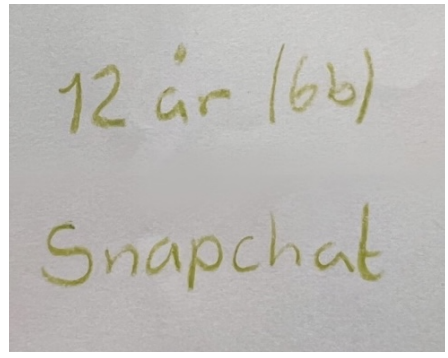
(a) P1



(b) P2



(c) P3



(d) P4

Figure 4.24: This figure presents responses from the participants from Focus Group 1, where they wrote down their favorite app and age on a note.

The participants were asked to write their name, age, and favorite app to warm

up. Their responses, excluding their name, can be seen in Figure 4.24. Further, we started discussing their hobbies and what they like to do outside school. They were all very active in hobbies such as football, climbing, and cross-country skiing.

Digital Habits

After establishing the concepts of digital devices and services, our focus shifted toward exploring the number of digital devices the participants owned. Remarkably, all participants possessed an iPhone and iPad, with the latter being the primarily used device. Furthermore, we delved into their digital habits and what they prefer to do on these devices. Discussing what apps they used for communication with their friends revealed some interesting insights. P4 mentioned using Snapchat and WhatsApp to stay in touch with friends, while P1 and P2 only used traditional text messages. P3 revealed that she uses WhatsApp and traditional text messages. She noted that WhatsApp played a crucial role in facilitating class communication, as not all participants owned iPhones and could not access the group iMessage feature. WhatsApp, being accessible across various devices, emerged as a viable platform for inclusive communication.

We continued to discuss their streaming habits, which revealed that when the participants wanted to watch television, they used a streaming platform on their iPad, except for occasions when the family engaged in collective movie nights, during which they utilized a TV (P3, 10 years). To determine whether the participants engaged in simultaneous usage of multiple services, they were asked if they ever checked their phones while watching a series. The participants of Focus Group 1 emphasized their conscious effort to avoid multitasking, as they preferred concentrating on one activity at a time. However, they admitted that occasional conversations with friends might occur if the conversation was important, or particularly if it involved messages from their parents (P2, 11 years).

Transitioning to the topic of parental regulations, the participants were asked if they had screen lime limits imposed by their parents. They all expressed that they didn't have a strict time limit; however, their parents usually told them to engage in other activities after an hour or so of watching TV or playing games on their iPad. In relation to screen time during school hours, the participants were asked about their frequency of digital device usage. They indicated that the extent of usage varied depending on the subject being studied. In Mathematics, for instance, they relied solely on iPads for reading and subsequently solving math problems by hand. Two specific apps, namely, *kikora* and *campus inkrement*, were highlighted as integral to their math learning process. These apps generated tailored math questions based on the pupil's performance, providing them with targeted practice and helping them improve (P4, 12 years).

Global Warming and Digital Impact

Thereupon, we zoomed in on the topic of global warming and the participants' level of awareness and engagement with this issue, which they said they were familiar with and discussed the concept at school. P2 suggested that "*the Earth is becoming too warm or something like that?*", which indicated a superficial grasp of the concept rather than a deep comprehension. I continued to ask what types of actions they take today, and without explaining what that meant, they gave examples like; "*we recycle our waste. Also, I inherit almost all of my clothes and then give them away instead of buying new ones*" (P4, 12 years) and "*I have an older brother, so I inherit a lot of clothes from him. And if those clothes have become too small, I donate them to Fretex*" (P3, 10 years).

The discussion shifted toward the environmental impact of oil and fossil fuels, a familiar topic for them all. When asked about the uses of oil and fossil fuels, they suggested transportation such as planes and cars. I then added that these energy sources are also utilized for electricity generation. Further, they were asked what they use electricity for, and they answered that they use it to turn on lights and charge their phone. I then stated that "*using digital devices and services is bad for the environment*" and P4 immediately said "*I think that I should perhaps spend less time looking at screens, maybe?*."

I acknowledged P4's insightful response before offering to elaborate further on the implications of using digital devices and services. During the explanation, a visual representation of a data center was presented and compared to a *giant computer* responsible for storing all their videos, text messages, and movies. It was emphasized that every time they access a video or send a message, it requires communication with this giant computer. It was added that whenever they access a video or send a message, it requires communication with this enormous computer and therefore needs constant power supply and cooling, just like a regular computer. They were queried about their experience of feeling the heat emitted from a charging computer, and their response was affirmative. Following this, they were encouraged to imagine the amount of electricity these giant computers required, and the collective response was: "*Oi.*"

Collective Efforts

Continuing the discussion, the inquiry was made regarding the types of collective efforts they thought we should make to limit this electricity usage. P4 first thought that children were a good place to start:

> "*for many children, you could say: this week, you can only have half an hour each day, or nothing each day [...] because there are so many*

children, so if everyone did it, or if all schools did it, then it would be less" - P4, 12 years.

P3 then added that:

"*This week, the 5th grade has a screen-free week, which means we are not allowed to use screens for the entire week. We've done it twice before*" - P3, 10 years.

which meant that P1, P2, and P3 all had a screen-free week. When asked whether this meant at school or at home, they answered that it was both. Subsequently, I inquired about their perspectives on how they felt about this, to which P3 responded: "*It's quite fun with the challenge*". I then asked how the teachers and parents were able to ensure that the pupils did not use their phones, and she again answered: "*one might feel guilty if they don't do it.*" Another suggestion was

"*to introduce a national screen-free day*" - P1, 10 years old.

They collectively agreed that this might be a positive initiative. However, P4 raised a valid concern about the challenges adults might face in disconnecting from technology due to work obligations. To this, P3 shared that: "*my dad wanted to join our screen-free week but with the exception of work-related responsibilities.*"

I proceeded by suggesting that downloading videos instead of streaming them live could be a beneficial action and asked them whether they perceived any barriers or obstacles associated with this approach. Participant 4 expressed concerns regarding storage limitations as a potential barrier. While she has downloaded movies for trips in the past, the limited storage capacity on her device restricts her from downloading a large number of movies, which could potentially lead to storage issues in the long run. Participant 3 quickly added to the discussion by highlighting that certain apps do not provide the option to download content. However, she promptly proposed that all digital services offering videos and movies should incorporate the capability to download content as an available feature.

Raising Awareness

Following that, I inquired about their perspectives on the most effective means of raising awareness. They had some suggestions regarding the matter; P4 suggested that we convey the message to a larger audience, including children; this way, we could:

> "*educate and encourage individuals to take these actions as well* [...] *many people may not fully comprehend the significance*" - P4, 12 years.

P3 also added that she would share this information with other kids, who might tell their parents, leading to a larger number of individuals adopting these changes. She then added:

> "*Children may find it easier to modify their habits since they have had less time to develop ingrained patterns compared to adults, who may have established different routines*" - P3, 10 years.

She also suggested that:

> "*I think maybe there should be more teachers who talk about it because maybe they are someone's role model, maybe they would listen more?*" - P3, 10 years.

She emphasized the influence that teachers have on pupils, as many pupils consider their teachers as role models and are more likely to pay attention to their guidance and messages. P4 added to the discussion with a suggestion to organize a play as a means to raise awareness. The concept involved inviting people to watch the performance, showcasing the excessive use of digital devices and the resulting consequences, such as environmental heat and destruction. She believed that through this creative medium, people would better understand the issue.

Concluding the session, participants were asked to provide their thoughts and insights regarding the session. They all had some thoughts, but P3 summed it up with the response:

> "*Now that I am aware of this information, I realize that I have been unaware of many aspects related to screen usage. Consequently, I am inclined to reduce the amount of time I spend looking at screens.*"
>
> - P3, 10 years.

4.2.2 Interview 1

With P5 I had the same warm-up exercise where she wrote down her favorite app, she asked to write two; the response can be seen in Figure 4.25. Following the exercise, the terms *digital service* and *digital device* were defined to be used later in the session. The participant possessed many devices, including an iPhone, laptop, and iPad.

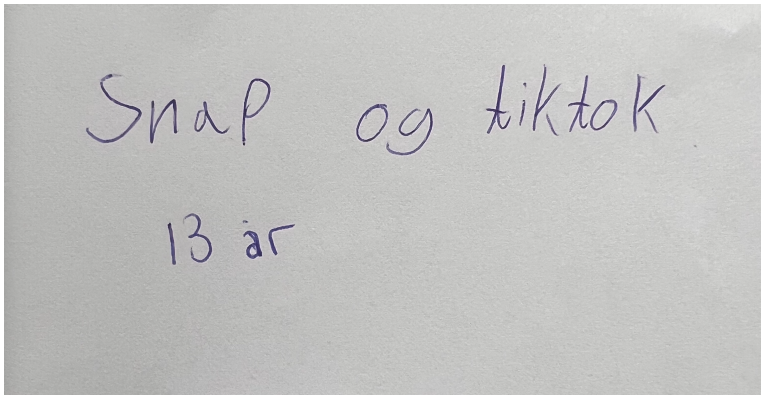


Figure 4.25: This figure presents a response from Participant 5 where she wrote down her favorite app and age on a note.

When asked about her phone usage frequency, she quickly suggested checking the built-in screen time monitor while stating: "*It's a bit scary, actually*," alluding to potential concerns about her phone usage. Unfortunately, her phone froze at that moment, preventing us from checking.

Digital Habits

When asked whether her parents have given her any screen time limitations or whether she consciously uses the built-in screen time monitor she referred to earlier, she brought up TikTok. TikTok has a new update addressing excessive phone usage. It introduces a feature where you have to enter a code after watching for an hour, and as a result, she explained that for her: "*it serves as a threshold, a small step to reenter the app*". P5 acknowledges that it is easy to bypass the feature, but it helps her be more aware of the time she's used the app making it more likely she'll exit it. However, her parents haven't given her any limitations concerning her screen time, and it is up to her how much she wishes to use her phone or tablet.

Global Warming and Digital Impact

Her understanding of the climate crisis revolves around the detrimental impact of human consumption on the environment, specifically citing the endangerment of polar bears, in her own words: "*We use more and more, and we want more and more.*" She emphasizes that the escalating consumption patterns are gradually depleting the Earth's resources. We then discussed that oil and fossil fuel harmed the environment, and I asked her what she thought we used the oil and fossil fuel for when she responded: "*cars and planes. Also, there are generators like that for them to keep running.*" Here she refers to the overall process of generating energy from burning oil, which indicates that she has a more profound understanding *or knowledge* than

the participants in Focus Group 1. We then discussed that these generators were used to produce electricity.

Similarly to Focus Group 1, Participant 5 was also asked about her current environmentally friendly actions. She took multiple actions, such as: "*plant flowers, tomatoes, and strawberries in addition to recycling waste*." She was informed about the environmental impact of digital services and devices, highlighting the electricity demand, as she referred to when mentioning the generators that produced electricity through oil combustion, we refer to this impact as a digital carbon footprint. To assess her understanding, she was queried about the method by which she could access a TikTok video posted by someone residing on the opposite side of the world. After pondering for a moment, she responded, saying, "*It's a network where beams (Norwegian: stråler) travel throughout the world*." I was pleasantly surprised by her answer as it demonstrated her comprehension of how the internet functions, exceeding my expectations for a 13-year-old. I continued to describe the data centers, in the same manner as explained to Focus Group 1, as a giant computer, with a high electricity demand, that stores all these videos.

Collective Efforts

Following this, she was asked if she had any suggestions for environmentally friendly actions we could take to lower our digital carbon footprint, similar to recycling. She suggests that we should all "*live in the present*," in addition to "*live like they used to in the old days*," where they were more outside and didn't have access to digital technologies. She added that today we use digital technologies to hinder boredom, "*it's good in the present moment you're living in* [...] *I'm not bored in that very second, but it affects the time ahead and the rest of the world, so... I wish we lived back in time*." Furthermore, when asked if she believed it would be possible to have a screen-free day, she replied: "*No because we use our mobile phones all the time* [...] *to contact friends, purchase bus tickets, and check bus schedules*." After a brief pause, she reflected and added: "*I could have managed it yesterday*" while recalling the various activities she had engaged in the day before.

Raising Awareness

Later, the discussion shifted towards exploring methods of raising awareness about this digital carbon footprint and to whom it would be more effective to inform. Participant 5 suggested children because: "*adults don't think about it*." However, children think about it more and care about: "*how things affect us and how things affect the world*" much more than what adults believe. She also added that she thinks children care more than adults do. She was then asked if she thought people would ration screen time for other activities that also had a negative impact; however, this would limit the simultaneous engagement in multiple detrimental behaviors. She

then replied: "*I think so* [...] *but it depends on what people enjoy doing that also pollutes. For instance, I think traveling and flying is fun*," so she would consider reducing screen time by an equivalent amount of pollution caused by the flight she would take for travel. Additionally, she emphasized the importance of incorporating such topics into the school curriculum, highlighting that these issues are significant for our society, and it is essential for children to be aware of the consequences of their actions. Without awareness, they can't actively contribute to improvement, such as rationalizing screen time, which is, as she puts it: "*unfair*."

Highlights form Section 4.2

- The pupils showed a willingness to change habits
- The pupils were quick to suggest solutions to the problem
- They identified lack of knowledge as a barrier
- They discussed that it is easier for children to change habits than adults seeing that their habits as well integrated into their lives

Chapter 5
Discussion

This chapter aims to discuss the results presented in Chapter 4. Section 5.1 will explore how the previous research and current calculators estimate the environmental footprint of digital services. Section 5.2 will discuss the results from the user survey and focus group sessions. Lastly, Section 5.3 will address any possible limitations related to this study.

5.1 RQ1: Calculations

In Section 2.2, multiple previous studies that aimed to calculate and evaluate the total impact the ICT sector has on the environment were assessed. Each presented the scope of the estimation and a number for the impact. Even though the studies referred to were all conducted between 2018 and 2022, they all shared different estimations and included slightly different scopes.

5.1.1 How is the Digital Carbon Footprint Calculated Today, and To What Extent Are These Calculations Documented?

The examined studies in Section 2.2 by Belkir et al., The Shift Project, Freitag et al., and Sharma et al. provide valuable insights into the scope and estimation of emissions associated with the ICT sector [BE18] [Fer19] [FBW+21] [SD22]. However, they had different calculations of what the impact of the sector is, ranging from 1.8 to 4% of all global GHGs.

The studies reviewed in Section 2.2 shed light on the challenges associated with quantifying the digital carbon footprint, revealing variations in the scope of calculations and resulting in different estimations. Despite these disparities, a common thread among the studies is the focus on two primary categories: user or electronic devices and network infrastructure. These categories are referred to differently across the studies. Belkir et al. categorized them as electronic devices and infrastructure facilities [BE18], Freitag et al. referred to them as user devices and

	Belkir et al.	The Shift Project	Freitag et al.	Sharma et al.
% of global emissions	3.0-3.6%	3.7%	1.8 - 2.8% or 2.1 - 3.9 %	4%

Table 5.1: The table provides estimations of the environmental impact of the ICT sector based on findings from four different sources [BE18] [Fer19] [FBW+21] [SD22].

networks [FBW+21], the Shift Project used the terms digital equipment and actions, and DIMPACT encompassed them under the umbrella of infrastructure process, network transmissions, and end-user devices. The variations in terminologies used can potentially introduce some ambiguity and lack of consistency in interpreting their findings.

Further, the studies have varying perspectives on the main contributor to the digital carbon footprint. As mentioned in Section 2.2 Jiang et al. suggest that user devices account for 20% of the impact, while data centers contribute to 19% [JVK21]. DIMPACT also aligns with this view, emphasizing the significant role of user devices in contributing to the overall environmental impact. On the other hand, Itten et al. propose a different distribution, suggesting that user devices contribute to 78% of the impact, while data centers only account for 15% [IHA+20]. In contrast, Belkhir et al. highlight the role of data centers as the primary contributors to the impact [BE18]. Additionally, Morley et al. assert that network infrastructure and data centers are the primary drivers of the digital carbon footprint, accounting for at least 90% of the impact [MWH18]. The studies by Freitag et al. Sharma et al. and the Shift Project did not address the weight of the different parameters in the scope.

Based on this, the substantial differences in the methodologies and considerations of these various projects are highlighted. The variations in scope, the inclusion of parameters, and the weighting of factors contribute to the discrepancies in their estimations. As a result, direct comparisons between these studies may not be meaningful due to their significant differences, which also has implications for how these impact calculations can be used, e.g., to trigger more awareness. Given the diverse approaches employed by the above studies, it becomes evident that standardization of methodology is crucial for accurately assessing and comparing the environmental impact of the ICT sector. Initiatives such as *Sustainable Web Design* seeks to establish a common methodological framework to address this challenge. By defining consistent boundaries, metrics, and assessment criteria, standardization efforts aim to provide a more robust and reliable basis for evaluating the digital carbon footprint. It is crucial to emphasize that the standardization of methodology should be implemented under the oversight of a neutral governing body so the integrity and impartiality of the methodology can be ensured, promoting transparency and

minimizing the potential for bias or manipulation.

Implementing a standardized method would enhance transparency, enable better comparability between studies, and facilitate the identification of the primary contributor to emissions within the ICT sector. Transparency is also crucial for the effectiveness of website calculators. While the primary goal of these calculators may not be to provide a precise estimation of a website's environmental impact, their purpose is to raise awareness to help people and website owners understand the significant consequences of their digital behaviors. There is a varying degree of transparency between different calculators, which raises the risk of losing credibility.

In this regard, it is understandable that if different calculators yield conflicting estimations, people may not take them seriously. The lack of consistency can result in individuals dismissing the issue and being less inclined to take any action. In order to motivate people to make changes, they need to trust the sources providing the information; otherwise, they may disregard it as fake news. As depicted in Table 2.2, the calculations are inconsistent, which creates uncertainty, ultimately eroding people's trust in the problem. To truly inspire individuals to modify their behaviors, the calculators must provide robust and trustworthy calculations. This reliability is crucial to evoke a response and prompt individuals to take action. Transparency can also help users understand the limitations of the estimations and foster trust in the provided information.

Therefore, it is vital to promote transparency in the design and operation of these website calculators. Hopefully, this can also lead to calculators adopting each other methodologies and becoming more united in their calculations. By ensuring calculators' transparency, reliable calculations, and a united front, website calculators can effectively trigger an emotional response in people, motivating them to reconsider their digital habits and make positive changes to reduce their environmental impact.

Highlights from Section 5.1

- Previous studies show variations in the scope of calculations and resulting in different estimations
- Studies highlight the challenges in quantifying the digital carbon footprint
- There is disagreement regarding whether data centers or user devices constitute the primary contributor to the environmental impact.
- Website calculators are important for raising awareness; however, the credibility of these calculators can be undermined when they provide inconsistent estimations.

- The lack of consistency can result in individuals dismissing the issue.
- Standardization of methodology is crucial for accurately assessing the environmental impact of the ICT sector.

5.2 RQ2: User Awareness

In the survey, participants reported engaging in various environmentally-friendly practices, including recycling waste, conserving electricity, and adopting plant-based diets. Similarly, the focus group participants echoed these actions while emphasizing additional measures such as inheriting and donating clothes to promote sustainability. These findings underscore the participants' collective investment in combating climate change.

However, while their dedication to environmentally-friendly practices is apparent, an important question arises: to what extent are they aware of their digital footprint, and are they willing to modify their digital habits when called upon? This section aims to discuss and delve deeper into the participants' attitudes and behaviors concerning digital consumption and explore the potential challenges and opportunities in aligning their digital activities with their commitment to environmental sustainability.

5.2.1 Are Digital Users Aware of Their Digital Carbon Footprint?

As Figure 4.20 illustrates, a significant number of participants agree with the statement that calculating the sector's impact is not a trivial task. While the exact reasons for this perception remain unclear, they express through the open questions presented in Section 4.1.7 that their limited knowledge about the topic makes it difficult to understand the process. They might feel uncertain about where to begin when it comes to assessing the impact. Additionally, as Borning et al. and Bull's research suggest, the metaphors used affect their comprehension of the technology, likely hindering them from grasping the process and the energy demand required [BFL20] [Bul15].

Based on Figure 4.6, the participants recognize digitalization's positive contributions to the environment. The latter also indicates a growing awareness of the potential benefits that digital technologies can offer in the context of sustainability. This can specifically be done by e.g., contributing to increasing the efficiency of the production of products and by the development of renewable energy. However, many of the participants expressed the belief that the production of digital devices has a negative impact on the environment. This awareness reflects an understanding of the environmental footprint associated with the life cycle of digital devices, including their manufacturing, use, and disposal. The participants' contrasting views regarding

the positive contributions of digitalization and the negative environmental impact of digital device production and use highlights the issue's complexity. It suggests that while participants recognize the potential benefits of digitalization in addressing environmental challenges, they also acknowledge the need to address the environmental drawbacks associated with its implementation.

Based on the previous research, there is evidence indicating that the aviation sector has a lower impact than the ICT sector has today [Fer19] [FBW+21]. However, only 46% of the participants acknowledged this fact, suggesting that it has not been effectively communicated to the public, leaving them to give little attention to this concern. However, the aviation sector has decreased its frequency of flying due to covid, and the use of the internet and digital devices has increased significantly in the same timeframe. Compared to the focus groups, when addressed that some researchers claim that the aviation sector has a lower impact than the ICT sector, they were surprised that this was not advertised enough. As P4 mentioned, it is important to inform people that "*it's not enough to simply stop flying*," but they should also change their digital habits.

Through the survey, it becomes clear that there is a perception among the respondents that there are more environmentally friendly search engines than Google. There are alternatives, such as Ecosia, which stands out by using the revenue generated from advertisements to found tree-planting initiatives [Eco]. However, Google, being a prominent player in the industry, is actively working to reduce the environmental impact associated with its data centers [SD22]. In addition to trying to convert their data centers to renewable energy, they also practice buying offsets or engaging in offsetting activities. These practices involve compensating for their carbon emissions by investing in projects that reduce GHG emissions elsewhere, thus helping to balance out their overall environmental impact. By combining efforts to adopt renewable energy and offset emissions, Google aims to minimize the carbon footprint associated with its data centers. However, Ecograder mentions that instead of relying on carbon offsets, it is essential that data centers are converted to run solely on renewable sources [Miga].

Among the survey participants, a significant majority (77%) expressed the belief that data centers have substantial emissions and exert negative impacts on the environment, as shown in Figure 4.20. This finding indicates a prevailing concern among the respondents regarding the environmental implications of data center operations. On the other hand, the same figure show that only 20% of the participants thought that by converting to renewable energy, data centers wouldn't pose a threat to the environment. Participants also had mixed perceptions about the ease of calculating the environmental impact of digital services as a whole. The majority recognized the increasing emissions from digital services as a problem, as about 50%

of the participants agreed with the statement; the increased emissions associated with the ICT sector have the potential to negatively affect their life situations. However, a significant 40% posed neutral to the statement. One possible explanation here might be that because of their lack of knowledge; they did not feel comfortable answering the question. As mentioned in Subsection 4.1.8, a participant expressed that "*It would be very satisfying to include a "solution" or fact box about carbon footprint and resource consumption in the survey - at the end.*" - Male 62, showing an interest in gaining more knowledge about this topic.

Despite the focus group participants' lack of prior knowledge about data centers, their perception of the energy requirements became apparent when they were introduced to the concept. Describing data centers as "giant computers" during the session allowed the participants to grasp the magnitude of energy consumption associated with these facilities. When asked about their estimation of the energy consumption involved, a realization quickly seemed to dawn upon them. They seemed to comprehend the gravity of the situation by drawing a parallel with the frequency of charging their phones, which made them realize the immense energy consumption associated with data centers. They then also understood that the increasing use of technology and data centers would be a problem in the future and that measures should be taken.

Overall, it is evident that participants generally had limited prior knowledge about their digital carbon footprint. The survey served as a valuable tool for raising awareness among participants, as highlighted in the concluding remarks part of the survey, addressed in Section 4.1.8. Participants also expressed a desire to learn more about the environmental impact of their digital habits after conducting the survey. However, a crucial question remains: are participants willing to modify their digital behaviors once they become more aware of the impact? This will be discussed in the following subsection.

5.2.2 Are They Willing to Change Their Digital Behavior to Decrease Their Footprint?

Based on the survey results, many participants expressed willingness to change behaviors to be more environmentally friendly. Specifically, in Figure 4.23, where different environmentally-friendly digital actions were presented, a notable willingness to change came through. However, several barriers hinder their ability to make these changes. One of the main obstacles mentioned by participants is a lack of knowledge on the topic. Many respondents feel that they do not have access to the necessary information to make informed decisions regarding environmentally friendly choices. This lack of knowledge creates a barrier to change as individuals struggle to find the information they need to understand the environmental impact of their behaviors

and make more sustainable choices.

In relation to environmental concerns, P5, from Interview 1, expressed frustration with the lack of awareness and understanding among the general population, which hampers their ability to make informed choices and modify their habits to address the environmental issue at hand. P5 emphasized this situation as unfair because individuals are willing to contribute to lowering global emissions, but without awareness, they are deprived of the opportunity to take meaningful action. The lack of awareness and understanding among the general population limits their ability to make informed choices and modify their habits to address the current environmental concern. This underscores the need for increased awareness and transparency surrounding such sectors to empower individuals to make positive changes. This perspective was also communicated in the survey when a participant stated, "*awareness is crucial. Otherwise, there won't be any change*" (Female 58).

Additionally, participants cited the overwhelming nature of the climate crisis as a challenge. With new information constantly emerging about what actions to take, individuals often feel inundated and unsure about what they can and should do. The weight of the global environmental situation can be paralyzing, leading to a sense of helplessness and a perceived inability to make a meaningful impact. Moreover, participants highlighted that environmentally friendly options often come with drawbacks. These drawbacks include higher costs, less user-friendly interfaces, and limited accessibility. The financial aspect poses a barrier, as sustainable alternatives may be perceived as more expensive or financially burdensome. Additionally, participants noted that environmentally friendly options might be less convenient or advertised, making them less visible and accessible to the general public. This aligns with Chetty et al.'s study from 2009, where they discovered that participants choose their own convenience over environmental benefits.

On the other hand, the focus group participants had a more optimistic perspective on the issue. After being presented with the negative effects of digital consumption, the participants began proposing solutions. Suggestions like designated screen-free days or weeks were put forward. They acknowledged that this might be more feasible for children than adults, given that children do not have work obligations. Therefore, they suggest implementing such initiatives in schools first, with the possibility of extending them to adults later, giving them the exception of work obligations. They also recognized that modifying habits may be easier for children than adults, as adults have integrated their habits more deeply. This sentiment aligns with a barrier identified by a survey participant who stated, "*Habits are so well integrated into my life that I rarely think about them*" Male 24. In Interview 1, P5 expressed the observation that children tend to be more concerned about the environment than adults perceive them to be. Additionally, adults themselves may not devote as much

thought to environmental issues as they ought to.

In the survey, when the participants were asked about their screen time, 50% reported that they spend less than two hours on their phone, 34% said between two and four hours, while 15% acknowledged using their phone for about four to seven hours. In contrast, during the focus group discussion, P1, P2, P3, and P4 all stated that they do not spend more than an hour on their devices, whether it was their parents telling them to do something else or that they got tired of looking at a screen, thereby wanting to do something else. P5, however, expressed that she spent as much time as she wanted on her phone if she was bored. All the participants from the focus groups did express having multiple after-school activities, naturally giving them less time to be digitally active. All these factors contribute to the children having natural screen time limitations, unlike the adults participating in the survey.

P5 demonstrated insightful thinking by acknowledging the potential repercussions of excessive screen time and relying on digital services to alleviate boredom. As opposed to some of the participants from the survey who stated that changing digital habits and lowering screen time might negatively impact their quality of living, P5 exemplified a different perspective. Her viewpoint demonstrated a willingness, especially among children, to consider the bigger picture and contemplate the future implications of their actions. In the study by Gnanaseekaran et al. [GFH+21], they brought up personal well-being as an indirect or direct link to environmentally positive consumption patterns. In their study, a participant stated that; "*I want an exciting life*" (Female 22), in relation to using screen time monitoring apps to limit her screen time. This contradicts the answers in this study, where only 12% of the participants use screen time monitoring, and where they link less screen time with boredom.

The primary motivation for people to be digitally active is entertainment, as indicated by both the survey participants, as Figure 4.10 illustrates, and the children in the focus groups. Socializing is the second most common reason, which presents a significant barrier to reducing screen time in today's society where the internet has fostered a sense of social connectivity, creating vast social networks. As one survey participant expressed, "*My only social life is through the internet, I am disabled and have no other options*" (Female 64). P5, from Interview 1, also highlighted the near impossibility of participating in a society without being digitally active, stating, "*we use our phones all the time* [...] *to contact our friends, purchase bus tickets, and check bus schedules.*" Additionally, a participant from the survey stated that all planning of events with colleagues occurred online on different platforms.

Interestingly, a common thread among all participants was a sense of guilt associated with excessive screen time; this was evident both in the survey responses

and during the focus group sessions. Firstly, the survey participants expressed feeling guilty when their screen time monitoring reported high usage. Not due to environmental concerns but rather because spending a significant portion of the day online is generally perceived as negative. Some participants expressed this guilt as an effective way to lower their screen time; however, a participant also confessed to disabling the feature due to this uncomfortable feeling. In the focus group, P3 stated that during the screen-free week, they relied on people's consciousness and experienced guilt if they cheated since they did not have a way to verify if the pupils stayed off their devices. Additionally, P5, in the interview, talked about TikTok's new feature, where they introduce a passcode after an hour of use. As she puts it, "*it serves as a threshold, a small step to reenter the app*," also implying that when you are reminded of the time spent online, you feel guilty and want to put it away.

The survey participants also highlighted familiarity as a significant barrier. They expressed concerns about changing habits that have become deeply integrated into their everyday lives and processes they have come to trust. For example, many participants mentioned their reliance on saving everything online and backing up documents, which they perceive as safer and more practical than having them physically stored on their computer or local hard drive. Furthermore, when analyzing and comparing Figure 4.18 and Figure 4.22, it is evident that the inclination to store files on a local hard drive is amongst the statements which have experienced the least increase.

The survey results indicate that 87% of participants either agree or strongly agree that major companies and politicians bear the responsibility of enabling environmentally friendly choices. This finding aligns with the research conducted by Elgaaied-Gambier et al., which emphasizes the importance of communication among all relevant stakeholders to enhance consumer awareness [EBB20]. The study argues that increasing awareness is a crucial prerequisite for individuals to grasp the issue and take concrete action. Furthermore, the research highlights that consumers attribute responsibility to companies rather than themselves, a sentiment also reflected in the aforementioned survey question.

Overall, the identified barriers are indications that effecting change necessitates a gradual process. Swift resolutions cannot be expected, but initiating action is important to drive future transformation. As the children suggested, education and awareness play a pivotal role in instigating change. Given their receptiveness and relative ease of adaption, targeting educational initiatives toward the younger generations becomes an auspicious starting point. By empowering younger generations with knowledge and fostering a sense of environmental consciousness, a solid foundation for broader change can be established.

Highlights from Section 5.2

- The participants conflicting views of the positive and negative effects of digitalization highlight the complexity of the situation.
- All participants show an interest in being environmentally friendly, also indication that they want to change digital habits to more environmentally friendly ones.
- All participants show a low level of knowledge and awareness.
- The survey participants mentions multiple barriers such as lack of knowledge, financial burden, and accessibility.
- The pupil participants suggested collective efforts such as a screen free week.

5.3 Limitations

This subsection will present the limitations encountered during this thesis project. These include sample diversity, potential biases, and time constraints.

5.3.1 Sample Diversity

The survey participants were primarily drawn from my personal network, as the survey was shared on my own Facebook page. This restricted the representation of a broader range of perspectives and backgrounds within the survey respondents to some extent. However, it is worth noting that - to mitigate this limitation - the survey was also disseminated through my parents, who shared it with their colleagues within the IT-sector. As a result, a broader range and more diverse set of users (e.g., in terms of age, professional occupation, etc.) had the opportunity to participate in the survey. Furthermore, the survey was distributed among a community with an environmentally activist orientation, indicating a heightened concern for environmental matters among the participants, potentially deviating from the attitudes prevalent in the wider population. Consequently, the outcomes regarding their willingness may be influenced by this distinct characteristic. Moreover, it is essential to note that the survey was exclusively conducted in Norwegian, thereby constraining the ability of international respondents to provide their input.

It is imperative to recognize the inherent limitations associated with this approach. By specifically targeting a particular audience, there is a possibility of excluding specific segments of the population, thereby rendering the results non-representative of the larger population. Consequently, this approach introduces a risk of incomplete representation and potential biases.

It is important to note that Sample 2 consisted exclusively of female participants, which was not the intended sampling strategy. This unintentional gender bias may have influenced the overall findings obtained during the sessions, as individuals of different genders may perceive the world differently, particularly within the age range of 10-13 years. Moreover, the limited sample size of only five participants from a specific geographical area may further impact the results, providing a restricted reflection of their unique life situations. These participants originate from an area in Oslo where a higher prevalence of higher education exists, which potentially shapes the children's perspectives on the world.

5.3.2 Potential Forms of Bias

A notable limitation of both the survey and the focus group session lies in the potential influence of the respective settings on participants' responses. In the survey, the explicit focus on participants' knowledge of the environmental impact of digital devices may have heightened their awareness of this issue, thereby potentially affecting their responses. It is plausible that participants may not have spontaneously considered the environmental impact in the absence of this prompt in an alternate setting. Similarly, in the focus group session, providing an explanation regarding the possible impact prior to soliciting participants' thoughts could have influenced their responses, as they possessed prior knowledge of the consequences.

Moreover, a few respondents expressed concerns regarding the leading nature of the questions, which may have influenced their perception of what constitutes a "morally correct" response. Therefore, one must consider the possibility of a social desirability bias influencing the results. However, it is worth mentioning that one participant who made this observation also mentioned making an effort to answer truthfully. It is essential to acknowledge that this individual's response might be unique, indicating that certain results could be more favorable than the actual reality.

5.3.3 Time Constraint

Unfortunately, due to time constraints, it was not feasible to conduct follow-up interviews with the survey participants. The approval process from Sikt, which took longer than anticipated, resulted in the inability to obtain access to their contact information. Conducting follow-up interviews would have provided valuable insights into participants' long-term thoughts and allowed for further elaboration on their responses. Additionally, such interviews could have mitigated the uncertainty surrounding participants' motivation to answer truthfully versus providing socially desirable responses. For instance, by examining their screen time data for the weeks following the survey, it would have been possible to assess whether their behavior

changed as a result of participating, thereby providing a more nuanced understanding of their attitudes and actions.

Furthermore, the time constraints imposed limitations on conducting an in-depth statistical analysis of the results. The analysis and interpretation of the data were restricted due to the available time frame. This constraint will be further addressed in Section 6.3.

Highlights from Section 5.3

- The survey sample was limited in terms of diversity as it primarily consisted of individuals from my personal network and Facebook pages.
- The survey was conducted in Norwegian, thereby constraining the ability of international respondents to provide their input.
- The composition of the focus group sample was not gender-balanced, as it was limited to female participants.
- A notable limitation of both the survey and focus group session is the potential influence of the respective settings on participants' responses, with prompts and explanations potentially affecting their responses. Potential social desirability bias in the received answers.
- Due to time constraints, follow-up interviews with survey participants were not possible.
- Time constraints limited the depth of statistical analysis.

Chapter 6
Conclusion and Future Work

This chapter concludes the study of the environmental impact of digital services and the corresponding user awareness. This master thesis explored how previous research highlights the connection between technological advancement and environmental sustainability. The research delved into existing literature to understand the methodologies employed in calculating the environmental impact of the ICT sector and examined the current state of website carbon calculators. Furthermore, empirical user studies were conducted to map the current level of awareness amongst digital users regarding the environmental impact of their digital behavior. The objective of this chapter is to answer the research questions presented in Chapter 1 (Section 6.1 and Section 6.2), and provide recommendations for future work (Section 6.3).

6.1 RQ1

This thesis revealed that it is nearly impossible to get an accurate estimation of the impact the ICT sector has today. While there is a consensus that the sector has a significant impact on the environment, the exact extent of the impact remains uncertain due to variations in methodologies and data sources. One consistent finding among the studies is the focus on two primary categories: user devices and network infrastructure, although they are referred to differently. While some studies emphasize the significance of user devices, others highlight data centers as the main contributors to the digital carbon footprint.

To ensure credibility and promote consistency, developing a standardized method for calculating the environmental impact of the ICT sector is imperative. A neutral organization should oversee this standardization to maintain transparency and integrity. By implementing a transparent and synchronized approach, the accuracy and reliability of calculations, both used in research and website carbon calculators, can be upheld, fostering a greater understanding while upholding individuals' trust.

6.2 RQ2

Given the widely acknowledged consensus on the genuine threat posed, it becomes imperative to elevate the awareness surrounding users' digital footprint. Participants in the survey and focus groups demonstrated a lack of awareness, with many recognizing the positive contributions of digital technologies. However, they also acknowledge the negative environmental implications associated with their production and use; however, because the process behind digital services is *invisible*, it is also hard to grasp from the users' perspective. There is, therefore, a need for more accessible information and education on the topic to empower users to make informed decisions about their digital consumption.

The survey revealed that most participants care about the environment and want to make changes to better the situation. Although people expressed a willingness to change their online behavior to decrease their digital footprint, they face several barriers. These include a lack of knowledge, the overwhelming nature of the climate crisis and the feeling of powerlessness, perceived financial burdens, and limited accessibility of environmentally-friendly options. However, the focus groups provided some optimism, suggesting solutions such as designated screen-free days, particularly for children, who may be more adaptable to changing habits.

From this research, we now know that users (and more specifically, the ones involved in the conducted study) do care about their digital carbon footprint, even though they might not be able to make the choices they wish to make or perhaps know what they should be doing. Addressing the environmental impact of the ICT sector requires a multi-faceted approach involving both individuals and companies. It is crucial to enhance user awareness, provide accessible information, and promote sustainable alternatives.

6.3 Future Work

There are several potential areas for future research that could be explored to enhance the scope and impact of this study. Firstly, by expanding the tested group to include a broader audience, a wider range of perspectives and insights can be obtained. These diverse insights can be invaluable in effectively reaching out to different population segments in a more customized and targeted manner. Exploring the perspectives of individuals with contrasting views, such as anti-climate activists, would provide valuable insights into their attitudes and beliefs. Distributing the survey to various people and assessing potential differences in responses would contribute to a more comprehensive analysis.

In addition, conducting a longitudinal user study would provide valuable insights

into the long-term effects of participants' digital behavior. It would be advantageous to track participants' screen time over an extended period of time after completing the survey, as it would be possible to observe any changes or trends that emerged over time. This approach would increase accountability and enable comparison between self-reported answers and actual behaviors. Additionally, it would provide an opportunity to address any questions or concerns that arose while analyzing the survey results.

Furthermore, incorporating interviews with experts within the ICT sector would add depth and credibility to the research. Given the limited existing research in this field, the inclusion of experts' specialized knowledge and insights would provide valuable context and enhance the understanding of the environmental impact of the ICT sector, as well as sustainable digital behavior. Their contributions would not only strengthen the credibility of the research but also shed light on potential strategies and solutions for promoting sustainability within the sector.

To strengthen the analysis, conducting an extensive statistical analysis would be beneficial for the future. This would yield a deeper understanding of the survey data and enable researchers to identify any significant differences in willingness and awareness based on factors such as generation and gender. This information could guide targeted sustainability campaigns and ensure maximum impact.

Given the increasing prominence of AI technologies, such as ChatGPT, it would be intriguing to review their potential environmental impact. Specifically, investigating the implications of their extensive data storage and retrieval processes would provide valuable insights into the environmental sustainability of these technologies.

By addressing these potential avenues for future work, researchers can expand the scope and impact of this research, providing a more comprehensive understanding of user behavior and advancing sustainable practices.

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Appendix A
Survey

This is the final completed survey that was distributed.

Ditt digitale fotavttrykk

Side 1

Obligatoriske felter er merket med stjerne *

Brukerundersøkelse til masteroppgave: Bevissthet rundt et karbonfotavtrykk knyttet til digitale tjenester

Denne brukerundersøkelsen skal brukes i forbindelse med en masteroppgave ved NTNU. Oppgaven omhandler hvilken påvirkning den økende bruken av digitale tjenester har på miljøet og i hvilken grad mennesker har kjennskap til dette.
Denne brukerundersøkelsen vil ta ca **10 minutter**.

For spørsmål til denne undersøkelsen kan du kontakte Anne Ørbæk på *asorbaek@stud.ntnu.no*.

Til info:

Begrepet digitale tjenester omfatter alt fra digitale enheter som smarttelefon, nettbrett, AppleTV og digitale klokker til digitale plattformer som Netflix, TikTok og Google Drive.

Persona

Hvilket år er du født? *

Hvilket kjønn identifiserer du deg som? *

- ◯ Kvinne
- ◯ Mann
- ◯ Ikke-binær
- ◯ Kjønnsflytende
- ◯ Vil ikke oppgi
- ◯ Annet

Hva er ditt høyeste utdanningsnivå. *

Oppgi hvilket nivå du er på nå dersom du ikke har fullført.

Eks. dersom du tar master - huk av det og ikke forrige nivå, som VGS.

- ◯ Grunnskole
- ◯ Videregående
- ◯ Bachelor
- ◯ Master

- Master
- Doktorgrad

Hva er din utdanningsretning? *

- Humanistisk (f. eks. språk, juss, kulturell)
- Sosiale studier (f. eks. økonomi, politisk vitenskap, antropologi)
- Naturvitenskap (f. eks. biologi, kjemi, geologi)
- Formell vitenskap (f. eks. datateknologi, matematikk, AI)
- Anvendt vitenskap (f. eks. business, ingeniør, medisin)
- Annet

Hva er din nåværende yrkesstatus? *

- Student
- Ansatt i offentlig eller privat sektor
- Manuelt arbeid
- Utøvende ledelse
- Selvstendig næringsdrivende
- Pensjonist
- Arbeidsledig eller arbeidssøkende
- Annet

Sideskift

Side 2

Obligatoriske felter er merket med stjerne *

Ditt forhold til klimakrisen

I denne delen skal du svare på noen spørsmål knyttet til klimakrisen, og hvilket forhold du har til den, samt hvilke tiltak du gjør i dag for å minske ditt klimaavtrykk.

Skalaen som blir brukt går fra sterkt uenig til veldig enig.

I hvilken grad er du enig/uenig i følgende utsagn?

	Sterkt uenig	Uenig	Litt uenig	Verken enig eller uenig	Litt enig	Enig	Veldig enig

Det er lite jeg som privatperson kan gjøre for miljøet	○	○	○	○	○	○	○
Jeg er urolig for verdens nåværende situasjon mtp. miljøet og hva det vil bety for fremtiden	○	○	○	○	○	○	○
Jeg tror det er store selskaper og politikere som har ansvar for å tilrettelegge for at vi kan ta miljøvennlige valg	○	○	○	○	○	○	○
Jeg synes det er lett å ta miljøvennlige valg	○	○	○	○	○	○	○
Jeg tror menneskeheten skader miljøet	○	○	○	○	○	○	○
Jeg føler meg i stand til å bidra med å løse klimakrisen	○	○	○	○	○	○	○
Hvis jeg kan velge mellom to like produkter velger jeg den som er best for andre mennesker og miljøet	○	○	○	○	○	○	○
Naturens naturlige balanse er svært robust og ikke lett påvirket	○	○	○	○	○	○	○
Jeg gjør en innsats for å kjøpe papir og plastprodukter som er produsert av resirkulerte materialer	○	○	○	○	○	○	○
Jeg føler ikke ansvar for å løse klimakrisen	○	○	○	○	○	○	○
Mennesker må leve i harmoni med naturen	○	○	○	○	○	○	○
Min private økonomi er viktigere for meg enn miljøvennlig adferd	○	○	○	○	○	○	○
Jeg har byttet produkter av miljømessige grunner	○	○	○	○	○	○	○
Jeg tror jeg som privatperson kan bidra positivt til miljøet ved å kjøpe produkter som er bærekraftige	○	○	○	○	○	○	○
Jeg har unngått å kjøpe ulike produkter fordi de er skadelige for miljøet	○	○	○	○	○	○	○
Jeg tror ikke klimakrisen er menneskeskapt	○	○	○	○	○	○	○

Huk av for hvilke miljøtiltak du som privatperson gjør:

- [ ] Resirkulerer avfallet mitt
- [ ] Er bevisst på å senke strømbruken der jeg bor
- [ ] Bruker kollektive transportmidler
- [ ] Spiser plantebaserte måltider minst 3 ganger i uka
- [ ] Støtter miljøvennlige organisasjoner
- [ ] Bruker elbil i stedet for diesel/bensin bil
- [ ] Har solcellepanel som energikilde
- [ ] Bruker en varmepumpe for å spare på energi

Er det noen andre miljøtiltak du tar som du vil legge til?

Sideskift

Side 3

Obligatoriske felter er merket med stjerne *

Digitalisering og klimakrisen

I denne delen skal du svare på noen spørsmål knyttet til i hvilken grad du tror digitalisering og digital teknologi har en positiv eller negativ påvirkning på miljøet.

I hvilken grad er du enig/uenig i følgende utsagn?

	Sterkt uenig	Uenig	Litt uenig	Verken enig eller uenig	Litt enig	Enig	Veldig enig
Digital teknologi er med på å løse klimakrisen	○	○	○	○	○	○	○
Et papirdrevet kontor er mer miljø-fiendtlig enn et digitalt kontor	○	○	○	○	○	○	○
Digitalisering bidrar til utviklingen av fornybare prosesser	○	○	○	○	○	○	○
Det er bedre med en time langt digi-talt Teams- eller zoommøte enn å kjøre 10 min i bil	○	○	○	○	○	○	○

Det er bedre med et digitalt Teams- eller zoommøte enn å fly til en annen by	○	○	○	○	○	○	○
Digitalisering bidrar til å effektivisere produksjonen av produkter, som igjen reduserer de tilhørende utslippene	○	○	○	○	○	○	○
Det er bedre for miljøet å livestreame et TV program enn å se på lineær TV	○	○	○	○	○	○	○
Produksjonen av digitale enheter har ingen negativ påvirkning på miljøet	○	○	○	○	○	○	○

Sideskift

Obligatoriske felter er merket med stjerne *

Materiell påvirkning

I denne delen skal du svare på spørsmål knyttet til hvor mange digitale enheter du tror du har, samt hva du gjør med dem etter bruk.

Hvilke type digitale enheter bruker du i hverdagen?

- ☐ Smarttelefon
- ☐ PC/Mac
- ☐ Nettbrett
- ☐ Apple TV eller Chromecast
- ☐ Ekstern PCskjerm
- ☐ Digital klokke uten tilgang på WiFi/trådløs nettverk
- ☐ Digital klokke med tilgang på WiFi/trådløs nettverk
- ☐ TV

Har du noen andre enheter enn de du har huket av for over? Hvis ja, hvilke?

Hvor mange av disse har du arvet/kjøpt brukt?

- ○ Ingen
- ○ 1 enhet
- ○ 2-3 enheter
- ○ 3-5 enheter
- ○ 6-8 enheter
- ○ 9-14 enheter
- ○ Fler enn 15 enheter

Hva gjør du som regel med enheter du ikke lenger bruker?

Ta utgangspunkt i enhetene i lista over.

- ☐ Gir bort
- ☐ Kaster i vanlig søppel
- ☐ Resirkulerer
- ☐ Leverer tilbake i butikk
- ☐ Legger dem i en skuff et eller annet sted
- ☐ Mister dem

Sideskift

Side 5

Obligatoriske felter er merket med stjerne *

Dine digitale vaner

I denne delen skal du svare på spørsmål knyttet til dine digitale vaner. Det vil si hvilket forhold du har til digitale tjenester og hvor hyppig du benytter deg av dem.

Ta utgangspunkt i de ***siste to ukene*** når du svarer på spørsmålene.

Til info: å være ***digitalt aktiv***
betyr å engasjere seg i aktiviteter som involverer bruk av digitale teknologier og plattformer. Dette inkluderer blant annet kommunikasjon med andre gjennom sosiale medier og e-post, bruke digitale verktøy for å fullføre arbeidsoppgaver, se en Netflix episode eller å delta i virtuelle arrangementer. etc.

Huk av for hva dine hovedgrunner til å være digitalt aktiv er?

Huk maks av 3.

- ☐ Studie

- [ ] Arbeid
- [ ] Kunnskap
- [ ] Sosialisering
- [ ] Underholdning
- [ ] Netthandel

Er det en annen grunn enn de listet over?

Gi et estimat på hvor mange timer skjermtid du har gjennomsnittlig på din mobil i løpet av en dag

- ◯ Er ikke på mobilen
- ◯ 0 - 20 min
- ◯ 21 - 40 min
- ◯ 41 min - 1 time
- ◯ > 1 time - 1.5 time
- ◯ > 1.5 time - 2 timer
- ◯ > 2 - 2.5 timer
- ◯ > 2.5 timer - 3 timer
- ◯ > 3 - 4 timer
- ◯ > 4 - 5 timer
- ◯ > 5 - 7 timer
- ◯ mer enn 7 timer

Hva er din mest brukte app?

Har du en app eller har mobilen din en innebygd funksjon som lar deg ha oversikt over skjermtiden din?

- ◯ Ja
- ◯ Nei
- ◯ Vet ikke

Bruker du noen av disse til å senke skjermtiden din? Hvis ja, hva bruker du?

Eks. Ha tidsbegrensning på apper/gjør skjermen din grå etter en viss periode.

Hvor mange timer strømmer du digitale tjenester som Netflix/HBO i gjennomsnitt hver dag på en vanlig uke.

- ◯ Ingen
- ◯ 0 - 30 min
- ◯ 31 min - 1 time
- ◯ > 1 time - 2 timer
- ◯ > 2 - 3 timer
- ◯ > 3 - 4 timer
- ◯ > 4 - 6 timer
- ◯ > 6 - 8 timer
- ◯ > 8 - 10 timer
- ◯ mer enn 10 timer

Huk av for hvilke strømmetjenester du har tilgang på

- ☐ Netflix
- ☐ HBO Max
- ☐ Disney+
- ☐ Viaplay
- ☐ Discovery+
- ☐ TV2 Play
- ☐ Amazon Prime
- ☐ Apple TV+

Omtrent hvor mye tid bruker du på sosiale medietjenester som TikTok/Facebook/Instagram per dag?

- ◯ Ingen
- ◯ 0 - under 30 min
- ◯ 30 min - 1 time
- ◯ > 1 - 1.5 time

- ◯ > 1.5 - 2 timer
- ◯ > 2 - 3 timer
- ◯ > 3 - 4 timer
- ◯ 4 + timer

Hvilke av følgende skytjenester benytter du deg av?

- ☐ Google drive Microsoft OneDrive
- ☐ iCloud
- ☐ DropBox
- ☐ Box

Noen andre?

Har du lagret samme ting på to forskjellige skytjenester?

Dette kan være bilder og/eller dokumenter.

- ◯ Ja
- ◯ Nei
- ◯ Usikker

Hvor mange timer spiller du online videospill på en gjennomsnittlig uke?

- ◯ Jeg spiller ikke
- ◯ 0 - 30 min
- ◯ 31 min - 1 time
- ◯ > 1 - 2 timer
- ◯ > 2 - 3 timer
- ◯ > 3 - 5 timer
- ◯ > 5 - 10 timer
- ◯ 10+ timer

Huk av for hvilke av følgende handlinger du gjør i hverdagen.

- ☐ Jeg sletter eldre epost
- ☐ Jeg skrur fullstendig av PCen min etter bruk
- ☐ Jeg laster ned filmer/musikk som jeg har tenkt å

se/høre på flere ganger

- [ ] Jeg legger inn bokmerker på nettsider jeg bruker hyppig
- [ ] Jeg bruker en miljøvennlig søkemotor, f. eks. Ecosia
- [ ] Jeg lukker ikke en fane før jeg er helt ferdig med den
- [ ] Jeg komprimerer vedlegg før jeg laster dem ned
- [ ] Jeg ser på videoer på lav til medium kvalitet kontra HD
- [ ] Jeg sender tekstmelding i stedet for på sosiale medier, f.eks. Messenger/WhatsApp
- [ ] Jeg begrenser nettbasert datalagring i skytjenester
- [ ] Jeg rasjonerer tiden jeg bruker på de ulike digitale tjenestene
- [ ] Jeg bruker bærekraftige nettbaserte lagringsmuligheter
- [ ] Jeg lagrer filer på en lokal harddisk
- [ ] Jeg begrenser skjermtiden min bevisst
- [ ] Jeg kjøper mobilen min gjenbrukt
- [ ] Jeg resirkulerer mobilen min

Sideskift

Obligatoriske felter er merket med stjerne *

Digitale tjenesters påvirkning på miljøet

I denne delen blir du stilt spørsmål relatert til i hvilken grad digitale tjenester kan ha en negativ eller positiv påvirkning på miljøet.

Tror du din bruk av digitale tjenester og applikasjoner påvirker miljøet negativt?

- ○ Ja
- ○ Nei
- ○ Vet ikke

Tror du luftfartssektoren har en større påvirkning på miljøet enn IKT sektroen?

IKT (informasjons- og kommunikasjonsteknologi) er et utvidet begrep som omfatter alt av digitale tjenester og digitale enheter, og kommunikasjonen mellom disse.

- ◯ Ja
- ◯ Nei
- ◯ Samme

I hvilken grad er du enig/uenig i følgende utsagn?

	Sterkt uenig	Uenig	Litt uenig	Verken enig eller uenig	Litt enig	Enig	Veldig enig
Datasentre har store mengder utslipp og påvirker miljøet negativt	◯	◯	◯	◯	◯	◯	◯
Dersom et datasenter blir drevet av fornybar strøm, er det ingen trussel for miljøet	◯	◯	◯	◯	◯	◯	◯
Det er lett å regne ut påvirkningen digitale tjenester har på miljøet	◯	◯	◯	◯	◯	◯	◯
De økende utslippene digitale tjenester har er et problem	◯	◯	◯	◯	◯	◯	◯
Min livssituasjon vil bli negativt påvirket av CO2-utslippet assosiert med digitale tjenester i fremtiden	◯	◯	◯	◯	◯	◯	◯

Jeg tror det finnes alternative søkemotorer til google som er mer miljøvennlige

- ◯ Sant
- ◯ Usant

Sideskift

Side 7

Obligatoriske felter er merket med stjerne *

Er du villig til å endre dine digitale vaner?

I denne delen skal du svare på hvilke endringer du tror du hadde vært villig til å gjennomføre i fremtiden for å senke ditt private digitale fotavtrykk.

Hvilke av følgende handlingene er du villig til å gjøre i fremtiden?

Huk av både for de du allerede gjør i dag og hva du kan gjøre i fremtiden

Huk av både for de du allerede gjør i dag og hva du kan gjøre i fremtiden.

- [ ] Slette eldre eposter
- [ ] Skru PC fullstendig av etter bruk
- [ ] Laste ned en film/video på enheten min istedet for å se/høre den live
- [ ] Legge bokmerker på nettsider jeg bruker hyppig
- [ ] Kun bruke miljøvennlig søkemotor, f. eks. Ecosia
- [ ] Ikke lukke en fane før jeg er helt ferdig med den
- [ ] Komprimere vedlegg før jeg laster den ned
- [ ] Se videoer på lav til medium kvalitet kontra HD
- [ ] Sende tekstmelding i stedet for over sosiale medier, f. eks Messenger/WhatsApp
- [ ] Begrense nettbasert datalagring i skytjenester
- [ ] Rasjonere tiden jeg bruker på ulike digitale tjenester
- [ ] Kun bruke bærekraftige nettbaserte lagringsmuligheter
- [ ] Lagre store filer på en lokal harddisk
- [ ] Begrense skjermtiden min
- [ ] Kjøpe min neste mobil gjenbrukt
- [ ] Resirkulere mobilen min når jeg er ferdig med den

Har du noen kommentarer til å endre vanene dine? Hva opplever du som mulige barrierer?

Tar du nå noen grep for å senke ditt digitale fotavtrykk i dag? Hvis ja - hvilke?

Har du noen kommentarer du vil dele?

Har du en tilbakemelding til undersøkelsen?

Appendix B
Sikt Application

This is the comprehensive application that was submitted to Sikt and approved on May 4, 2023. However, due to an unexpectedly lengthy approval process, not all the requested tasks could be completed within the given timeframe.

Sikt

Meldeskjema

Referansenummer
802832

Hvilke personopplysninger skal du behandle?

- Fødselsdato
- E-postadresse, IP-adresse eller annen nettidentifikator
- Lydopptak av personer
- Bakgrunnsopplysninger som vil kunne identifisere en person

Beskriv hvilke bakgrunnsopplysninger du skal behandle

Utdanningsnivå, utdanningsretning og arbeidserfaring.

Prosjektinformasjon

Prosjekttittel

Fotavtrykk tilknyttet digitale tjenester

Prosjektbeskrivelse

Gjennomføring av brukerundersøkelser relatert til masteroppgave om digitale tjenesters påvirkning på miljøet og bevisstheten rundt dette.

Begrunn hvorfor det er nødvendig å behandle personopplysningene

Disse personopplysningene vil være nyttig for å kartlegge om utdanningsnivå og/eller identitet har tydelige forskjeller i hvilken grad av bevissthet.

Ekstern finansiering
Ikke utfyllt
Type prosjekt
Studentprosjekt, masterstudium

Kontaktinformasjon, student
Anne Ørbæk, asorbaek@stud.ntnu.no, tlf: 46660020

Behandlingsansvar

Behandlingsansvarlig institusjon
Norges teknisk-naturvitenskapelige universitet / Fakultet for informasjonsteknologi og elektroteknikk (IE) / Institutt for informasjonssikkerhet og kommunikasjonsteknologi

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)
Katrien De Moor, katrien.demoor@ntnu.no, tlf: 73594798

Skal behandlingsansvaret deles med andre institusjoner (felles behandlingsansvarlige)?
Nei

Utvalg 1

Beskriv utvalget

Digitalt aktive personer.

Beskriv hvordan rekruttering eller trekking av utvalget skjer

Ved å distribuere link til spørreskjema til bekjente og i ulike forumer.

Alder
16 - 120

Personopplysninger for utvalg 1

- E-postadresse, IP-adresse eller annen nettidentifikator

Hvordan samler du inn data fra utvalg 1?

Elektronisk spørreskjema

Vedlegg

Samtykkeskjema spørreundersøkelse (1).pdf

Grunnlag for å behandle alminnelige kategorier av personopplysninger
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Informasjon for utvalg 1

Informerer du utvalget om behandlingen av personopplysningene?
Ja

Hvordan?
Skriftlig informasjon (papir eller elektronisk)

Informasjonsskriv

Samtykkeskjema spørreundersøkelse.pdf

Utvalg 2

Beskriv utvalget

Barneskoleelever.

Beskriv hvordan rekruttering eller trekking av utvalget skjer

Ved å kontakte skoler i eget nettverk, deretter vil skolen rekruttere elever.

Alder
8 - 12

Personopplysninger for utvalg 2

- Lydopptak av personer

Hvordan samler du inn data fra utvalg 2?

Gruppeintervju

Vedlegg

Samtykkeskjema fokusgruppe barneskolen (2).pdf

Grunnlag for å behandle alminnelige kategorier av personopplysninger
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Hvem samtykker for barn under 16 år?
Foreldre/foresatte

Informasjon for utvalg 2

Informerer du utvalget om behandlingen av personopplysningene?
Ja

Hvordan?
Skriftlig informasjon (papir eller elektronisk)

Informasjonsskriv

Samtykkeskjema fokusgruppe barneskolen.pdf

Utvalg 3

Beskriv utvalget

Videregående elever over 18 år.

Beskriv hvordan rekruttering eller trekking av utvalget skjer

Ved å kontakte skoler i eget nettverk, deretter vil skolen rekruttere elever.

Alder
18 - 20

Personopplysninger for utvalg 3

- E-postadresse, IP-adresse eller annen nettidentifikator
- Lydopptak av personer

Hvordan samler du inn data fra utvalg 3?

Gruppeintervju

Vedlegg

Samtykkeskjema fokusgruppe VGS (1).pdf

Grunnlag for å behandle alminnelige kategorier av personopplysninger
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Informasjon for utvalg 3

Informerer du utvalget om behandlingen av personopplysningene?
Ja

Hvordan?
Skriftlig informasjon (papir eller elektronisk)

Informasjonsskriv

Samtykkeskjema fokusgruppe VGS.pdf

Tredjepersoner

Skal du behandle personopplysninger om tredjepersoner?
Nei

Dokumentasjon

Hvordan dokumenteres samtykkene?

- Elektronisk (e-post, e-skjema, digital signatur)
- Manuelt (papir)

Hvordan kan samtykket trekkes tilbake?

Det er mulig å trekke tilbake samtykke ved å sende epost. Dette er mulig frem til personopplysningene slettes.

Hvordan kan de registrerte få innsyn, rettet eller slettet personopplysninger om seg selv?

Det er mulig å få innsyn, rettet eller slettet personopplysninger ved å sende epost. Dette er mulig frem til personopplysningene slettes.

Totalt antall registrerte i prosjektet
10.000-49.999

Tillatelser

Skal du innhente følgende godkjenninger eller tillatelser for prosjektet?
Ikke utfyllt

Behandling

Hvor behandles personopplysningene?

- Ekstern tjeneste eller nettverk (databehandler)
- Maskinvare tilhørende behandlingsansvarlig institusjon
- Private enheter

Hvem behandler/har tilgang til personopplysningene?

- Student (studentprosjekt)
- Prosjektansvarlig
- Databehandler

Hvilken databehandler har tilgang til personopplysningene?

Nettskjema kommer til å bli brukt i sammenheng med denne undersøkelsen.

Tilgjengeliggjøres personopplysningene utenfor EU/EØS til en tredjestat eller internasjonal organisasjon?
Nei

Sikkerhet

Oppbevares personopplysningene atskilt fra øvrige data (koblingsnøkkel)?
Nei

Begrunn hvorfor personopplysningene oppbevares sammen med de øvrige opplysningene

Ved mulighet for oppfølgingsintervju er det gunstig å se hva de svarte i spørreskjemaet.

Hvilke tekniske og fysiske tiltak sikrer personopplysningene?

- Personopplysningene anonymiseres fortløpende

Varighet

Prosjektperiode
23.01.2023 - 19.06.2023

Hva skjer med dataene ved prosjektslutt?
Data slettes (sletter rådataene)

Vil de registrerte kunne identifiseres (direkte eller indirekte) i oppgave/avhandling/øvrige publikasjoner fra prosjektet?
Nei

Tilleggsopplysninger

Appendix C
Guide for focus group

This is the comprehensive guide to the focus group session that was attached to the Sikt application.

Guide for fokusgruppe 5-7 klassinger i klasserom

Introduksjon og kontekst

Informasjonen som gir her vil være en del av muntlig informasjon som gir til barna, i tillegg til at de får gitt eget samtykke på om de ønsker å være med.

1. Introduksjon av intervjuet og leder av fokusgruppen (masterstudenten)
2. Hva handler studiet om?
3. Kjøreregler:
    a. Du kan si "pass" dersom du ikke ønsker å svare
    b. Det er lov å si at du ikke vil være med lenger, si ifra når som helst så kan du gå tilbake til klasserommet
    c. Ta god tid på å tenke før du svarer
    d. Si ifra om du ikke forstår meg, eller om jeg ikke forstår deg
    e. Det er ingen rette eller gale svar
    f. Jeg forteller ikke andre hva du har sagt
    g. Prat i tur og orden
    h. Ingen erting

Oppvarming

1. Tar en runder hvor alle skriver navn på en lapp med hva deres favorittapp er
2. Hva liker du å gjøre på fritiden?
3. Forklarer begrepene "digitale tjenester" og "digital enhet"

Klimakrisen

1. Hvilket forhold har du til global oppvarming og hva er det? *vil vise til illustrasjoner*
2. Tar du noen grep for å være mer klimavennlig? *resirkulerer avfall?*

Digitale vaner

1. Hva er digitale vaner? *vise til eksempler som netflix og spill på et nettbrett*
2. Hvilke enheter har du? *mobil, nettbrett?*

3. Gir foreldrene deres noe tidsbegrensning på hvor lenge dere kan være på en digital tjeneste?
    a. Hva føler de om det?

Hvordan påvirker digitale tjenester miljøet?

1. Forklare at digitale tjenester kan påvirke miljøet
2. Hva tenker de om det?
3. Skjermtid

Endre digitale vaner

1. Hva tenker de om å begrense skjermtiden deres nå som de er litt mer bevisst på konsekvensene?
2. Hvilke andre tiltak tror de at kan hjelpe?
3. Føler de at denne kunnskapen er nyttig og har de lært noe?
4. Ønsker de at foreldre er strengere på å senke skjermtiden deres?

Avslutning

1. Oppsummere litt av det vi har snakket om
2. Er det noe mer du ønsker å legge til? Spørsmål, kommentarer e.l?
3. Takk for deltakelsen!

Appendix D
Consent form focus group

This is the comprehensive consent form for the focus group session that was attached to the Sikt application.

Informasjon og samtykke for prosjektet "Carbon Footprint of Digital Services, Raising User Awareness" (Ref.802832)

Informasjon om prosjektet

Du blir invitert til å delta i et masterprosjekt som omhandler hvordan digitale tjenester påvirker miljøet og hvor bevisst mennesker er på dette. I dette skrivet gir jeg deg informasjon om bakgrunn og formål for prosjektet, samt hva deltakelse i prosjektet innebærer.

Formålet med prosjektet

Prosjektet er en del av masteroppgave i kommunikasjonsteknologi hos Norges teknisk-naturvitenskapelige universitet (NTNU), veiledet av Katrien De Moor.

Oppgaven har som formål å kartlegge relevant kunnskap og bevissthet digitalt aktive mennesker har om påvirkningen digitale tjenester har på miljøet. Oppgaven vil både dekke bevisstheten til voksne mennesker samt barn over 8 år.

Hvem er ansvarlig for prosjektet?

Masterstudentene Anne Ørbæk Institutt for informasjonssikkerhet og kommunikasjonsteknologi ved NTNU er ansvarlig for prosjektet, sammen med prosjektveileder Katrien De Moor.

Hva innebærer deltakelsen i prosjektet for deg?

Deltakelse i studien betyr at barnet ditt deltar i en fokusgruppe, som tas opp gjennom lydopptak med varighet på maksimalt en time, og trenger samtykke til at barnet ditt kan delta i fokusgruppen.

Selv om du som forelder sier ja til at ditt barn kan delta, er det fortsatt frivillig for barnet om de velger å delta eller ikke. Som forelder har du rett på å få se liste over tematikk på forhånd. Ta kontakt med masterstudenten eller prosjektansvarlig om du ønsker denne informasjonen.

Frivillig deltakelse og mulighet for å trekke deg

Deltakelse i prosjektet er frivillig. Ved å fylle ut og sende inn dette skjemaet, samtykker du til at barnet ditt deltar i studien. Du kan trekke tilbake samtykket ditt uten grunn. Alle barnets personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg eller barnet ditt hvis dere ikke vil delta eller senere velger å trekke dere.

Hva skjer med opplysningene dine når jeg avslutter forskningsprosjektet?

Alle lydopptak av fokusgruppen og koblingsnøkler slettes når masteroppgaven avsluttes juni 2023. All annen data vil være fullt anonymisert.

Ditt personvern – hvordan jeg oppbevarer og bruker dine opplysninger

Jeg vil bare bruke opplysningene om barnet ditt til formålet jeg har fortalt om i dette skrivet. Jeg behandler alle opplysninger konfidensielt og i samsvar med personvernregelverket. Det er kun veileder Katrien De Moor, og studenten Anne Ørbæk ved NTNU som vil ha tilgang til dataene i prosjektet.

Persondata til ditt barn vil anonymiseres og forbindelsen ditt barn erstattes med andre navn som lagres på egen liste adskilt fra øvrige data. Dette lagres separat med passordbeskyttelse. I publikasjoner vil dataene være anonymisert. Det er likevel en mulighet for at barnet gjenkjenner egne uttalelser fra fokusgruppen.

Dine rettigheter

Så lenge ditt barn kan identifiseres i datamaterialet, har du rett til:

- Innsyn i hvilke personopplysninger som er registrert om ditt barn, og å få utlevert en kopi av opplysningene.
- Sletting og ev. endringer av ditt barns personopplysninger
- Klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?

Jeg behandler opplysninger om barnet ditt basert på ditt samtykke. På oppdrag fra NTNU har Sikt vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?

Hvis du har spørsmål til studien eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- Forskningsveilederne Katrien De Moor, katrien.demoor@ntnu.no
- for praktiske spørsmål kan du kontakte student Anne Ørbæk, asorbaek@stud.ntnu.no

- Vårt personvernombud: Thomas Helgesen, thomas.helgesen@ntnu.no

Hvis du har spørsmål knyttet til vurderingen som er gjort av personverntjenestene fra Sikt, kan du ta kontakt via:

• Epost: personverntjenester@sikt.no eller telefon: 73 98 40 40

Med vennlig hilsen,

Anne Ørbæk

Samtykkeerklæring

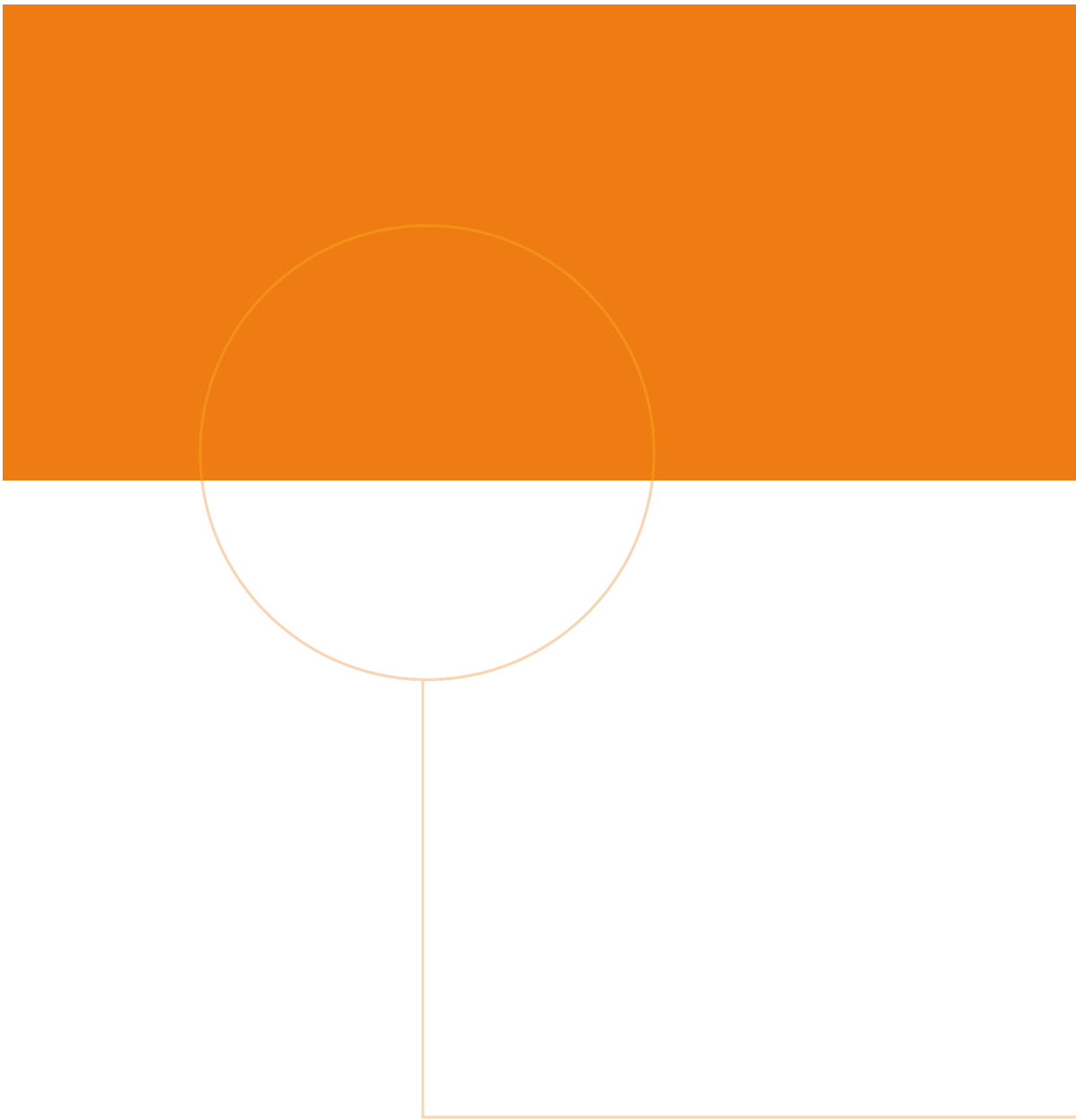
- ☐ Jeg har mottatt og forstått informasjonen om prosjektet "Carbon footprint of digital services, raising user awareness" og fått anledning til å stille spørsmål. Jeg samtykker til at barnets opplysninger behandles frem til prosjektet er avsluttet.

- ☐ Jeg samtykker til at barnet mitt skal delta i fokusgruppe med lydopptak.

Elevens navn: _____

_____

(Foresattes signatur, dato)



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