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Increasing End-Users' Awareness of the Environmental Impact of Software

An Exploratory Case Study

Master's thesis in Software Engineering

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Department of Computer Science and Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021

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Abstract

With the growing energy demand connected to the use of data and more specifically digital services, there is action required to make the software engineering industry sustainable both now and in the future. There are different aspects to consider when talking about sustainable software. Both the aspect of developing sustainable software as well as how much you as an end-user use the software and thus how much energy you use.

The goal of this thesis is to find out how it is possible, through software, to affect end-users to become more aware of the impact they have on the environment while making use of different software and at the same time make sure that future software is sustainable.

The method used to reach the goal of the thesis was an exploratory case study. This consisted of a literature study to create a basis for the survey in the study. Following, based on the survey results interviews were held to deepen and broaden the knowledge gained through the survey. Finally, a checklist with suggestions on how to impact the users of software was put together based on the three previous steps. This checklist was further validated with help from a focus group.

The literature review resulted in an understanding of the field and previous research conducted. Following, the survey resulted in an understanding of the characteristics of the end-users of digital services and software. Moving on, the interviews resulted in a deeper knowledge and understanding of what the best ways to impact the end-users to act more sustainable would be. Finally, the general outcome and contribution of the study was a checklist consisting of suggestions on how to make end-users awareness of software's environmental impact increase as well as what to consider and what not to do in this regard.

It can be concluded that there is a need to raise awareness with end-users of software for them to act more sustainable. Further, it can be concluded that there should be information provided to increase this awareness and that this, in turn, should be based on the end-user's individual motivators. Overall, it can be concluded that the most important aspect is to through the provided checklist try and make the end-users aware that no matter what software they use, it has an impact on the environment

Keywords: Sustainability, software engineering, end-users, end-user awareness, sustainable software engineering, sustainable software, exploratory case study, environmental impact, nudging.

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I would like to thank my brother, my father- and mother-in-law, my sister-in-law, my aunt, as well as the rest of my family for being there for me no matter what I have needed through the past six years.

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On a final note, I would like to thank my mum—who has not been here for the past years physically, but who always is in my heart.

Anne Keller, Gothenburg, June 2021

Contents

List of Figures

List of Tables

1
Introduction

By 2030, to protect the planet as well as the people living on it, the United Nations (UN) has provided 17 goals for a sustainable future for coming generations.[1] In the set goals the UN states the following [61],

> We are determined to protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations.

This is a responsibility which can be considered to not only lie on the UN and its country members, but on every single individual on the planet [61]. The impact of flying and the importance of changing your flight habits as well as the focus on whether it is more sustainable to eat less meat are both examples of what is being discussed to meet the goals [53]. An environmental issue, which is not shed light on to the same extent as the earlier mentioned two, is the great energy use which is heavily increasing through the use of software.[2]

Data centres are expected to be one of the largest consumers of energy in the future [29]. This due to factors such as data centres producing high amounts of waste heat or energy being used to host servers used for computing. There is increased use of digital services such as social media, streaming platforms, video conference services as well as an estimation of 7 trillion Internet of Things devices being connected to the internet in 2025 [4]. Due to this, there is a need to store more data as well as to conduct more computations [60]. More data centres are needed to meet these demands and these, in turn, consume high amounts of energy, sometimes as much as a small city [60].

What is considered and spoken of as "the Cloud" is actually data stored on servers in data centres [36]. With an increased number of data centres comes a great challenge, among other aspects, in changing the way that data centres function and among other factors cater for all the waste heat that is produced. It becomes increasingly important to ensure the data centres are as sustainable as possible. This can be done by, for instance, using the appropriate 'clean' energy to power the centres as well as ensuring that the centres are placed in locations as cold as possible to make the catering for waste heat smoother [64].

With the growing energy demand, there is action required to make the software engineering industry sustainable both now and in the future [16]. By sustainability

[1] `https://sdgs.un.org/2030agenda`

[2] `https://hbr.org/2020/09/how-green-is-your-software`

Table 1.1: Principles of Green Software Engineering

Area	Description
Carbon	Build applications that are carbon efficient.
Electricity	Build applications that are energy efficient.
Carbon intensity	Consume electricity with the lowest carbon intensity.
Embodied proportionality	Build applications that are hardware efficient.
Energy proportionality	Maximise the energy efficiency of hardware.
Networking	Reduce the amount of data and distance it must travel across the network.
Demand shaping	Build carbon-aware applications.
Measurement & optimisation	Focus on step-by-step optimisations that increase the overall carbon efficiency.

we mean software not having a negative impact on the environment such that the future of coming generations is compromised. Sustainability can be looked at in different ways. When it comes to the sustainability of software there are two perspectives to consider: The software, meaning how much you use the software and thus how much energy you use. This is the aspect that the end-user can influence. Then there is the other aspect, which is how the software is developed, for instance, what energy it is hosted by, among other aspects such as the hardware efficiency as well as the aspects concerning networking.

Considering the aspect of sustainability of software, how it is developed there are several steps to consider, according to Hussain [19]. Hussain has brought forward eight principles, presented in Table 1.1 which more precisely are eight different areas of impact on the environment to consider when developing your software. These principles seem to be the most complete ones there are as of today.

Even though the aspects in Table 1.1 cover a wide range of important aspects there is still a gap when it comes to how to use the principles. Moreover, what is not included in the eight principles in Table 1.1 is how to fulfil and obtain success with them. Neither is there any principles concerning end-user awareness of software impact on the environment which too is an important factor. Several aspects can be considered to make a change for the software engineering industry to become more environmentally sustainable [50]. In this thesis, the concern of sustainability and the focus lies on the interaction with software. The focus lies on what the end-users can affect.

That said, there does not seem to be a clear and common understanding of how to obtain sustainable software [41]. In addition, neither does there seem to be a common understanding concerning end-users' impact on the environment through their software use.

The UN goals [61] are everyone's responsibility and while waiting for data centres to become more sustainable or for policies on how to write code in the most efficient ways, other types of action must be taken [19].

Such action is for end-users of software to be made aware of the impact they have on the environment when using the software. More specifically, when using different

digital services. Sixty percent of the world's internet traffic is video streaming and this part of the internet traffic produces approximately 300 million tonnes of CO2 every year according to the Shift Project [8].[3] This is equal to the amount of 65.2 million passenger vehicles driven for one year.[4] If end-users can understand how their actions affect the environment there is a possibility that changes can be made, while waiting for other perspectives of sustainability to be reached. Feedback systems providing direct feedback to the end-users has shown to be efficient in the change of behaviour [15, 58].

Software engineers need to have a shared basis for how to follow sustainability principles like the ones presented in Table 1.1. Additionally, end-users must be enlightened in regard to these consequences or rest assured that all other measures, as presented in Table 1.1, are fulfilled.

Ellegård and Palm states in their research that "it is important to develop new paths to smart and climate-friendly energy use that continue to facilitate peoples' everyday lives" [11]. This emphasises together with Penzenstadler [41] the need for finding new sustainable solutions. There is a need to shed light on the importance of sustainability in the software engineering field as well as create awareness with end-users of software [39].

To conclude, there is a need to protect the environment in several ways. The more data we use, the larger the demand for data centres. While this is researched on there is a need for the software engineering field to become more sustainable, but as of now there does not seem to be a common understanding of how this shall be done. There are two perspectives of sustainability covered, one focusing on software development and one focusing on what the end-user can do to make a change. Sixty percent of the internet traffic comes from streaming with an impact on the environment equal to 65.2 million passenger vehicles driven for one year. In this thesis, we will focus on how to, by affecting end-users, decrease the impact software has on the environment while using digital services. In the next section, the problem will be concretised and described further in detail.

1.1 Problem description

Previous to this section the issue concerning how it is possible to protect the environment was raised. We believe that the software engineering field must be more sustainable. With the growing use of data, there are more data centres needed and thus action has to be taken to minimise their impact. This thesis focus on how this can be done. In this section, the problem is described and more details will be provided concerning the problem description.

[3] https://theshiftproject.org/en/article/unsustainable-use-online-video/
[4] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

The goal of this thesis is to find possible ways to, through software, affect end-users to be aware of the impact they have on the environment, as well as make these users take more sustainable decisions. To this end, there is a need to understand if and with what measures/techniques it might be possible to affect the end-user in making more sustainable decisions.

There is a need to foster learning concerning end-users of software for them to understand that interacting with software is something, which affects the environment. There are obviously many other measures of importance as well as other actions to be taken in order to solve the environmental issues we are facing, this should not be seen as a solution to the entire problem but rather a step in the right direction for the software engineering field.

To summarise, the goal will be to find ways, through software, in which it is possible to affect end-users to be aware of their impact on the environment while using the software. In the next section, the purpose and aim of the study will be described.

1.2 Purpose and aim of the study

The purpose of the thesis is to be a step towards making users understand how much the environment is affected when using software such as digital services, e.g., what times of the day is it more efficient to use certain software or how much does a certain amount of usage affect the environment, to bring forward but a few examples. In addition, the purpose is for the thesis to be a part of the software engineering field decreasing the impact on the environment.

The goal of the study is as mentioned previously to understand how it is possible to affect end-users of software to become more aware of the environmental impact of software as well as contribute these findings to the software engineering field in general.

The aim and the outcome as well as the contribution of this thesis will be to bring forward a best practice checklist consisting of general approaches derived from nudging[a] techniques to ensure sustainability is captured by the requirements as well as the design process of any software development in the future.

[a]Gently guide the users into making certain choices [63]

There are current initiatives, such as Plantfix, but there is of today no common known way in presenting environmental impact to make the end-user aware of the impact the use of digital services has.[5] Nor does any systematic software approach exist which aims to affect the end-user to make less unsustainable decisions in their use of digital services. There is also no commonly used and known sustainability standards for software development.

[5]Plantfix is an initiative where it is possible to carbon compensate for your streaming by paying a monthly fee to plant trees

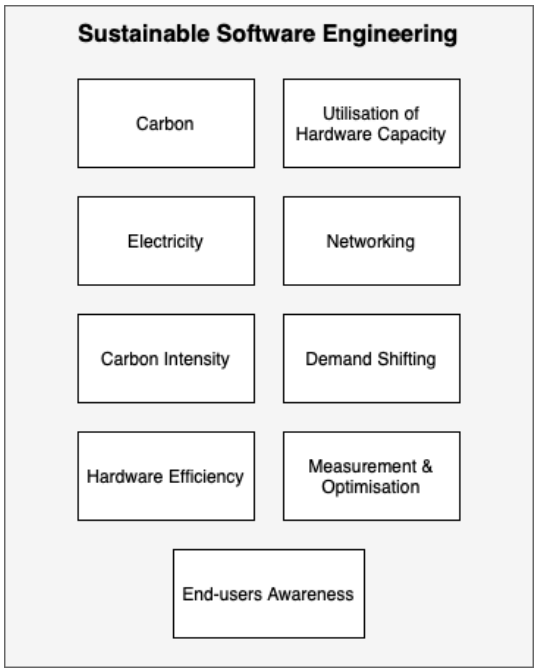

Figure 1.1: Sustainable Software Engineering as developed from the Principles of Green Software Engineering [19]

To conclude, this study will aim to encourage the uptake of greener digital services as well as foster learning. This study will also aim to contribute to the software engineering field as a whole by trying to find general advice and **provide a checklist of best practices** to integrate into the requirements as well as design process of software development. In the next section, the project scope will be described.

1.3 Project scope and delimitations

In the previous section, the goal and aim of the study were elaborated on. In this section, the project scope will be detailed.

The scope of the project is limited to users of digital streaming services. The research will only concern this type of digital services as well as its users. The research will cover the concept of sustainability in relation to the use of digital services only and will not compare the action of streaming to other more or less sustainable everyday actions. Neither will the research focus on anything other than the environmental aspects of sustainability concerning the general advice provided through the checklist.

The study will aim to assess whether it is possible to affect users of the software to make more sustainable choices. What is considered as areas of importance considering whether the software is sustainable can be found in Figure 1.1.

To specify the research further the contribution to the software engineering field the Guide to the Software Engineering Body of Knowledge is used [52]. The research of the thesis will be positioned within the scope of Software Requirements (Ch.1, Sects. 1.1, 1.1.2, 1.1.3) as well as Software Design (Ch.2, Sects. 2.4, 2.4.4, 2.4.5) and

Software Engineering Professional Practice (Ch. 11, Sects. 11.1, 11.1.2).

1.4 Research questions

The goal of the study is, as previously mentioned, to explore in what ways it is possible to make end-users aware of the effect their use of digital services has on the environment. In addition, the aim is to generalise the findings and contribute to the software engineering field by establishing how the effects on the end-users can be integrated into the requirements as well as design process of software development and ensure future software being more sustainable. Following, the research questions set for meeting the goal as well as the aim is presented.

> **RQ1:** *How could software make the end-user aware of the CO2 emissions of using digital services?* For instance, is there a way to send notifications through software to the user, to let them know how much of their daily CO2 'budget' they have used and by so affect them to make a change in their habits of using digital services?
>
> **RQ1.1:** *What types of nudging, as conveyed through software, could make the end-user take a more environmentally sustainable action?* This question aims to determine the appropriate ways to affect the users to act more sustainable.
>
> **RQ2:** *What measures can be integrated into the requirements as well as design process of software development to make it possible that when developing software to take sustainability into consideration?* The question will consider what tasks can be incorporated into the requirements as well as the design phase of software development as a best practice checklist to ensure end-users understand the width of the software's impact on the environment.

The research questions to meet the goal as well the aim of the study has been presented and in the upcoming section, the outline of the thesis will be described.

1.5 Outline of the thesis

Chapter 1 has described the background of the research subject as well as presented the reader with the problem statement together with the purpose and aim. Moreover, the research questions of the study were introduced in this chapter.

Chapter 2 covers the research methods employed in this study and describe the research design in detail. Chapter 3 presents the content of the literature review i.e., the related work and introduces the reader to the theoretically relevant background of the study. In Chapter 4, the survey, its design, validation and data collection, and results are described. In Chapter 5 the interviews are described in-depth, i.e., the design, validation, data collection, and results. In Chapter 6 the process of developing the checklist is described and presented. Chapter 7 discusses the results. Further, Chapter 8 covers possible future work. Chapter 9 covers validity threats and conclusions are presented in Chapter 10. Finally, following the chapters and the bibliography are a number of appendices.

2
Method

This chapter describes the research methods used to answer the stated research questions of the study. In this chapter, the design of the research, as well as the details of the exploratory case study, are described. As the last part of this chapter, the literature review of the study is described. The main parts of the case study: survey, interviews, and validation, will all three be covered in more detail in their respective chapters. In these chapters, the design, evaluation, data collection, and analysis of each of these research methods are described. The survey is described in Chapter 4, the interviews are described in Chapter 5, and the checklist of suggestions, considering what to include in the software process for sustainability to be taken into consideration, and its validation, is described in Chapter 6.

2.1 Research methods and research design

In this section, the design chosen for the research will be presented and described in detail. In the field of software engineering, there are many different research methods used [54]. Both qualitative and quantitative methods are used within the field. Broadly speaking, qualitative methods provide detailed information about few cases, whereas quantitative methods provide broad information about many cases. Examples of different types of studies within software engineering are, e.g., field studies, field experiments, sample studies, and laboratory experiments. All of these different types of studies consist of several research methods. Examples of these are case studies, interviews, experiments, systematic literature reviews. Field studies and field experiments can both consist of qualitative as well as quantitative methods to answers research questions. Sample studies are typically consisting of research methods that are quantitative with the possibilities of using qualitative methods if needed. Whereas laboratory experiments use, generally speaking, quantitative methods only.

The type of research chosen for a study does depend on what type of aim the study is pursuing and what the goal of the research is rather than certain methods being better or worse [55]. Within the field of software engineering it is possible to distinguish between knowledge-seeking and solution-seeking studies where knowledge-seeking studies aim to gain knowledge about, for instance, software systems, and users and developers, as well as their behaviours [55]. Solution seeking studies, on the other hand, focus more on developing a solution to a certain problem [55].

In this study, an exploratory case study was used to obtain the aimed for re-

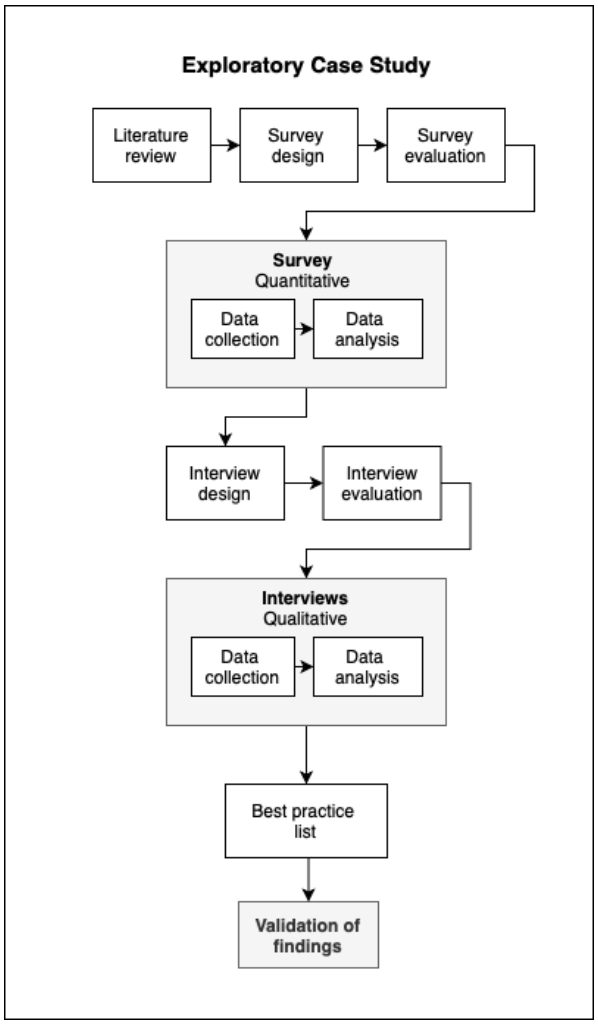

Figure 2.1: Visualisation of case study

sults (knowledge-seeking study). Case studies are empirical and are described by Runesson and Höst to be an empirical method aiming towards "investigating contemporary phenomena in their context" [45]. Runeson and Höst have defined four types of case studies suitable for software engineering research: exploratory, descriptive, explanatory, and improving [45]. To answer the research questions of this study, an exploratory case study was conducted based on the fact that the study aimed to seek new insights [45]. The decision of making a case study was based on the usefulness of such a study within the field of software engineering and based on it providing a deeper knowledge of the subject which the study covers [45]. Triangulation was applied within the case study by conducting a data collection consisting of a literature review, a survey, as well as interviews. This was done to make sure that different angles/perspectives were covered [45]. The same results would not have been possible to obtain with just parts of the case study as the information found would not be as comprehensive. Neither would there have been any basis for the upcoming step without the prior one. In addition, triangulation would not have been attained, the quality of the study would not have been as thorough, and the found answers would not have been possible to validate in the same manner.

2.2 Case study

The case study and data collection consisted of three parts as previously mentioned. As stated by Runesson and Höst, a case study can include other research elements such as surveys and interviews to collect data which also was the case in this study [45]. The case study constituted of a literature review, a survey, and interviews with experts within the field of study, as well as a final validation of the created checklist (see Figure 2.1). The initial step of the study was to conduct a literature review to create a foundation for the survey. The literature review was not systematic nor exhaustive but should rather be seen as an overview of the subject.

A survey was then conducted with the aim of finding what to investigate further in the interviews following the survey. The goal of the survey was to collect a wide range and number of characteristics, i.e, users' different choices as well as motivators regarding the environment, with the purpose to later deepen the knowledge of as well as validate these characteristics in expert interviews. The survey conducted was cross-sectional [10]. It was validated with the help from software engineering and sustainability researchers. This to ensure clarity of the questions as well as to include the appropriate content to meet the goal of the survey.

When the data from the survey was collected and analysed, it was possible to lay a foundation for the interviews. These interviews were semi-structured and the interview subjects were experts within the field to validate the outcome of the survey as well as get a deeper understanding of the subject. The interview questions were validated together with sustainability engineers for ensuring the appropriate content and with a software engineering researcher to ensure clarity and understandability of the questions.

After the interviews, an analysis of the data collected was made to be able to answer **RQ1**, *How could software make the end-user aware of the CO2 emissions of using digital services?* and **RQ1.1**, *What types of nudging, as conveyed through software, could make the end-user take a more environmentally sustainable action?*.

When the data had been analysed, the aim was to put together a checklist consisting of the findings, validate them, to then be able to answer **RQ2**, *What measured can be integrated into the requirements as well as design process of software development to make it possible that when developing software to consider sustainability?* and to contribute to the software engineering field.

To conclude, the case study was put together consisting of a survey, interviews, and development and validation of a checklist as a contribution to the software engineering field. How the questions from the survey and interview instrument was connected to the research questions and goal of the thesis can be seen in Figure 2.3.

2.2.1 Literature review

The case study was as previously mentioned initialised with a literature review. The review of the literature was conducted to make sure that the literature of matter was included in the study to gain deeper knowledge within the field as well as make a solid foundation for the survey.

The literature review was conducted by looking at the common databases rele-

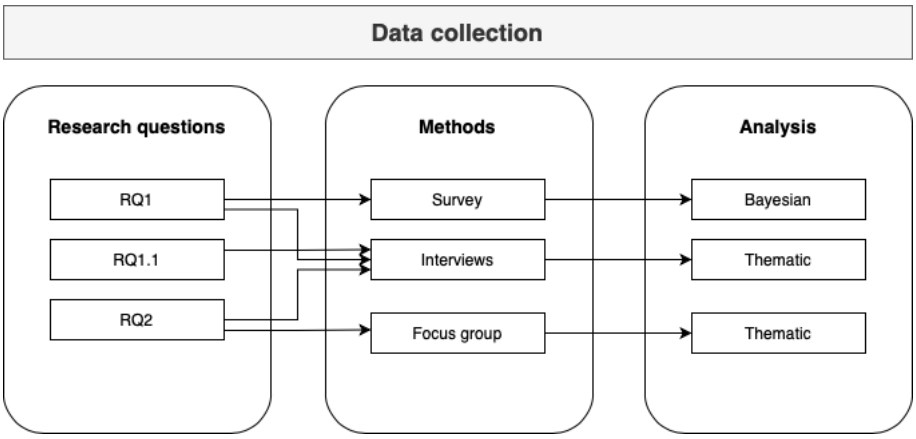

Figure 2.2: Data collection

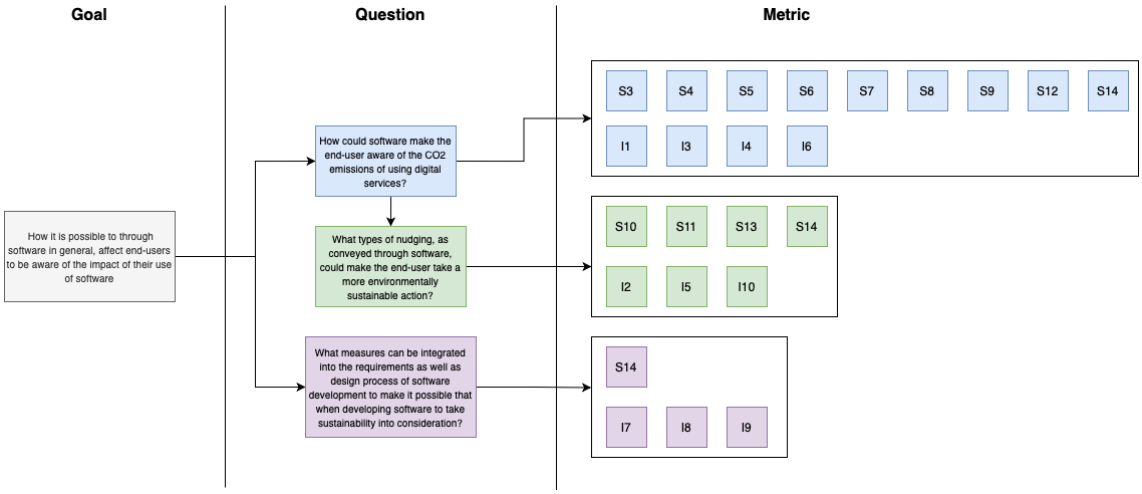

Figure 2.3: The overall thesis goal, connected to the RQs and the questions in the survey as well as the interviews. Questions marked with S concern the survey, questions marked with I concern the interviews. The metrics are connected based on what the questions in the each of the two instruments cover.

vant for the field such as Elsevier, IEEE Explore, and Wiley to mention but a few. Literature was found by looking at certain keywords such as sustainability and green software to mention two of the most important ones. The search should not be seen as exhaustive but rather representative of what is relevant in relation to the topic of research. By looking at the relevant articles and their used references a snowball sample of articles could be found. To conclude, the relevant literature was found to likely be a representative sample of the field.

In the upcoming chapter the content of the literature review, i.e., the related work, is presented.

3
Related work

In this chapter the outcome of the literature review is presented, i.e., the related work of the study will be covered. The related work covers the environmental impact of the internet as well as of software. In addition, the environmental impact of streaming services will be covered. Connected to this, related work concerning end-users' behaviour is presented. Additionally, a summary of nudging and feedback is covered.

The related work has been found by searching through different relevant databases by searching for certain keywords. Further, articles were found by looking at the reference lists of already read articles to find what had been cited concerning the study. The literature should not be considered an exhaustive search of the field but rather a representative search.

The related work and outcome of the literature review served as a basis for the later conducted survey.

3.1 Environmental impact of the Internet

The footprint of the internet is already high and today the internet is estimated to use 7% of the world's energy consumption. The demand is not decreasing and looking to grow up to 30% in some countries by the year of 2030 [9, 36, 37]. Patsavellas and Salonitis mention in their research that "by 2020, it is estimated that for every person on earth, 1.7 MB of data will be created in the duration of every single second" [40]. This means that there is extended use of data, which also has been concluded by Belkhir and Elmeligi.

The Information and Technology Communications (ICT) sector have both positive as well as negative impacts on the environment and a question for the future is whether it is possible to decouple economic growth from energy consumption [3, 28, 34]. Bhor et al. describe initiatives and actions taken to minimise the impact of ICT on the environment [37]. Similarly, Moloney and Strengers bring forward the same conclusions in their research: "an additional danger of this approach is that new resource-intensive practices may emerge that are not deemed part of the small suite of small or large actions necessary to 'go green'. New ICTs are posing particular problems in this regard. For example, the consumer electronics sector, encompassing entertainment technologies, computers and gadgets, is now one of the fastest growing areas of electricity consumption in the home" [33].

Jenkins et al. point out that there is a need to make IT and software more sustainable as it consumes large amounts of energy [21]. Currently, researchers are

focusing to evaluate what kind of impact software has on the environment and in combination suggest what software developers can do to lower environmental impact, such as increasing the performance when writing their code [23]. Ellegård and Palm agree that it is important to find methods and solutions to keep up with peoples energy demand in their everyday life [11].

Røpke and Christensen state in their research that "the growing use of ICT in relation to more and more activities—such as entertainment, reading the news, banking transactions and communication in general—supports a partial decoupling of practices from their previous time-space location. One example of this is mobile broadband and smartphones with internet access, which make it possible to read the latest news or check the latest updates on Facebook from almost everywhere (at least from places with mobile broadband coverage) and while on the move." [44]. This connects to the growing demand for more data [9].

One of the important issues that we face in today's society is how to become more sustainable and additionally how to use less energy [48]. (Data centres consume at least 1% of the entire world's electricity [35].) With an increased demand for storage and computation comes the need for more computing power. As the data centre industry increasingly grows and the sustainability of these centres become more monitored, as well as reviewed, there exists a need to create awareness around the environmental impact of the data centres as well as understand what influences the high environmental impact [13]. To meet the demand, more data centres are needed that in turn make use of a large number of servers that have a high energy consumption [29, 60]. Altogether, there are already measures and policies for how to keep data centres as sustainable as possible [59]. Not only is there a need for these to be followed and improved, but also for other measures to be taken.

Another challenge is that there is a lot of waste heat produced in data centres [64]. To take action on these problems, data centres can be made more sustainable in several ways [43]. One possibility is to make use of the waste heat that is produced within the data centre [62]. The waste heat can either be used for district heating networks or greenhouse farming [20, 29].

Digital services are in 2030 expected to grow to 21% of the world's electricity use [65]. The largest contributor to this, with its high data demand, is YouTube with an almost 50% watching demand across households [65]. Widdicks et al. has presented in their research that "from our findings of Internet-disconnection adaptation, we can suggest four areas of future research: 1) for creating limits to usage behaviours that drive Internet infrastructure growth; 2) for the promotion of slow values through Internet disconnection; 3) for Internet non-use, and 4) for discussing the undesign of Internet services" [66].

In conclusion, the impact of the internet and the ICT sector is high, but there is still no common ground for how to improve the current situation [23]. The impact of the ICT sector and the internet can be broken down and analysed through the impact of software.

3.2 The environmental impact of software

As well as for the internet as a whole, there seem to be key concepts missing on how to develop sustainable software according to Kern et al. and Oyedeji and Penzenstadler [23, 39]. They argue that few tools connect all of the aspects of sustainability to ensure a better understanding of the sustainability of software [39]. What they emphasise is the need to use requirements engineering to ensure the sustainability of software as the requirements phase is what establishes and lay the ground for how any software turns out [39, 42]. They also mention the importance of including sustainability into the requirements phase as an advantage both for stakeholders as well as end-users of software [39].

There seem to be many different takes on how to ensure that software is sustainable [23]. Kern et al. tried to find a label for software. This label was to be put on software in cases where software did impact the environment less than or equal to other software [23].

There are different approaches towards making software more sustainable which does not have to be limited to carbon emission only [18]. Both the process as well as the product is of interest when talking about sustainable software [21, 32]. The maintenance process shall also be included in the sustainability aspect of the software, according to Penzenstadler [41].

What is also argued by Penzenstadler is that there is a need for conceptualising the term sustainable software as well as create a common understanding of what it is within the field of software engineering [41]. Shenoy and Eeratta suggest that sustainable decision making shall be included as well as standardised in the software development [50]. By developing a model for a sustainable way of thinking they argue that there is an awareness in each step of the development process to move towards more green and sustainable software [50].

Naumann et al. has also composed a model which focuses on the sustainability of the development, purchasing, operating, as well as using software which fulfils what they have established to be sustainable [38]. According to Ellegård and Palm, there is more information required on how everyday life affects energy consumption, and this information needs to be comprehensive for the end-users to understand and use it [11].

Moreover, there have been attempts in finding and applying different models [38]. Naumann et al. has tried to find a suitable model, the GREEN SOFT model, to ensure green and sustainable software [38]. Whereas Uddin and Rahman has focused more on energy-efficient techniques and algorithms to solve the issues of high demand on computing power [60]. Another suggestion that seems to cover several important aspects of sustainability is the Principles of Green Software Engineering [19].

In summary, there is no unified and clear advice or concepts suggesting *what* sustainability of software engineering is [46]. There is still concrete guidance needed for the field [41].

Figure 3.1: Example from Greenpeace [9]

3.3 Environmental impact of streaming services

There are many large video streaming platforms today, Netflix and Prime Video are just two examples amongst the large category of players [22]. Greenpeace has published an overview of some of the most common and well-known actors on the internet as well as their choices concerning energy use [9]. The information is gathered from what the companies have provided regarding their energy performance [9]. The paper published by Greenpeace presents the different platforms categorised into classes based on the sustainability of their energy provided to their data centres [9]. The classes which each company is graded with covers what type(s) of electricity the company has chosen to use—the more green energy the better the grade [9]. Figure 3.1 shows an example of a streaming service, in this case, Netflix, where the class that they have gotten is D. This is based on their sources of energy where 17% is clean energy, 30% is coal, 24% is natural gas, and the remaining 26% of the energy is provided by nuclear power plants.

This is one action towards transparency and showing the end-users how much green energy is used. It should be noted that, when it comes to streaming video, the end-users are the ones responsible for the majority of the energy use [49].

In their research, Patsavellas and Salonitis mention that "Belkhir and Elmeligi have stipulated that the two largest contributors of carbon emissions in the ICT sector are Data Centers (usage phase) and Communication Networks (data transmission phase)" [40]. This emphasises what has been mentioned previously about data centres as well as sheds light on the data transmission which is increasing through the use of software, there among streaming services [40].

Widdicks et al. brings forward the fact that half of all the peak data traffic is video streaming [65]. Morley, Widdicks, and Hazas suggest that there are problems concerning when, meaning what time of the day, the user is streaming video content [34].

Widdicks et al. suggest that there urgently needs to be taken actions upon binge-watching "as the shift to Internet-based services has an increasing impact on people, society and the planet" [65]. Widdicks et al. also mentions in her research that there is a risk that, as people are tending to turn to online content when watching, it can be expected in the future that multi-watching streaming content on several streams will increase [65].

Widdicks et al. points out that, "although it is hard to imagine that users would restrict their Internet use for sustainability, it is considerably easier to imagine that these motivations can be combined, e.g. restricting Internet use due to reasons pertaining to sustainability and data misuse and productivity. [...] Based on our study and through taking undesign goals and principles into consideration, we argue that it should be made easier for users to disconnect from the Internet and specific services accessed through it. [...] Our suggestions concerning the redesign of affor-

dances of various tech companies (Facebook, Netflix) services are situated at a level in between the individual and regulation but it might be the case that change at that level will only happen through regulation" [66]. The previous quotation from Widdicks et al. accentuates the need for this study in our opinion.

In summary, other than the Greenpeace Clicking Clean report [9], there is not much transparency regarding the impact of streaming services. As the impact of the streaming services is high as well as increasing [65], there is room for improvement and new solutions.

3.4 Nudging and feedback

Information can be a strong motivator when it is presented correctly for a user. Thaler suggests that while waiting for politics as well as policies to come around, nudges can make a difference [58]. It is also suggested by Cappa et al. that some of the large challenges faced today can efficiently be tackled by using nudging [7]. Nudges are used to make people steer towards a certain behaviour or to do less or more of a certain action [7, 58]. What Thaler emphasises, as a concluding point, is that nudges towards a behaviour should do little harm for people already having a certain behaviour which is of interest to further strengthen [58]. It is possible to give the end-users freedom of choice as well as nudge them towards the desired behaviour at the same time [58].

This is also something which Geelen et al. describe in their paper where they do mention that overall, any direct feedback will in relation to the users prompted with it, be effective and even more so the more immediate the feedback is [15]. Moreover, Geelen et al. have shown that feedback is effective when trying to make households change their level of energy consumption [15]. This has also been shown to work by Kjeldshov et al. [25] They showed that to change households' energy consumption, feedback, as well as guidance, are methods which makes it possible to stimulate the improvement actions and change the behaviour towards a conservation behaviour. By providing the users with daily feedback Kjeldskov et al. could show that there was a potential for the consumers to save up to 15% of the household's energy consumption [25].

By using various methods there are ways to nudge people towards a desirable option or behaviour, for instance, as done within the field of marketing by limiting the number of products a customer is allowed to purchase. What is of more relevance to this study is research concerning digital nudging and how it is possible to affect the user by presenting the choices they can make to obtain a certain result [31, 63].

An advantage of using mobile apps to gather considerable amounts of data when trying to affect people is the information to be extracted from the app. This data can be used to get a better understanding of how to nudge people more appropriately and efficiently. For instance, when using Fitbit[1] the user's exercise patterns can be tracked and thus creating nudging reminders based on activity [63]. Székely et al. conducted a study concerning how it is possible to affect the booking pro-

[1]A Fitbit is an activity monitor that keeps track of your daily activity by registering your movement.

cesses of flights, and how it was possible to affect and increase the carbon-offset payments [57]. Another research topic concerning nudging that has been looked into recently is concerning CO2 emissions as well as energy consumption concerning smart homes [27]. Nevertheless, Schneider et al. assert that there is no way of designing a nudge that fit all types of end-users [47].

As pointed out by Kobus et al., there is a need for feedback to be in real time [26]. This is something that Geelen et al. also state, as immediate feedback seems to be more efficient [15]. Kobus et al. have also found that feedback must be available to the end-user over a period of time and by so become a part of everyday life [26]. Moreover, they found that there was a need for the feedback device to remain attractive to use for the end-user [26]. Finally, Kobus et al. pointed out that there was a need for energy consumption to be shown in a way that was easy for the user to understand as CO2 emission can be hard to comprehend. In addition to this, Geelen et al. point out that for the end-users to engage with the feedback, it needs to be easily accessible as well as relevant [15].

The feedback given can be both of positive as well as negative [24]. Kirman et al. state that most often, rewards are involved when trying to change a user's behaviour. If there is a feedback program designed to change the user's behaviour there is often a lack of any meaningful feedback when there is no reward obtained [24]. Kjeldskov et al. bring forward that there is an importance in not only using the positive reinforcement but also use negative reinforcement as this too can make *positive* changes [25]. That said, using negative reinforcement can potentially also be a pitfall as there is a risk that they cause frustration [25].

People are very different and are motivated by different factors and this Kjeldskov et al. points out. There should be tailored use of feedback in applications used for affecting peoples' behaviour [25]. What could be concluded from the study of Kjeldskov et al. is that having a mobile device was beneficial for the users as they could load their data wherever as well as whenever [25]. Kjeldskov et al. mentions that "research has also shown that, to raise awareness about electricity consumption, timely feedback and guidance is required to stimulate conservation and enable users to change their behaviour in a way that decreases their power usage. For example, by providing daily feedback, consumers can potentially save between 5% and 15% of the electrical household energy consumption" [25].

3.4.1 End-user behaviour

Recently, there has been a larger focus on sustainability and by so an aim to create awareness of the joint responsibility for the environment [25]. It seems that there is not a clear understanding amongst people of what actions are good for the environment and which ones are not [56]. Studies show that people, in general, are more reluctant to concern themselves with their individual issues rather than global problems with the need for collective actions [17]. What tends to affect users is when they can compare their own actions to what other people in their community are doing [25, 56]. There is also a preference among people in general for immediate rewards rather than rewards that come over time.

Making people aware of the carbon footprint that they are making could be

done in several ways, for instance: “One way to help people make more sustainable decisions on the individual level would be to give consumers feedback on the carbon footprint of the wares they are about to purchase, for example by taking advantage of self-scanning systems, where customers scan their products themselves before paying for them. In addition to the accumulated price with each product, the system could also provide the customers with an accumulated carbon footprint estimate of their wares” [53]. This could be informative as well as nudging people to make other choices that are more sustainable [53].

Skjølsvold, Jørgensen, and Ryghaug mention in their research that “In sum, our account poses some radical challenges to observers, analysts, system designers and technology developers, who aim to make feedback technologies a central element of the transition towards a low carbon energy system. [...] As a very hands-on example: how should feedback technologies look, and what kinds of feedback should they provide?” [51].

To summarise this chapter, there is room for improvement both when it comes to the sustainability of the whole ICT sector and the software engineering field, but also more specifically when it comes to software. Through different studies, it has been emphasised that there is a need for finding new solutions and ways to make it more clear what sustainable software is. Also, to create awareness concerning this issue, potentially through nudging and feedback, which is where this thesis is positioned. In the next chapter, the method of the survey will be covered in detail.

4
Survey

In the previous chapter, the result from the literature review was presented. Based on the literature review the survey could next be created. In short, the literature review served as a basis for the survey. It was essential to understand what research that had previously been conducted and what was of relevance to include in the study to investigate further. The challenges and issues that other researchers had encountered were also of importance to bear in mind for the survey.

Following the literature review, the survey was designed. The aim and purpose of the survey was to receive an understanding of certain characteristics of end-users of digital services and software. By conducting a survey the possibility for a rapid turnaround of answers in conjunction with the possibility for a large sample increased [10]. By getting a larger sample the reliability of the outcome of the survey increased [10].

The purpose of using a survey, as stated by Fowler, is to produce useful statistics which describe certain aspects of the study population [10, 14]. The survey used in this study was cross-sectional and unsupervised [10]. In the upcoming section, the design of the survey is described.

4.1 Survey design

The survey design process was based on work by Fowler and Creswell [10, 14]. To create a survey of a satisfactory quality the following survey process was followed:

1. Formulate research questions/objectives
2. Identify the population to be studied
3. Select the sample
4. Choose the mode of data collection
5. Construct the survey instrument
6. Pretest the survey instrument and establish reliability/validity
7. Data analysis

4.1.1 Formulate research questions/objectives

The objective of the survey was to get an understanding of end-users behaviour in relation to digital services, e.g., when they use them and for how long, to mention

but a few examples. Moreover, the intention was to understand what actions could be taken by the end-users to change their behaviour in terms of sustainability.

4.1.2 Identify the population to be studied and select the sample

The data collection of the survey was initialised by considering the intended sample of the survey. When creating the survey all of the aspects from the list previously presented (by Fowler) were considered along with the possible errors which could be introduced into the survey. Potential errors in the survey could be sampling error as well as introducing any kind of bias into the survey. To avoid sampling error the aim was to get as large a sample as possible as this would decrease the sampling error risk. To avoid selection bias the survey was distributed through several different types of channels where the targeted people were encouraged to share it further into their channels and by so reaching a larger part of the population. This, however, also indicates a weakness with our study, i.e., the response rate can not be estimated.

The population under study was end-users of digital services, more specifically of streaming services. Thus, the population of the survey was anyone making use of streaming services for the past month. In the fourth quarter of 2020, Netflix had more than 200 million paying subscribers to their service world wide.[1] It can therefore be assumed that the entire population of users of streaming services potentially can be larger than the number of Netflix subscribers due to the considerable amount of different streaming services.

In the field of software engineering, there is a challenge in the sampling process and thus there is a need to rely on convenience sampling rather than random sampling. Many times it is not possible to decide how large our sample will be based on the lack of sampling frames within the field [1].

The sample for this study was chosen by convenience sampling and in this case there was an advantage in having a population consisting of end-users of streaming services as most people today use some kind of streaming service and thus it was easy to reach out to the population which was considered to be large. Although, having a large population does not make any promises about the sample itself.

The sample size will aim to be consisting of 377 people based on a margin of error of 5% with a confidence level of 95%.[2] As mentioned, the aim was to get as large a sample as possible and the estimated sufficient sample size of 377 should be seen as a goal only (often such a large sample size is not realistic in software engineering research). The sample was not stratified.

4.1.3 Choose the mode of data collection

QuestionPro[3] was chosen to use as a platform for the survey due to its convenience concerning designing the survey, in addition to it having an interface considered easy to use and due to it having a wide range of useful functions considering the

[1] https://bit.ly/33gguuS
[2] http://www.raosoft.com/samplesize.html
[3] https://www.questionpro.com

design. The questions of the survey aimed to be both clear and easily understood, not to mention being meaningful and not with a double meaning based on the recommendations from Fowler on survey design [14].

4.1.4 Construct the survey instrument

The chosen questions for the survey were based on the literature found as presented in Chapter 3. What was of interest and discussed partly in some of the literature were the habits of the respondents and their feelings connected to trade-offs in relation to the environment. Also, the respondents' reasons for performing certain actions was interesting, to get an initial understanding of end-user behaviour. In addition, motivational factors which had been mentioned in previous research was included too.

To make sure that the questions of the survey added value, they were explicitly connected to the research questions. The demographic questions and the first few questions regarding streaming habits were not related to the research questions. The aim of these demographic questions, as well as the initial question on streaming habits, was to get an understanding of the respondents' age and gender as well as what streaming services the respondents subscribe to. How the other questions were connected can be seen in Table 4.1. For instance, Q13, covering motivation was connected to RQ1.1 as this concerned how the user could be motivated to decrease their use of streaming services which was based on literature findings in Chapter 3.

Table 4.1: Connection between RQs and survey questions

Research Question	Item on Survey
RQ1	Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q12, Q14
RQ1.1	Q10, Q11, Q13, Q14
RQ2	Q14

The research questions are presented again in Table 4.2. The two first questions, RQ1 and RQ1.1, were in focus for the survey.

Table 4.2: Research questions

Question Nr	Research Question
RQ1	How could software make the end-user aware of the CO2 emissions of using digital services?
RQ1.1	What types of nudging, as conveyed through software, could make the end-user take a more environmentally sustainable action?
RQ2	What measured can be integrated into the requirements as well as design process of software to make it possible that when developing software to take sustainability into consideration?

The questions that were asked in the survey can be seen in Table A.1. Question 9, 11 and 13 were all questions containing several Likert scale questions, and thus they are divided into parts in the table.

Table 4.3: Survey questions

Question Nr	Question
Q1	What gender do you identify with the most?
Q2	How old are you? Please choose your age among the options in the list.
Q3	What of the following streaming services have you used more than once for the past month? Please tick as many boxes as you feel apply. If you do not find your streaming service of choice, please specify which one you use in "other".
Q4	What device do you most often use, to watch your media on? The device you use is the one where you load your app from and the main hardware used to watch your videos on.
Q5	How many devices are usually active in your household at the same time streaming video content? Remember that any streams running simultaneous counts. For instance, using YouTube on your phone while watching a stream on the TV. Please give an estimation of what you think, your answer does not have to be exact.
Q6	How many days a week do you estimate that you usually stream content on the previously mentioned streaming services? Please give an estimation of what you think, your answer does not have to be exact.
Q7	How many hours a day, do you estimate that you spend on the previously mentioned streaming services? This also includes background streaming such as keeping YouTube on for music or a series on for company. Please give an estimation of what you think, your answer does not have to be exact.
Q8	How concerned do you think we should be of software's impact on the environment?
Q9	How much would you trust information about carbon emission/environmental impact if you heard it from/if it was communicated by any of the below: Please choose the option that you find most suitable on each row.

Continued on next page

Table 4.3 – continued from previous page

Question Nr	Question
Q9.1	Family member/friend
Q9.2	Scientist
Q9.3	The government
Q9.4	An energy supplier
Q9.5	An environmental organisation
Q9.6	An application on your phone
Q9.7	Media (news/radio/papers)
Q9.8	The internet
Q10	What of the following options do you think would be the hardest to give up entirely? Please choose the option that you think fits best. With non-green energy means any energy source which is not renewable. Non-green energy is typically lower cost.
Q11	Below you will find a list of everyday activities. For each of the activities that you do regularly, please indicate your main reason for doing so. Please tick the box on each row that you feel apply on each row. If it is not an activity that you perform, please tick the box "I do not perform this activity".
Q11.1	Walk/cycle to work
Q11.2	Public transport
Q11.3	Turn off lights I'm not using
Q11.4	Recycle
Q11.5	Following a vegetarian diet
Q11.6	Turn off your computer overnight
Q11.7	Take as short showers as possible
Q11.8	Buy second hand

Continued on next page

Table 4.3 – continued from previous page

Question Nr	Question
Q12	Whose main responsibility do you think it is that streaming services are sustainable? i.e. reducing the environmental impact of streaming services
Q13	What of the below actions/incentives would motivate you to decrease your use of digital services? Please choose the option that you find most suitable on each row.
Q13.1	Notifications informing me about my daily CO2 emission
Q13.2	Information regarding the implications of the use of digital services in relation to emissions
Q13.3	Setting goals in relation to emission to motivate a decreased use of digital services
Q13.4	There is nothing that could motivate me to decrease my use of digital services
Q13.5	Logging my use of digital services to see my behaviour over time and get suggestions on how to improve
Q13.6	Streaming services being blocked by an app after a certain amount of CO2 emission
Q13.7	See the CO2 impact of video streaming related to other activities having impact on CO2
Q13.8	Suggestions to use streaming services at another point in time, which could result in lower CO2 emission
Q14	Do you have any other inputs or ideas that you would like to share to increase sustainability in relation to use of digital services?

The survey consisted of three main categories of questions. The first part of the survey was demographic questions, the next part consisted of questions regarding end-users' behaviours in relation to streaming services. Lastly, a part concerning sustainability and habits concerning CO2 impact of digital services was included. The answers to these questions consisted of a mix of categorical scales and Likert scales. Additionally, a final open question was added to enable the user to add

any thoughts on the sustainability of digital services. All of the questions had a small help text available to the respondents to read if they felt that they did not understand the question fully.

In addition, the three parts of the survey were spread out on three separate pages—when the respondents had answered the questions on a page and pressed the next button moving on to the next page they would not be able to go back and change their answers. This was done due to the fact that the survey consisted of questions regarding sustainability, which can be connected to a feeling of guilt. Thus, there was a risk that answers could be affected and there could be a feeling of wanting to change answers after reading other questions. The content included in each section is described in the coming paragraphs.

Demographic questions. The demographic questions were asked to obtain background information about the respondents. There were only two demographic questions. The first one, (Q1) asked the respondent about their gender and the second one, (Q2), asked about the respondents' age. The age was asked for in a roll-down menu instead of having age groups to ensure that any important characteristics could be distinguished in the analysis of the data in the later stage (i.e., continuous analysis instead of categorical).

Streaming habits. Following the demographic questions came a section containing questions regarding the respondents' streaming habits. These questions were asked to understand what the habits of end-users look like today to get an overview and understanding of the starting point of the survey. The aim of this section was to get an understanding of respondents' behaviour. Along with this, further questions were asked about habits of using the streaming services, e.g., how often they use them in addition to for how long. Furthermore, questions followed concerning the device of their choice and also how many devices the respondents usually keep active at the same time.

Question 3, was a checkbox question asking the respondent how many of the presented streaming services they had used for the past month. The respondent was asked to tick as many boxes as they felt applied.

Question 4 was a multiple choice question with a single select answer, asking the respondents to provide information about what device they most often use to make use of digital services. The options that the respondents had was: TV, Computer, Tablet, Smartphone and other, where the other option took an input.

Question 5 asked the respondent, once again through a multiple-choice question. The question concerned how many devices they would usually keep active at the same time. Ranging from non to more than 4 devices.

Question 6 contained a question regarding the weekly habits of the respondents, asking for how many days a week the respondents would stream media. Once again this question was a multiple-choice question asking for one single answer. Here the first option was zero days a week and the last option was every day a week.

Finally, Question 7, covered streaming habits. The respondents were asked to provide information about how many hours a day, in general, they would spend on digital streaming services. Again, the question was a multiple choice question with a single answer required. The answer options were a range of hours starting from zero hours a day to more than seven hours per day.

Sustainability and habits concerning CO2 impact of digital services. As mentioned, questions were also asked concerning more general sustainability matters along with sustainability in relation to streaming services to understand the respondents' actions and interaction with software.

This section of questions started by asking the respondents concerning the impact software has on the environment. In addition to this, further questions, such as how much information about the sustainability of software could be trusted, was asked. In addition, what actions could motivate the respondent to decrease their use of and inform them of the impact of digital services.

Question 8 was the first question of this section, containing a 5-point Likert scale. The question asked the respondent how concerned they were about the impact of software on the environment. Ranging from not concerned to concerned.

The next question, Question 9, concerned how much the respondent would trust information about the environmental impact from different sources. The question was a 5-point Likert scale, where the options ranged from 'don't trust' to 'trust' and the different options were: family member/friend, scientists, the government, environmental organisations, an application on your phone, media (news/radio/ papers), and lastly the internet.

Question 10 was a multiple choice question where the respondent had to choose one option that they considered to be the hardest to give up entirely. The options they could choose among were: driving a car, flying, streaming video, eating meat, buying non-green energy, buying new clothes and lastly, they could choose to not specify what they would find hardest to give up. Also, for this question, an answer text was added where the respondents were asked to motivate their answer.

Moving on to the next question, Question 11, the respondents were presented with a list of different environmentally-friendly activities where they should choose among different reasons for performing that action. The options were: walk/cycle to work, public transport, turn off lights I'm not using, recycle, following a vegetarian diet, turn off their computers overnight, take as short showers as possible and, lastly, buying second hand. The options available for *why* this action was performed were the following: to save money, to protect the environment, health, habit, moral obligation, other, or I do not perform this activity.

Question 12 asked the respondent, through a multiple-choice question, for who they thought has the main responsibility for streaming services being sustainable. The option given was: the streaming platforms, the end-users of streaming platforms, energy producers, energy provides, policymakers (e.g., politicians) or finally 'other', which came with the option to provide their own answer.

Question 13, the last Likert scale question. The question was a 7-point scale and asking the respondents to provide an answer to the question of what would motivate them to decrease their usage of streaming services. They could choose any of the options in the range of 'strongly disagree' to 'strongly agree' with the following options: notifications informing me about my daily CO2 emission, information regarding the implications of the use of digital services in relation to emissions, setting goals in relation to emission to motivate a decreased use of digital services, there is nothing that could motivate me to decrease my use of digital services, logging my use of digital services to see my behaviour over time and get suggestions on how to

improve, streaming services being blocked by an app after a certain amount of CO2 emission, see the CO2 impact of video streaming related to other activities having an impact on CO2 and, finally, as a last option for them to make a decision about, suggestions to use streaming services at another point in time, which could result in lower CO2 emission.

As a concluding question, Question 14, it was possible for the respondent to freely express any general ideas on how to decrease the impact of software on our environment. All the questions asked, exactly as they were stated in the survey can be found in Appendix A.1.

Overall for the survey certain settings were applied. Whenever the respondent had finished one of the parts of the survey, they were *no longer* able to go back in the survey and change their answers. This setting was applied, as earlier mentioned, as the survey is concerning sustainability and software and thus, people could possibly be tempted to change their answers when coming across new questions. This was thus added to minimise the possible bias of people changing their answers due to possible guilt or shame. All of the questions from the survey can be found in Appendix A.1. After the survey design had been completed the survey had to be evaluated.

To sum up, the survey questions were based on the literature review previously conducted. The aim for the survey was established, which were to get an understanding of end-users' behaviour in relation to digital services and the questions were formed accordingly. QuestionPro was used as a tool for creating the survey due to its convenience. The survey questions were divided into three separate parts: demographic questions, streaming habits and sustainability, and habits concerning the CO2 impact of digital services. How the survey questions were evaluated is presented next.

4.2 Survey evaluation and pretest

The evaluation of the survey was done through different measures. The survey was *pretested* by several individuals giving feedback on the questions together with the comprehension of the survey. To ensure that the survey was pretested through structured means reliability and validity was ensured.

4.2.1 Reliability

The reliability of a survey aims to establish whether the result of the surveys is roughly equally distributed at every run of the survey. The reliability aspects consist of test-retest, alternate form, internal consistency, in addition to the inter-rater agreement. In this study, the focus was on *alternate form reliability*, to ensure that the survey measured what it was intended to measure. To ensure alternate form reliability of the survey it was distributed to a smaller sample in its original form for them to answer. When the answers were collected the questions of the survey were then reshuffled as well as rephrased, and the survey was yet again distributed to the same sample.

After the reliability of the survey was considered the survey was sent to a small group of people to ensure the *readability*, *explicitness*, along with the *understandability* of the survey questions and by so make a first step towards the validation. This was done to make sure that the mentioned aspects of the survey was considered and established, and thus there could be a more exact validation of the contents.

4.2.2 Validity

The validity of the survey aims to establish whether the survey measures what it is intended to measure. For validity, *content*, *criterion* and *construct* validity is typically of interest.

Content validity is obtained by an assessment of how appropriate the survey seems to a group with knowledge within the subject in question. Criterion validity is assured by comparing the instrument with another. Finally, the construct validity of the survey assesses to which extent it is possible to get the same result through different data collection approaches. Construct validity is often hard to achieve and does require many years of experience for a researcher to be confident in obtaining.

In our study, content validity was the only validity considered and obtained by using a focus group of two experts within the field who pretested the survey. The pretest was performed by having the focus group looking at the survey to ensure that there was no ambiguous nor unnecessary questions included, in conjunction with identifying whether anything was missing in the survey. The experts also considered the content and assured that the questions asked were appropriate together with the overall content being in line with the aim of the survey. The people in the focus group conducted the validity check independently of each other. By taking these two steps the reliability and validity of the survey was increased.

In conclusion, the survey as a whole was evaluated and pretested, and thus reliability and validity could be ensured to a certain degree. When this had been established and finalised the next step was to initialise the data collection.

4.3 Survey data collection

The survey was sent out not with the aim to be open for a set amount of days or weeks but rather with the focus to obtain a certain amount of responses. The first day of the survey being available consisted of distributing it to different channels. The survey was distributed to popular social media platforms, e.g., Facebook, Twitter, and LinkedIn. Here several different people shared and retweeted the survey and thus the survey was distributed to a larger population. Moreover, the survey was distributed internally at research institutes and the people at these institutes then distributed it in different channels such as Twitter, LinkedIn, and the institutes' home page. In addition to this, the survey was shared in different groups and forums on Facebook where the aim of the groups and forums was to distribute surveys.

The survey was open for respondents to answer for approximately one week and resulted in a total of 464 responses where 295 of these were complete answers which were the only ones used for the analysis (i.e., a complete case analysis was conducted since we could not formalise a model concerning the causality). In short,

the responses were collected through different means and the complete answers were extracted for the analysis to begin.

4.4 Survey data analysis

After finalising the data collection and closing the survey the answers were analysed. This was done by using Bayesian data analysis [30]. The understanding of Bayesian statistics along with how the data has been analysed require previous knowledge and will not be described in depth nor in detail. If Bayesian statistics is of interest to understand more thoroughly the reader is suggested to read *Statistical Rethinking* by McElreath which covers the steps that have been taken to analyse the data in this thesis [30].

The purpose of the analysis of the survey data was to find and make explicit the characteristics of the respondents of the survey, i.e., end-users, and to be able to lay the ground for the upcoming interviews and thus move further towards answering the research questions.

To initialise the analysis the data was firstly cleaned (complete case analysis) and then coded according to standard practices (e.g., making sure Likert scale are coded as numbers $1, \ldots, n$ and continuous covariates being standardised).

The data were converted from the QuestionPro tool into an Excel file and thereafter categorised and coded based on what type of question and responses the question consisted of. When the data had been coded, a Github repository[4] was set up and an RMarkdown file was created to ensure reproducibility. All the code used for the analysis is available in the Github repository and the analysis is completely reproducible. The file was set up with the appropriate libraries for the analysis. The data, the coded Excel file, was imported accordingly and the analysis could be initiated by now starting to design the appropriate Bayesian models. To be able to do this, the `brms` package was used [6]. This package was used due to its seamless way of handling predictors, i.e., by using the `mo()` function it was possible to use the defaults of the `brms` package rather than having to do extra work which would have been required with, e.g., the `rethinking` package [6, 30].

The questions in the survey were considered and categorised into being either predictors or outcomes. For the analysis, 7 predictors and 26 outcomes were defined. With this many outcomes, the analysis resulted in 26 different models.

In order to calculate a posterior probability distribution, each model needed a likelihood defined (assumptions about the underlying data generation process) and priors set on each parameter we wanted to estimate.

$$\text{Prior} \times \text{Likelihood} \propto \text{Posterior} \tag{4.1}$$

The predictors were chosen based on the variables consisting of factors that could be helpful in the prediction of the outcome, i.e., what could be considered as the users' attributes and pattern of action. The outcome is the variable we want

[4] doi: 10.5281/zenodo.4738918

to obtain knowledge and understanding about [30]. The chosen outcome variables were questions that described the respondents' personal opinions and thoughts.

Further, Bayesian models were developed based on the chosen predictors and outcomes. It was first intended to create multivariate models, i.e., several connected outcomes. This did, however, not show any particular effects concerning out of sample prediction, and instead, models with single outcomes were designed.

The first step was to choose what likelihood to use for each model. A model comparison was set up with the Cumulative, Adjacent-Category, and Sequential families. Sampling these three models, and doing a comparison between them, no significant difference could be detected. Thus, we opted for the Cumulative likelihood for Likert scale outcomes, as it has a solid mathematical foundation.

For categorical outcomes, the same procedure was followed. But instead, the comparison was between the Categorical and Multinomial families. In this case, the Categorical family was chosen. The mathematical expression for the two types of models can be seen below (with further details in the replication package).

$$y_i \sim \mathsf{Cumulative}(\phi_i, \kappa) \tag{4.2}$$
$$\text{logit}(\phi_i) = \beta_a * \text{Age}_i + \beta_g * \text{Gender}_i + \beta_n * \text{NrOfSub}_i + \beta_d * \text{Device}_i + \tag{4.3}$$
$$\beta_{ad} * \text{ActiveDev}_i + \beta_{daw} * \text{DaysAWeek}_i + \beta_h * \text{HoursADay}_i \tag{4.4}$$
$$\kappa \sim \text{Normal}(0, 1) \tag{4.5}$$
$$\beta_{...} \sim \text{Dirichlet}(2) \tag{4.6}$$

$$y_i \sim \mathsf{Categorical}(\phi_i, \kappa) \tag{4.7}$$
$$\text{logit}(\phi_i) = \beta_a * \text{Age}_i + \beta_g * \text{Gender}_i + \beta_n * \text{NrOfSub}_i + \beta_d * \text{Device}_i + \tag{4.8}$$
$$\beta_{ad} * \text{ActiveDev}_i + \beta_{daw} * \text{DaysAWeek}_i + \beta_h * \text{HoursADay}_i \tag{4.9}$$
$$\kappa \sim \text{Normal}(0, 1) \tag{4.10}$$
$$\beta_{...} \sim \text{Student-}t(3, 0, 2.5) \tag{4.11}$$

The next step in the analysis was to choose priors. The chosen priors are presented in the mathematical models too and further details can be found in the replication package. Moving on, the analysis required to make prior predictive checks. This was done to ensure that the chosen priors were appropriate for the model [6]. The check covered how the chosen priors performed on the outcome scale compared to the empirical data.

Following, a function was run to see the population-level effects of the model and to be able to establish the significance of each of the predictors for the outcome in question. Then details were examined in several different visualisations to investigate what the priors implied on the outcome scale.

Altogether, the Bayesian models were created and analysed based on the questions from the survey. The upcoming sections cover the quantitative, as well as the qualitative, results of the survey.

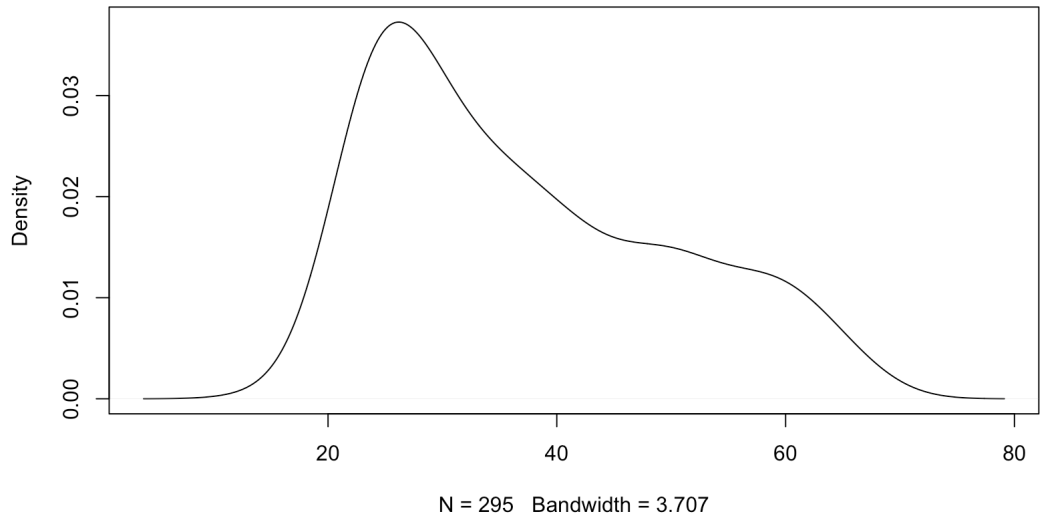

Figure 4.1: Density plot of Age variable. A large part of the sample consisted of subjects around 30 years of age

4.5 Results from survey data analysis: Quantitative

After the Bayesian analysis of data had been completed the results were interpreted. The results of the survey data analysis resulted in 26 models (summarised in detail in Appendix C). In this section, a brief summary of the quantitative and qualitative results will be presented.

4.5.1 Descriptive statistics

The survey offered the possibility to identify with three different choices of gender: either female/transfemale, male/transmale, or non-binary. In this case, the first category, female/transfemale, consisted of 135 respondents which make up 45.8% of the total amount of answers. The next category, male/transmale, consisted of a total of 160 respondents, which makes up the remaining 54.2%. The non-binary category had to be removed due to the fact that it consisted of very few respondents, which then would have resulted in too much uncertainty for this category. The distribution between the genders resulted in 135 of the respondents identified as female/ transfemale and the remainder, 160 respondents, identified as male/transmale.

Moreover, the data collection resulted in 295 complete survey responses, i.e., answers where all of the questions had been answered completely. Of these responses, the age varied from the youngest respondent being 15 years old, to the oldest respondent being 68 years old. The mean age of the group of respondents was 37.15 years. The descriptive statistics of the age variable can be seen in Figure 4.1.

The next predictor of interest, the number of subscriptions, was not asked for in the survey but could be calculated by using the question concerning what different streaming services each respondent used. The descriptive statistics for the number

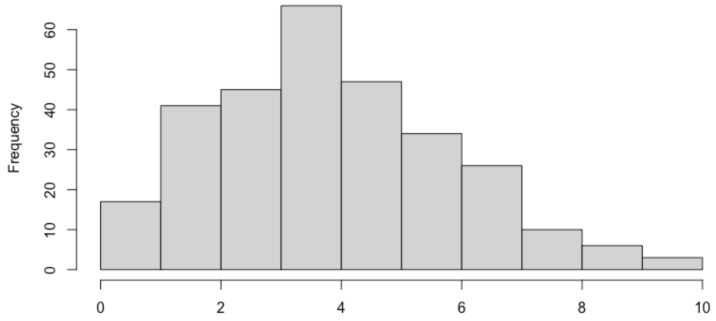

Figure 4.2: Histogram of NrOfSub variable

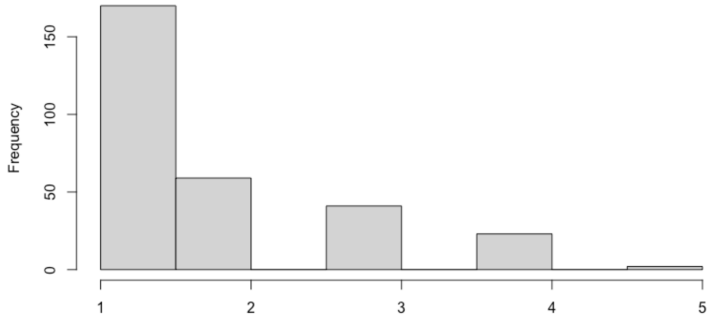

Figure 4.3: Histogram of Device variable

of subscriptions can be seen in Figure 4.2. This was of interest as a predictor to see whether there was a difference in how people acted based on the number of subscriptions they had.

In addition to the previously mentioned predictors, it was asked what type of device the respondent used most often for streaming content. The statistics can be seen in Figure 4.3.

Along with the question of what device the respondent most often used for streaming content followed a question concerning how many devices the user kept active at the same time. The results of this question can be found in Figure 4.4. This factor was interesting as this is a habit with the potential to be decreased.

When having asked for the age along with the gender of the respondents, what

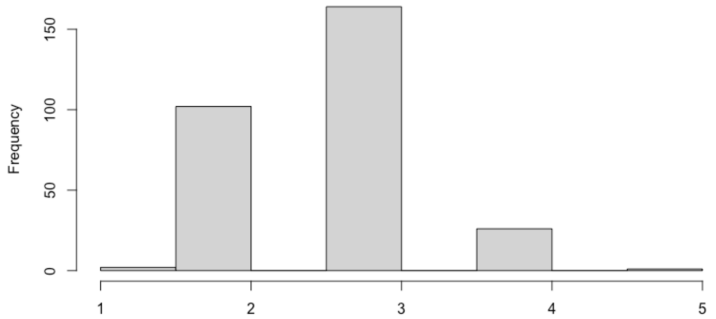

Figure 4.4: Histogram of ActiveDev variable

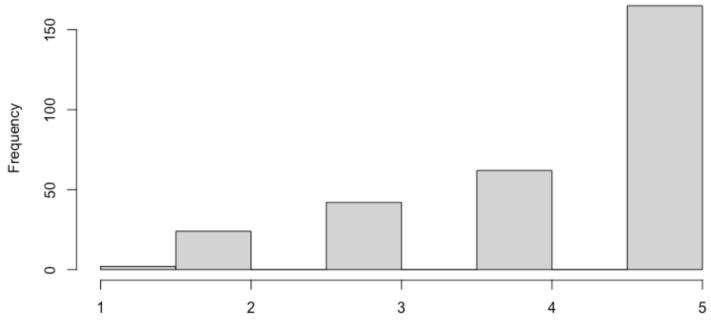

Figure 4.5: Histogram of DaysAWeek variable

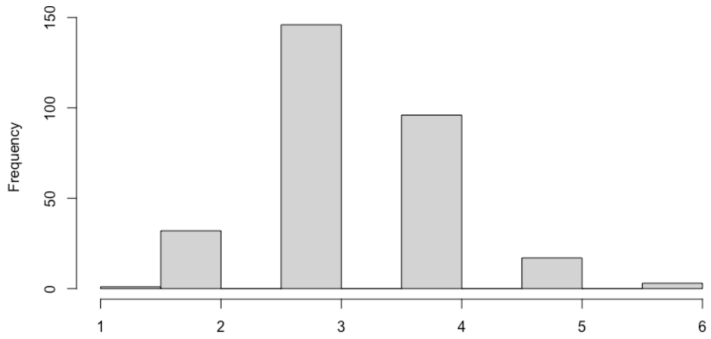

Figure 4.6: Histogram of HoursADay variable

streaming services they subscribed to, what devices was used as well as how many at the same time, came an interest of finding out how often these devices were used (see Figure 4.5). In addition to the previously mentioned predictors, this too was a habit of interest with the potential to be decreased.

Last but not least, came a question asking the respondents to report how many hours a day they spent daily using streaming services. This too is a predictor with the possibility to affect the different outcomes. These statistics can be found in Figure 4.6.

4.5.2 Inferences

Through the analysis, it was possible to determine certain characteristics among the respondents of the survey. Beginning with how concerned the respondents were with software's impact on the environment, here the predictors gender along with hours per day were the two factors influencing the outcome. This means that how concerned the respondents were concerning software's impact on the environment were predicted using the predictors gender as well as how many hours a day they spent streaming content. The first predictor, age, can be seen in Figure 4.7. Together with the predictors in Figure 4.8 and Figure 4.9 these predictors were chosen as they were particular interesting concerning the question discussed. It was checked whether the predictors were significant on the 95% level. Here the concern is presented on the y-axis and the gender presented on the x-axis. Gender does only have two options as earlier described, 1 which is female/transfemale and 2 which is male/transmale.

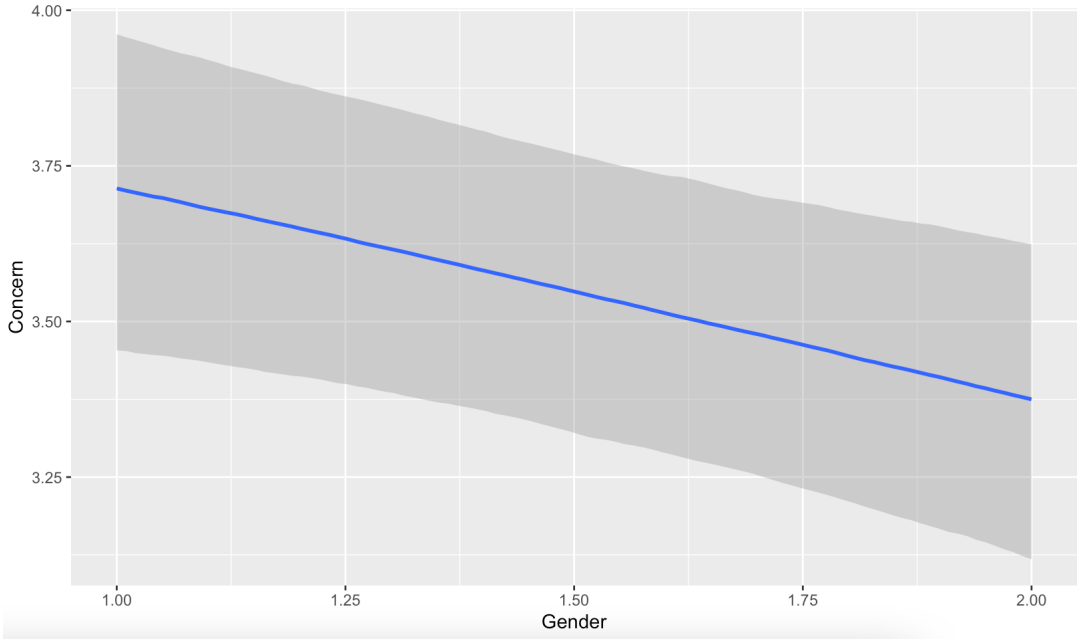

Figure 4.7: Q8: Predictor Gender

It can thus be concluded from the graph that female/transfemale respondents are more concerned regarding the environment than male/transmale respondents.

For the next predictor, HoursADay, the result can be seen in Figure 4.8. Here, the concern is once again presented on the y-axis and the hours a day one stream content is presented on the x-axis. Here it can be determined by looking at Figure 4.8 that the more hours a day you stream content, the less concerned the respondents would be of the impact software has on the environment. It is notable that the uncertainty is very much higher at low and high number of hours a day.

4.5.3 Motivation

Furthermore, the next question focused on what would motivate the respondents to decrease their use of digital services. Here, notifications about daily CO2 emissions and information regarding the implications of the use of digital services in relation to emissions were two of the options that the respondents found would motivate them to decrease their use of streaming services. When it came to the notifications as a motivator, gender was a significant predictor that affects the outcome, see Figure 4.9. Male/transmale respondents answered that they would be less motivated than female/transfemale respondents, nevertheless, both gender groups found that this was a significant motivator. The same was considered by the respondents of logging my use of digital services to see my behaviour over time and get suggestions on how to improve. Seeing the CO2 impact of video streaming related to other activities having an impact on CO2 and suggestions to use streaming services at another point in time, which could result in lower CO2 emission were too factors that were considered by the respondents to be motivating.

As previously mentioned, a detailed description of the results from the analysis of each of the 26 models can be found in Appendix C.

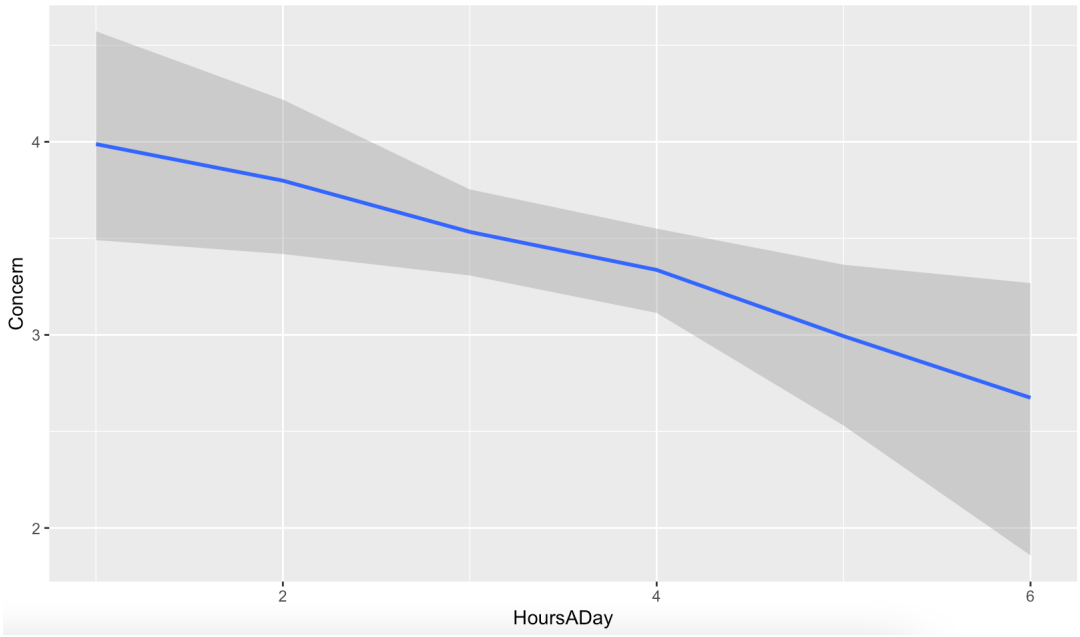

Figure 4.8: Q8: Predictor HoursADay

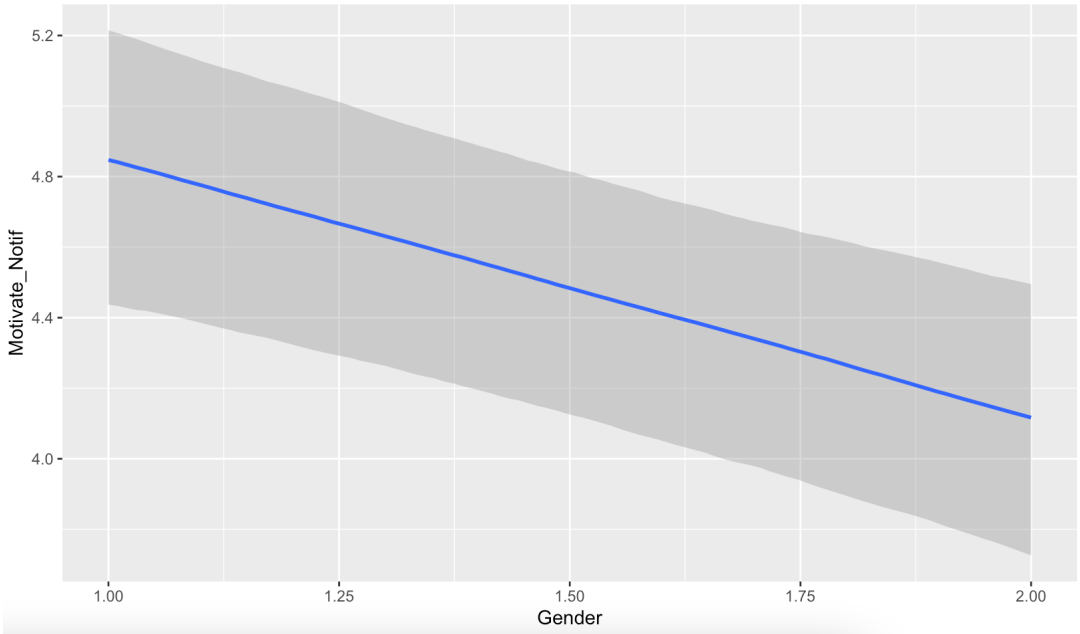

Figure 4.9: Q13: Predictor Gender

4.6 Results from survey data analysis: Qualitative

The other part of the results from the survey were qualitative. These results came from the questions in the survey where the respondents had the possibility to express their thoughts freely in text.

4.6.1 Tradeoffs

The survey concerned a question regarding trade-offs and focused on what the respondents would find the hardest to give up. The alternatives given can be seen in Table 4.4.

Table 4.4: Q10: Alternatives

Option	Alternative
1	Driving a car
2	Flying
3	Streaming video
4	Eating meat
5	Buying non-green energy
6	Buying new clothes
7	Do not want to specify

Of all the alternatives in Table 4.4 the majority of the respondents found that the hardest to give up entirely would be driving a car. The next hardest was shared by two alternatives which were eating meat and streaming video, both of these being harder to give up than flying. The ranking for all of the alternatives can be found in Table 4.5 ranging from the hardest to give up to the easiest at the bottom of the table.

Table 4.5: Q10: Ranking

Option	Alternative
1	Driving a car
2	Eating meat
3	Streaming video
4	Flying
5	Buying new clothes
6	Buying non-green energy

4.6.1.1 Give up: Driving a car

Concerning giving up driving a car, one of the respondents commented that *"Driving a car is usually necessary for my everyday life, and my family and I would have a much more complicated everyday life if that's not possible"*. Another point which was made by one survey respondent was that *"Being able to drive my own car provides me with flexibility and comfort that I would not be able to give up entirely."*

4.6.1.2 Give up: Flying

Moving on, hardest to give up flying was motivated by *"All others have some reasonable alternative whereas if you want to travel far, flying really is the only option"* as well as *"That would limit global travel. I would see less of the world. Travelling and working with individuals around the globe builds trust and helps world peace to use big words. The other things can be overcome with setting your mind right."*

4.6.1.3 Give up: Streaming video

That streaming is ranked high, can be affected by the ongoing COVID-19 pandemic where people spend more time in their homes and perhaps have more time which is spent on entertainment in general.

One of the respondents found that streaming would be the hardest to give up and brought forward the motivation that *"Because none of the reports/news/studies I read or know about ever mention the environmental impact of streaming a video."*

Another comment made by a respondent that claimed that it would be hardest to give up streaming was *"There's no real alternative to streaming in the way content is created and published. And it's easier to see that I should not fly/drive unnecessarily than not to contribute to energy consumption."* One of the other respondents made a similar claim about streaming *"Streaming video encompasses so many different kinds of content, and by now it's difficult to come up with valid alternatives. I feel like each of the other options have more or less valid/easy alternative options (other kinds of transport, lots of vegetarian food options, second-hand clothes, etc.), but not necessarily streaming services."*

In addition, one of the respondents made another motivation about not wanting to give up streaming *"It would mean a change of our everyday life. Streaming is the*

biggest source of entertainment in our household. Stop eating meat would also be hard, because we do it so often, but there are bigger motivations for me personally to stop eating meat than to stop streaming. I guess I don't know the impact of streaming."

Additional comments about not wanting to give up streaming were *"I don't have a drivers license. I would hate to give up travelling but it is not a necessity to me. I already like to eat a vegetarian diet from time to time, and I know it wouldn't be difficult to make a habit of it. So I think streaming entertainment would be the most difficult as it is how I distract myself from day-to-day stress."*

4.6.1.4 Give up: Eating meat

Concerning not wanting to give up eating meat, seemed in general to concern liking meat as a primary product. The motivation brought forward were *"I eat meat regularly (compared to the other options), so it would the hardest to give up"*, in addition to *"It would be sad to give up something that I really like."*

4.6.1.5 Give up: Buying non-green energy

Giving up buying non-green energy was another aspect that was considered to be among the hard elements to give up. The motivation for these choices was varied. One respondent stated that the hardest would be to give up buying non-green energy with the motivation that there is *"No need to change my behaviour."*

4.6.2 Sustainable streaming services

The previous sections have all focused on comments made about trade-offs concerning the elements presented in Table 4.4. Moving on, the next question of interest was whose responsibility it is that streaming services are sustainable. Here, the majority of the respondents answered that this was the streaming services' responsibility. The comments made from the respondents here were that they did not know that streaming services in fact could be sustainable as well as that they thought that there should be policies to make the streaming platforms sustainable.

4.6.3 General input

To sum up, the last question of the survey asked the respondents to add any other inputs or ideas that they would like to share in order to increase sustainability in relation to the use of digital services.

4.6.3.1 Information

One of the respondents shared that *"I work in the software industry. The issue is clearly that people don't connect the use of digital services and big amounts of data to environmental issues, e.g., if we throw away food we know we are wasting, but if we stream something and are not really watching we don't realise this has an environmental impact. Really interesting research for your thesis!"*

Other comments made from the respondents were *"I think just spreading awareness and suggesting solutions would help. People just watch without knowing anything about the consequences."*

Points that were made several times were comments like *"I don't think people, in general, have any idea what impact streaming has to the environment"* and *"I'm not sure if this is applicable or if I'm living in my own bubble, but I don't see this being talked about. I was not aware that streaming services were even considered to be on the map for emissions prior to this survey."*

Following, another respondent brought forward that *"I think the main thing would be to inform how much of an environmental impact it really does have. Me personally, I'm interested both in ways to save the environment and in technical advancements, and yet I very rarely think about the impact that streaming specifically has. It's not at the forefront of our minds because we rarely see where in the chain of streaming the impact is mainly made (I think?)"* along with the comment that *"The subject itself is something I honestly haven't even considered to be an environmental impact and would gladly like to learn more!"*

Other comments which were made several times were that *"Information is always good. I don't think people in general make the connection between streaming and CO2 emissions. Spreading awareness is important to change behaviour I think"* Another respondent of the survey found that a good suggestion would be *"ideas on other activities to break the habit of streaming."*

As a last comment concerning the streaming services, one respondent made the comment *"Very interesting study! I think it could be interesting to also increase awareness of how much energy simply hosting all that video requires... Those servers must run 24/7, right?"*

4.6.3.2 Comparisons

Another theme that was reoccurring were respondents suggesting comparisons. One of the comments on this were *"Perhaps see some form of intuitive illustrations of how much a digital service impacts the environment in comparison to things that we all do regularly, like eat food. How many cheeseburgers is one 4K Netflix movie? It's probably very hard to estimate. However, if possible, an easy explanation of how it's done and what's taken into account would suit well with it"* Further, some of the respondents found that health was a theme that should be considered.

4.6.3.3 Health

One of the respondents considered that rather than focusing on CO2 emissions when it came to streaming services, it should be about peoples health *"I think that the main aspect of sustainability that end-users care about is their own health and time spent. While everything we do can be measured in CO2 and displayed in order to help nudge people to a more sustainable lifestyle, I assume that other activities make up bigger sources of CO2 emissions than streaming services. Helping users limit their time spent on streaming services for health reasons is far more compelling as it directly affects the persons own health and free time. I'm also more interested in seeing which services I use that run on renewable electricity. Being able to compare*

services based on their footprint rather than thinking whether I actually need to watch the news or not seems more reasonable to me."

In addition, a comment was made saying that *"More science on why the use of social media/streaming/YouTube etc. is 'bad' for us as individuals. How will it affect our kids and how can we be role models when most of our day to day chores can be done on the phone?"*

4.6.3.4 General settings

General settings were another theme to consider and which there were comments about. One of these was that *"I accidentally pressed forward before being done. Not sure if there was any question about changing how I use streaming services, but I don't mind if the quality is reduced if that is done to reduce emissions. I could also imagine watching video on a smaller screen at times, e.g. during energy/internet peak hours."*

In this chapter, the design of the survey has been presented in detail. The evaluation has been described together with the data collection and the analysis of the found data. To sum up, the results of the survey has been presented based on themes found. Furthermore, the complete quantitative analysis can be found online and the analysis can be reproduced—many more findings can be found in that reproducibility package.

In the next section, the interviews will be described in detail.

5
Interviews

Moving on from the survey analysis as well as the survey as a whole, interviews were held with chosen experts within the field. The generalisability of the study was covered by the quantitative survey, and the focus of the interviews was to be qualitative. The interviews were semi-structured [10], which means that the questions were more towards open-ended questions to make the interview subjects elaborate freely on the questions asked.

Based on the statistical analysis of the data from the survey as well as the free-text answers that the respondents of the survey provided, the interviews were planned. The aim and goal of the interviews were to validate the findings from the survey and deepen as well as broaden the knowledge to be able to ensure and provide a validation of the findings and provide a general best practice list for the field of software engineering. The first part of the interviews was to design appropriate questions relating to the research questions.

5.1 Interview design

To initialise the design process of the interviews, the interview subjects were chosen. The interview subjects were found through recommendations from other researchers and through searching based on research topics related to this thesis. The interview subjects were considered experts within their respective fields and were chosen on this basis. With their expertise and knowledge within the fields, they were considered to be able to provide valuable insights. Their research was both within software engineering as well as sustainability and within the two combined; what was common for all of them was that their fields were all related to the research topic of the thesis. Their fields of research are presented in Table 5.1.

The interviews with the respondents were planned to be 45 minutes with each of

Table 5.1: Interview subjects' field of research

Respondent	Field of research	Research interests
R1	Software Engineering	Requirements engineering
R2	Information systems	Digitalisation
R3	Software Engineering	Requirements engineering
R4	Software Engineering	Sustainability
R5	Human-Computer Interaction	Digital technologies and everyday practice

the participants, to ensure that the time for the interview was extensive enough to get valid outputs but at the same time limit the interview time to avoid fatigue. Initially, at the start of the process, interviews were booked with five different respondents. Five interview subjects were chosen as a starting point with the possibility to be extended if there seemed to be a need for more data and saturation was not reached.

After the respondents had been chosen and the length of the interviews was established, questions for the interviews were developed. The interview questions were formed with the aim to deepen and broaden the knowledge in regards to the topics in the survey. The interview questions were based on the results of the survey. Based on the significant factors and the topics on the survey, which showed interesting results, questions were formed to explain the outcome of the survey results, as well as deepen the knowledge concerning the results. They covered information and motivation, requirements and design, as well as open questions making it possible for the respondents to bring forward their ideas. A large deck of any relevant and interesting interview questions were put together.

The aim was to put together 8–10 question based on the 45 minutes length of the interview. This was done both to let the respondents have time to elaborate on the topic and to think before they answered, i.e., so the interview did not seem stressful and thereby assuring the quality of the responses on the questions.

When the design of the interviews had been finalised, it was time to evaluate the deck of questions to ensure that they captured the latent variables of interest. The interview evaluation is described next.

5.2 Interview evaluation

When the deck of questions had been put together it was time to evaluate and select the most useful, as well as the most important questions, in terms of relation to the research questions. This was done in collaboration with a group of two researchers having knowledge within the topic, i.e., sustainability. Given the deck of questions, each of the questions was discussed concerning the research questions as well as the intended outcome of the study and by so the deck of questions decreased.

After this first evaluation of the questions, the remaining questions chosen to use for the interviews were discussed once again with another researcher for them to be evaluated and refined further. In each of the evaluation iterations, the questions were made more clear and understandable. In addition, the researchers were able to add nuances and point out any additions to be made, with the hope to get more interesting insights from the respondents. A reminder of the research questions is presented in Table 5.2.

Table 5.2: Research questions

Question Nr	Research Question
RQ1	How could software make the end-user aware of the CO2 emissions of using digital services?

Continued on next page

Table 5.2 – continued from previous page

Question Nr	Research Question
RQ1.1	What types of nudging, as conveyed through software, could make the end-user take a more environmentally sustainable action?
RQ2	What measured can be integrated into the requirements as well as design process of software to make it possible that when developing software to take sustainability into consideration?

All interview questions are presented in Table 5.3. In total, 11 questions were kept after the evaluation.

Table 5.3: Interview questions

Question Nr	Question
Q1	To introduce the topic, I would like to start the conversation talking about recycling which is something people do without any thought today; how do you think can it be made natural to act sustainable concerning software?
Q2	When you recycle plastic bottles, at least in Sweden, you do it to get your money back and so you have a motivator for recycling. If this were to concern software, should people be motivated to act sustainably in relation to software (or should the motivation come from within)? If so, what do you think could be a good motivator?
Q3	If we move on to the information that possibly can be provided to the end-user for them to act more sustainably and be aware that software has an impact on the environment. How do you think that information about sustainability can be trustworthy, if communicated through an app?
Q4	How, with the use of an app, do you think that information about sustainability can be provided without the receivers of the information being overwhelmed? (In addition, how often do you think it would be suitable to provide the end-users with information?)
Q5	Moving on, information about the implications of streaming services and as well software can motivate users to decrease their use, what do you think would be the most important information to provide the users with?
Q6	In the previous conducted survey there was signs that age and gender was two factors showing a difference in how people felt about sustainability in terms of what would motivate them to decrease their use of software e.g. streaming services, how do you think that the less motivated group should/could be motivated?
Q7	What do you think could be included in the requirements process of software for it,

Continued on next page

Table 5.3 – continued from previous page

Question Nr	Question
	the software, to be more sustainability concerned and create awareness of its environmental impact with the end-users?
Q8	How do you think that software can be designed, to make an impact on the users to decrease their use and thereby impact as well as understand that software too is something having an impact on the environment?
Q9	If there were to be a marking/carbon emission stamp on software, what criterion's do you think would be of importance to include, e.g., what should be measured to constitute and make the basis for this marking?
Q10	Blocking streaming services is something which has proven to not be a sufficient way to decrease the use of streaming services, is there any other solutions or alternatives that you think too is not sufficient for the purpose of decreasing the impact of software and if so, why?
Q11	Is there anything you would like to add on the topic?

The interview questions were connected to the research questions accordingly (see Table 5.4).

Table 5.4: Connection between RQ's and interview questions

Research Question	Interview Question
RQ1	Q1, Q3, Q4, Q6
RQ1.1	Q2, Q5, Q10
RQ2	Q7, Q8, Q9

In addition to the evaluation before the interviews, the questions were evaluated *during* the interviews. Based on how the respondents reacted as well as answered the questions, there could be made both deductions as well as additions to particular questions after an interview. This was done in most cases to clarify something which the respondent questioned. This would not change the questions *per se* but make improvements to make the question more understandable and straightforward.

To conclude, the evaluation of the interview questions has been described. The questions were evaluated and connected to the research questions. Following, the data collection will be covered and described in detail.

5.3 Interview data collection

To initialise the data collection, an explanatory text was sent to all of the interview subjects informing them of the topic of the master thesis. In addition, the aim, as well as the intention of the previously conducted survey, was described. Moreover, the interview subjects were informed of the goal of the interviews. This was done to ensure that they had the appropriate background information to understand and relate to the aim and better understand the questions asked. Importantly, only a brief overview was sent to the respondents regarding the study and the interviews. This to not give the respondents too much information for them to make up their thoughts before the interviews.

The interviews started with an introductory part, asking more general questions. These questions concerned the sustainability of software in general and asked the respondents what their thoughts on sustainability of software was. Moving on, the next part of the interview focused on the information and motivation that end-users could be nudged with and by so become more sustainability-focused. The last part of the interview concerned requirements as well as the design of the software. These questions concerned what measured could be taken to make newly developed software more sustainable. The interview was wrapped up with an open question where the subject could fill in any other thoughts concerning the topic. There were five interviews scheduled originally and that was considered enough after all of the five interviews had been conducted. This decision was based upon the outcome of the interviews where several of the respondents repeated what had already been said in other interviews and, thus, it could be argued that at least partial saturation was reached.

The interviews were all recorded after consent been given from the respondent. Thus, all of the nuances, which easily could have been lost, could be captured through the recording.

5.4 Interview data analysis

In this section, the data analysis of the interviews will be described. The data analysis was started after all of the interviews had been conducted. All of the interviews were transcribed.

The method for analysis chosen was thematic analysis, which is a common method used for analysing qualitative data [5]. Thematic analysis, generally speaking, consists of the following steps:

- Familiarisation
- Coding
- Generating themes
- Reviewing themes
- Defining and writing themes
- Writing up

5.4.1 Familiarisation

To initialise the interview analysis the interviews were transcribed word by word by using the recording from the interviews. This did also fulfil the first step of the thematic analysis, which was to familiarise with the content. This was done both by first conducting the interviews as well as then going through the content again when the interviews were transcribed.

The transcription of the interviews was done by writing down what the respondent said word by word. These transcripts were then imported into NVivo, a program used for qualitative analysis.[1]

5.4.2 Coding

When the transcripts had been imported into NVivo, they were coded one by one. Each of the transcripts was looked through and codes were generated based on what could be of interest to later answer the research questions. The coding aimed to describe the data from the interviews. This was done by reading the transcripts repeatedly and adding codes accordingly. After the coding was completed, the next step was to generate themes.

5.4.3 Generating and reviewing themes

After the coding of the data themes were generated. The generated themes were based on the content from the questions as well as the answers from the respondents. Each of the transcriptions was read through once again and based on the codes the themes were generated. This was done for each of the five transcripts accordingly by looking at similarities among the codes and then match them into themes. When this had been done for all of the transcripts the themes were reviewed and looked through to ensure that they were themes, meaning on a higher level than codes. When this was ensured, the analysis of the transcripts was complete.

As a consequence of the analysis and more specifically the themes, it was then possible to identify the most important results from the interviews and the results from the interviews could be extracted. Following, the results will be presented.

5.5 Interview data analysis: Results

In the following, the results of the interview analysis will be described. The five respondents from the interviews are referred to as R1,. . . ,R5 due to reasons of anonymity.

The themes that were established through the analysis and covered by the respondents were: information, comparisons, requirements, and design and motivation. All of the themes might not be covered by all respondents, as the interviews were semi-structured and, thus, the content of the interview could vary.

[1] https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Overall, to summarise what all of the respondents felt, they all said that there was an uncertainty regarding how sustainability was to be ensured in software engineering. They all had thoughts but in addition, they all seemed to feel uncertain regarding the topic.

Below, a summary of the interview results are presented, where the most important findings are covered.

5.5.1 Information

The first themes covered by the respondents were information. Overall the respondents felt that there was a lack of information and that awareness should be raised. Also, that when information is to be provided it has to be done with care and that there are several aspects to take into consideration such as timing and how the information is presented.

5.5.1.1 Respondent 1

R1 brought forward thoughts on information, comparisons as well as requirements and design. With software, there is missing information on what is sustainable and what is not, R1 said. Respondent 1 claimed that there is information needed about what the energy consumption of software is. Considering information, R1 found that it is good to show awareness by just displaying statistics. In addition, they said that this information should not be to tell the user what to do or what not to do.

5.5.1.2 Respondent 2

In the interview with R2, many different themes were discussed, starting with thoughts on information.

It was brought forward that the user needs to know how much energy they are using and how much each activity consumes. Respondent 2 also emphasised that there needs to be information, but it is important to avoid information overload. There is a need to make the non-visible, visible.

The information that the users shall be provided with, R2 mentioned, shall be at the time of streaming or downloading. The information can be colour coded and it should be positive. It should be in close connection to what motivates people. The users shall also be able to choose themselves how they want to be communicated with, R2 said.

5.5.1.3 Respondent 3

For the interview with R3, the respondents brought forward that it is a challenge that people are not aware of software's impact on the environment. Respondent 3 also said that there is limited information there is an impact on the environment by using streaming services. A lot is missing when it concerns understanding and awareness, R3 said. The respondent did not think that people were aware of the fact that there is an impact.

The respondent suggested that information before using the services should be available, for instance: "if I use this service for two hours that is equivalent to this much carbon emission, also where the data is streamed from. The end-user needs to know how much impact the software does have when being used", R3 emphasised. Also, R3 agreed with R2 concerning the importance of this being included in the education at universities for future software to be improved.

5.5.1.4 Respondent 4

The important information to provide the user with, R4 said, is that everything you do has an impact on the environment, just that you do not see it does not mean that it is not there and that users should be conscious of when they use it. Instead of saying that they should not use software, try and educate the end-users to just use it when they need it, rather than just letting it run in the background. An example, that P4 pointed out, was: *"Say you know what if you gonna watch a movie once, watch it online, if you are gonna watch it 127 times, cause it is your favourite movie in the whole wide world, maybe download it?"*

The respondent also said that strategies to get people to decrease their use should be positive. Shaming just makes you do things in secret. It is better to get them to question their motives, R4 said.

5.5.1.5 Respondent 5

R5 mentioned that the main task is to raise awareness. It is important to make people understand that when software is used it has an impact. There is no awareness among end-users considering that when you are on a network there are other computers used than the one you use. To change this and raise awareness, P5 emphasised, there is a motivation needed. Moreover, motivation varies for different people which has to be taken into consideration.

Concerning information, R5 said that information should be provided weekly or if consumption changed it would be useful to intervene. Intervening should be done strategically. Maximum once per session. And it does not have to be about energy, R5 brought forward, it can be about other things, like, is this how you want to be spending your time? In conclusion, reports should not be sent too often and the users should be able to choose for themselves how information should be presented.

5.5.2 Comparisons

The next theme of interest covered comparisons. Meaning that the respondents brought forward the need for the emissions presented being connected to something which the receiver of information could relate to; whether that would be other types of emissions.

5.5.2.1 Respondent 1

How much energy is used and whether that matters is not clear at this point. It is important to have a relative comparison to figure out what the better alternative is

when software is concerned.

When things consume more resources they should be more expensive, R1 said. And this, in turn, R1 says, would mean that companies such as Netflix would give the crisis onto the customer.

In addition, by measuring all the consumption, R1 argued that, it is possible to see the emission in relation to other things. For instance, how bad is one action in comparison to other actions and how bad am I in relation to other people?

Respondent 1 thought this could then lead to reflection and then possibly a behavioural change. Furthermore, R1 found that a good option could be to see what you have done and what is the status at the moment of your emissions. Also, R1 recommended that it has to be as non-disruptive as possible.

5.5.2.2 Respondent 2

As of today, R2 found that there is no information about how much energy is used if I watch cat movies on YouTube for x amount of hours, to mention one example.

5.5.3 Requirements and design

Requirements and design was the next theme of interest from the interviews. Here it was, in summary, brought forward that there was an importance in including sustainability in the requirement process of software. It was also mentioned that it would be useful to have design recommendations regarding sustainability.

5.5.3.1 Respondent 1

When discussing the requirements, R1 found that if sustainability requirements are to be included they must be non-functional, but still measurable and testable. Also, R1 considered that guidelines on sustainable design would be useful. In conclusion, it must be made easier to be sustainable and regulation might be needed.

5.5.3.2 Respondent 2

Respondent 2 brought forward that there is great importance in finding out how sustainability can be included in the requirement phase and in addition, students must be educated. They must know how to make requirements for sustainability and how to test them. The respondent argued that there is currently a lack of this in education.

Moving on, R2 said that there need to be solutions designed where sustainability is incorporated.

5.5.3.3 Respondent 3

Concerning requirements and design, R3 found that the developers could do quite a lot to make the software more sustainable, i.e., how to build sustainable code and to incorporate sustainability into requirements engineering.

5.5.3.4 Respondent 4

Concerning requirements engineering and design, R4 found that it would be important to use requirements engineering to create requirements to ensure that the user would be informed of the environmental impacts of software.

Moving on, in the interview with R4, they pointed out that developers have to recognise that software has second- and third-order effects and understand what the impact of the software that they create is.

5.5.4 Motivation

The last theme covered was motivation. Here the overall assumption was that it was important for the motivation to decrease software to be individual and based on motivators that trigger the individual, rather than trying to get end-users to change their behaviour in the same way.

5.5.4.1 Respondent 2

Respondent 2 stated that there is a need to find what triggers the individuals to do something—is it for the greater good, is it to earn money, or is it something completely different? People are not going to quit using streaming services, so there is a need for tips and suggestions, for instance, download content during night time. Respondent 2 argued that what is needed is to find a way to improve on already existing habits that the end-users have; however, as habits are hard to change, building upon existing habits is easier than to change a habit entirely.

5.5.4.2 Respondent 3

When considering getting end-users to decrease their use, the respondent did not think that it would be efficient to block the streaming services. There must be a motivation for doing better and by so decreasing the use. Respondent 3 brought forward that there might not always be a possibility to be better, but as long as the users get the information, that is good.

5.5.4.3 Respondent 4

Respondent 4 also stated that there always seem to be additional incentives needed to protect the environment. In addition, knowing that something is good for us is not sufficient. The trouble with sustainability is that it is not graspable for people, R4 said.

The respondent found that the problem lies both with end-users as well as professionals, such as developers. The problem lying with developers is that if they want to be sustainable and if they are environmentally conscious there is limited guidance on what to do. Furthermore, people, in general, are not aware of the impact software has on the environment. Respondent 4 brought forward that there are two ways to improve this, either by data or by stories. The stories need to be positive and the statistics need to be in relation to something else that people can relate to (relative comparisons).

5.5.4.4 Respondent 5

Respondent 5 mentioned that if this was to be delivered through an app you could work with different themes over seasons, say that during winter you try and impact streaming services, during spring social media, etc. Then software would become more of a coach for the end-user. When habits like leaving a podcast on to fall asleep to or wander around with stuff in the background without watching it could be suggested by the app for the user to act differently. Watching several screens is another example where this suggestion could be feasible, R5 said. Another idea that R5 brought forward was having default settings. For instance always starting at standard definition, when streaming content. Respondent 5 argued that it is harder to change from standard definition to HD, or 8K, rather than the other way around.

The important aspect is, in conclusion, how one can get people to engage in reflections about what is meaningful as well as worth it and then get them to decide. People are good at deciding, especially when it comes to things like streaming.

To conclude this chapter, five interviews were conducted and the results have been described. The main finding are concerning information, motivation, comparison, as well as requirements and design. In the upcoming chapter, the results from the survey, as well as the interviews, will be used to design the previously mentioned checklist.

6

Best practice checklist for sustainable use of software

This chapter will present the background as well as the creation and validation of the best practice checklist. The chapter will start with the findings from the survey as well as the interviews and how they contrast as well as complement each other. Furthermore, the design of the checklist will be described. Next, we will move on to the validation of the checklist which was done together with a focus group. Finally, the entire checklist is included in the chapter.

6.1 Checklist design

The background for the checklist is based on the literature, survey, as well as interviews from the case study. The themes previously described, which were consistent throughout the analysis of the survey as well as the interviews, were used as the basis for the checklist topics.

The checklist was divided into three parts. Suggestions of what to *do*, *consider*, as well as what to *don't* to inform and nudge end-users of their behaviour in relation to software, are present in the checklist. For each of the themes that were common, these themes were added to the *do*, *consider*, and *don't* sections of the list.

The suggestions for each of the themes were added to the best practice checklist. The suggestions were added to the *do* section if several respondents, both through the survey as well as interviews mentioned the suggestion. What was added to the *consider* section was mentioned just in one of the two, i.e., either survey or interview. The final part of the list was the *don't* part. For this part, whatever was considered to have a negative impact on the end-users was added to the *don't* section of the list. This even if it was mentioned only in just the survey or just the interviews.

The checklist was first validated in several iterations by one software engineering researcher to make sure that the checklist was clear and understandable. When this was assured it was possible to move on to the next step and validate the checklist further.

To conclude, the checklist was designed based on the themes identified and validated by one researcher before it was passed through to the focus group who were to validate it further.

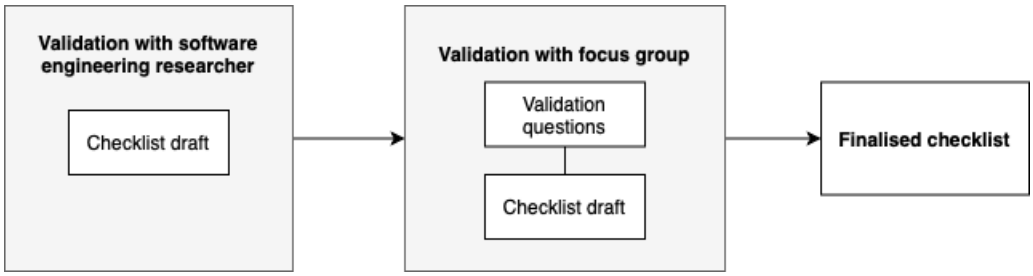

Figure 6.1: Validation of checklist

6.2 Validation of checklist

A focus group consisting of two researchers and two newly graduated software engineers were put together to validate the checklist after the first iteration of validation with the software engineering researcher. This was done to validate that what has been found during the execution of the study was of relevance, as well as to make sure that it was considered to be useful. The validation is visualised in Figure 6.1.

6.2.1 Validation design

The validation was designed to target the previously mentioned researchers within the field of software engineering and sustainability. In addition, the validation targeted newly graduated software engineers as they were considered the future influence of software development. The questions that the researchers and software engineers were asked to consider during the validation were the following:

- **Question 1:** Is anything on the checklist redundant? If so, why?
- **Question 2:** Is anything on the checklist missing? If so, what? And why?
- **Question 3:** What problems do you see that this checklist could contribute in solving/be a part in solving?
- **Question 4:** On a scale from 1 to 10, how useful do you think this checklist is? If below 5, how do you think it could be improved?

In short, the evaluation of the validation questions constituted of a software engineering researcher going through the questions to ensure that they were easily understood as well as help validate and improve the checklist. When this was ensured, the checklist could be sent to the focus group for validation.

6.2.2 Validation

The validation was based on researchers, which were chosen due to their expertise within the field. The two experienced participants in the focus group were one software engineering researcher and one sustainability researcher. The software engineering researcher was part of the interview sharing their thoughts on what could

be useful to include on the checklist, thus the input from this researcher was considered valuable as this person were able to validate information, which they already were familiar with.

The other researcher participating in the validation was a sustainability researcher who was not familiar with the content and, thus, was able to provide new perspectives and thoughts on the checklist i.e., was not part of any previous steps of the study.

Further perspectives were provided by two newly graduated software engineers. Their thoughts were considered important as they were the target group for the checklist and can be considered responsible for ensuring that future software is sustainable. These two were neither part of the study before being part in the focus group.

The focus group participants were provided with the checklist together with a set of questions to base their validation on. This was provided through email for them to look through without any time pressure. They did not have a time limit for when to provide their feedback, meaning that they were able to read the checklist several times and consider its content thoroughly.

6.2.3 Validation results

When the four focus group participants returned with their comments and answers on the set of provided questions, the checklist could be revised and updated accordingly. Not all of the participants in the validation provided feedback where change was needed. The feedback from the respondent is presented below, separated question by question.

6.2.3.1 Question 1: Is anything on the checklist redundant? If so, why?

Concerning whether some things are redundant, the one researcher mentioned that "provide users with information on the impact of the current activity", was interpreted as providing information to the user while doing something. This, the researcher said, would mean that the user would be interrupted and that could cause annoyance. The researcher suggested instead that one would provide information before or after any activity.

Further comments from the researcher concerned clarity and structure of the checklist, rather than anything being redundant. One of the suggestions, which the researcher found of high importance, was to "Suggest the user downloading during the night", which was found to be of high importance as this could have a high impact on the environment. The researcher also found that under the Default settings section there could be a suggestion added for updates to be scheduled during nighttime.

The second researcher found nothing on the checklist redundant. The same answer was provided by the two software engineers.

6.2.3.2 Question 2: Is anything on the checklist missing? If so, what? And why?

The first researcher did not comment on anything that was missing. The researcher mentioned that overall for the "Do" part of the checklist the suggestions seemed good and they were considered as useful and meaningful related to creating awareness of environmental impact. Further, the researcher said that particularly now, in the beginning, when the most important task is to raise and increase awareness of software's environmental impact, the checklist would be useful.

The second researcher found that there was nothing missing that they could think of. The same feedback came from the two software engineers.

6.2.3.3 Question 3: What problems do you see that this checklist could contribute in solving/be a part in solving?

The first researcher provided feedback that the checklist would probably not *solve* any problems, however, the researcher found that it would be a good start to bring awareness on the environmental impact of software for users and developers of software.

The second researcher, with a focus on sustainability, found that it could be useful when developing software to be able to, as a software developer, look at the list before making any decisions on the development.

The first of the two software engineers believed that the checklist would be able to reduce pure leisure usage of software. In addition, the software engineer found that the checklist could potentially enhance awareness regarding these questions.

The last participant in the validation, the second software engineer, brought forward that the checklist would be a step in the right direction to solve environmental problems, but also help users not waste time by watching something they might not even want to watch.

6.2.3.4 Question 4: On a scale from 1 to 10, how useful do you think this checklist is? If below 5, how do you think it could be improved?

On a scale of 1–10 the first researcher found that it would be a 7 concerning how useful the checklist would be. The researcher found that it would be useful in bringing awareness, as a first step. That said, it was mentioned that it would be hard to achieve that everyone would use and follow the checklist. Also, it would be a challenge to keep all users happy, but it would be a good and useful start.

The researcher in software engineering found that it was good to include the "Don't" section of the checklist to be explicit on what to not do.

The researcher within sustainability found that the checklist was helpful overall but suggested that it would be helpful with more specific examples. The researcher considered the checklist to be a 6 on the 1–10 scale. The researcher mentioned that it would be helpful if the checklist was more visual. For instance, having the checklist in columns with matching icons and illustrations, each of which would have a short name and explanation. Meaning, the suggestion that is on the list would now be

combined with a very specific example. This would make it even more useful, the researcher said.

Both of the software engineers selected a 7 on the 10-point scale. One of the software engineers brought forward that the checklist is a helpful guide, but thought that too much information could probably be overwhelming to the users so perhaps some way of choosing the most important features would be good.

6.3 Finalised checklist

When the validation had been completed the checklist was adjusted based on the comments from the researchers. The software engineering researcher mentioned that some of the suggestion in the "Do"" section were not in the right place and thus they were moved to the correct section. In addition, the phrasing of some of the suggestions were adjusted based on comments during the validation. What was not adjusted was the comment made by the sustainability researcher concerning the suggestion of making the checklist into columns. This was not changed, as there was not any evidence found in the study for specific examples or figures. Thus, as there was no evidence that this particular suggestion would be useful, or that it was significant, it was instead suggested for future research. This was added to Chapter 8.

The checklist is divided into three different parts, "Do", "Consider" and "Don't". The "Do" section contains suggestions to include in the requirements and design process, which is recommended for the developers to follow. The "Consider" section contains suggestions for the developers to go over as suggestions to include. Finally, the "Don't" section contains advice for what *not to do* when trying to impact the end-users of software to become more environmentally aware.

The three sections all contain certain themes which have been covered during the previous survey as well as the interviews. Each of these themes comes with different suggestions based on the finding in the survey and/or the interviews. In connection to each of these suggestions, we have added *where* this was found and established, i.e., literature, survey, or interviews.

Checklist

Do:

- **Information:**
  - Provide information on how to improve/decrease impact, i.e., recommended course of action *(survey, interviews)*:
    - Provide the users with information on the impact of the current activity *(survey, interviews)*:
      - Comparison with other well know actions, such as keeping a light bulb on *(survey, interviews)*
      - Comparison with other people in the community/friends/ family *(literature, interviews)*

        - Suggest the users to only use, for instance, streaming applications, when really needed/wanted with the aim to make them reflect on their behaviour *(interviews)*
        - Suggest the user to watch at another point in time *(survey, interviews):*
            - o When the electricity is cheaper *(literature, interviews)*
            - o When the electricity is greener *(literature, interviews)*
        - Inform the user prior to their action of choice what the impact is. For instance, what impact this movie has in comparison to something else *(survey, interviews)*
        - Suggest the user to not keep things running in the background when not using it *(literature, interviews)*
        - Suggest the user to download during night *(interviews)*
    - Make the incentive concerning software use positive, rather than negative *(survey, interviews)*
    - Make the feedback based on the user's individual motivators (*survey, interviews)*
        - Suggestions on what has been used previously and worked for others:
            - Motivation based on earning money *(interviews)*
            - Motivation based on planting trees/helping the environment *(interviews)*
            - Motivation based on seeing the action in the community *(literature, interviews)*
            - Motivation based on earning points/rewards *(interviews)*
        - Use colour coding as feedback to the users, with the appropriate colours for the context *(interviews)*

- **Settings/Default settings:**
    - Set the default settings to be the ones with the lowest environmental impact. For instance, set the default settings for streaming services to be lowest quality *(literature, interviews)*

Consider:

- **Customisation:**
    - Make it possible for the users to customise how they see the information concerning impact on the environment *(interviews)*
- **Information:**
    - Type of information:

        * Suggest the user to download frequently used content *(interviews)*
        * Suggest the user to consider their behaviour when having software running on more than one screen *(interviews)*
    - Design the software to become a coach rather than telling the user what to do *(interviews)*

- **Settings:**
    - Suggest the users to set a daily limit for themselves, which cannot be changed immediately *(interviews)*
        * Possibility to, in relation to this, suggest another action/ activity *(survey, interviews)*
        * Possibility to, in relation to this foster learning and provide information concerning the impact *(survey, interviews)*
    - Suggest the users to put in reminders for when they want to be interrupted in their use of software/streaming services *(interviews)*
        * Possibility to question the user if the current activity is how they want to spend their time *(interviews)*
    - Suggest the users to set goals to decrease their use of digital services *(survey)*
    - Make updates of the software to be scheduled during nighttime

- **Motivation:**
    - Make it possible for the user to log their use of the software in question *(survey)*

Don't:

- **Information:**
    - Do not tell the user what to do or not to do *(literature, interviews)*
    - Do not present CO2/kilowatt-hours without making a comparison with other well-known activities (such as light bulb, driving a car, etc.). *(interviews)*
    - Do not provide the user with negative feedback about their habits/ actions *(literature, interviews)*

- **Motivation:**
    - Blocking:
        * Do not block the users from the software *(survey, interviews)*
        * Do not decide on a certain number of hours the users are able to use the app for *(interviews)*

In this chapter, the checklist, which is the main artefact of the study and the main contribution to the software engineering field, has been presented together with its design and validation. In the upcoming chapter, the results will be discussed.

7
Discussion

In this chapter, the findings and results will be discussed and elaborated on further. The answer to the research questions will be presented. In each of the sections, the questions from the survey and interview instrument connected to the research question will be presented. The connection is elaborated on and, finally, the answers to the research questions are presented.

7.1 Answer to research questions

In this section, the answers to the research questions presented in Chapter 1 are presented. Figure 7.1 show how the overall goal of the study is connected to the research questions and finally how the questions on the survey and in the interviews are connected to each question. Research question 1 is coded as blue, RQ1.1 is coded as green, and RQ2 is coded as purple.

Questions starting with S are from the survey and questions starting with I are from the interview (Figure 7.1). The questions for the survey was based on the literature as previously described, the survey created the basis for the interviews, and the interviews created the basis for the checklist.

7.1.1 RQ1

The first research question is connected to question S3–S9, S12 and S14 from the survey. Research question 1 is also connected to I1, I3, I4 and I6 from the interview. All of the questions can be found in Table 7.1. The connection between the questions and the research question is described in this section. Further, the answer to RQ1 is presented.

Table 7.1: Blue coded questions relating to RQ1 and referring to Figure 7.1

Question Nr	Alternatives
S3	What of the following streaming services have you used more than once for the past month? Please tick as many boxes as you feel apply. If you do not find your streaming service of choice, please specify which one you use in "other".
S4	What device do you most often use, to watch your media on? The device you use is the one where you load your app from and the main

Continued on next page

Table 7.1 – continued from previous page

Question Nr	Question
	hardware used to watch your videos on.
S5	How many devices are usually active in your household at the same time streaming video content? Remember that any streams running simultaneous counts. For instance, using YouTube on your phone while watching a stream on the TV. Please give an estimation of what you think, your answer does not have to be exact.
S6	How many days a week do you estimate that you usually stream content on the previously mentioned streaming services? Please give an estimation what you think, your answer does not have to be exact
S7	How many hours a day, do you estimate that you spend on the previously mentioned streaming services? This also includes background streaming such as keeping YouTube on for music or a series on for company. Please give an estimation of what you think, your answer does not have to be exact.
S8	How concerned do you think we should be of software's impact on the environment?
S9	How much would you trust information about carbon emission/environmental impact if you heard it from/if it was communicated by any of the below. Please choose the option that you find most suitable on each row.
S12	Whose main responsibility do you think it is that streaming services are sustainable? i.e. reducing the environmental impact of streaming services.
S14	Do you have any other inputs or ideas that you would like to share to increase sustainability in relation to use of digital services?
I1	To introduce the subject, I would like to start the conversation talking about recycling which is something people do without any thought today; how do you think can it be made natural to act sustainable concerning software?
I3	If we move on to the information that possibly can be provided to the end-user for them to act more sustainable and be aware that software has an impact on the environment. How do you think that information about sustainability can be trustworthy, if communicated through an app?
I4	How, with the use of an app, do you think that information about sustainability can be provided without the receivers of the information being overwhelmed? (In addition, how often do you think it would be suitable to provide the end-users with information?)
I6	In the previous conducted survey there was signs that age and gender was two factors showing a difference in how people felt about sustainability in terms of what would motivate them to decrease their use of software e.g. streaming services, how do you think that the less motivated group should/could be motivated?

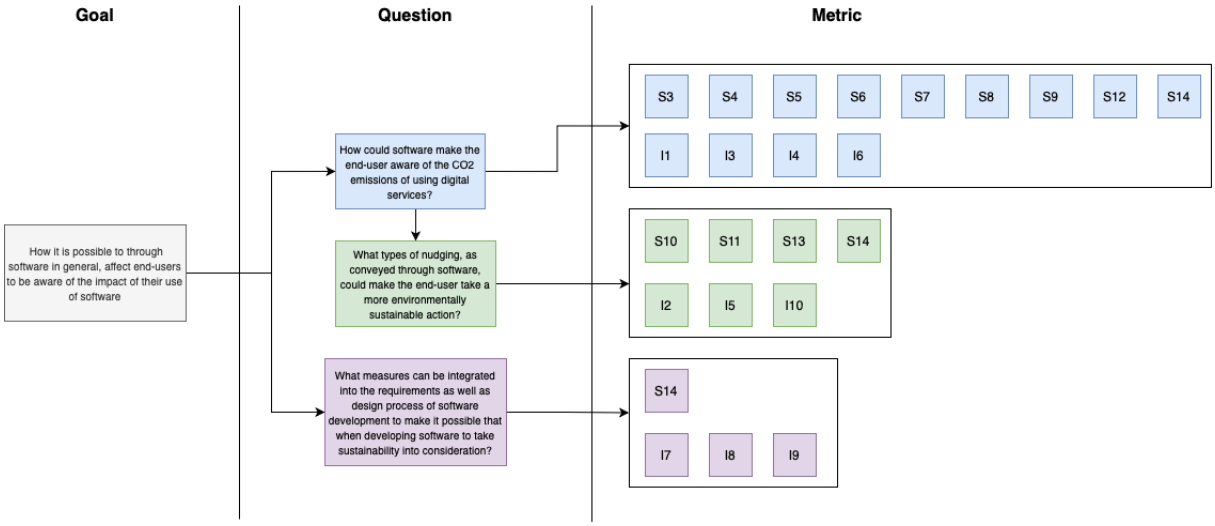

Figure 7.1: Figure describing the overall thesis goal, connected to the RQs and the questions in the survey as well as the interviews. Questions marked with S concern the survey, questions marked with I concern the interviews

S3–S7 were questions where the focus was to figure out the habits of the user. By understanding what habits the users had relating to their streaming services, it was possible to get a foundation for how the users could be made aware of the emissions using digital services.

Moving on, S8 was asked to try and get an understanding of how large the general concern with people is related to the impact of software on the environment. In that way, it would be possible to get a general understanding of how much awareness of software's impact there was among end-users.

Further, question S9 concerned with what would be the appropriate ways to in fact affect end-users. As a whole, the question aimed towards establishing how trustworthy the end-users would find information concerning environmental impacts from different sources. By so, the question was connected to RQ1.

The last question on the survey, S14, was an open question and connected to RQ1 as this question concerned anything related to streaming services where there was an opportunity for the respondent to express their general thoughts.

Moving on to the interview questions, I1 was connected to RQ1 as it more generally focused on how it could be made more natural to act sustainable concerning software. I3 covered the same subject as S9 from the survey, but this more in detail if the information were to be provided specifically through an application. Meaning, how information could be communicated through software and at the same time seem and be trustworthy to the end-users. Further, I4 was regarding how information could be provided to the users without them being overwhelmed.

Lastly, I6 was concerned about how to motivate less motivated groups of people. Once again this question focus on how it is possible to make the end-users aware of the emission from using digital services. This concerning motivation, and how the less motivated groups can be made aware of this.

To conclude, the overall goal of the questions from the survey and interview instrument was to get a general understanding of what could make end-users aware

of the emissions using digital services.

RQ1: How could software make the end-user aware of the CO2 emissions of using digital services?

Software with the aim to make end-users aware of the CO2 emissions should provide information with the most important aspects of the environmental impact of the digital services, i.e., to raise awareness concerning the environmental impact it has.
This should be done by providing the end-user with information and finding individual motivators to match the end-users. Further, information should be provided at such a level that the end-users are not overwhelmed.

In the upcoming section, the connected questions and the answer to RQ1.1 are covered and described.

7.1.2 RQ1.1

In this section, the answers to RQ1.1 will be summarised and presented. Before presenting the answers to RQ1.1, the questions from the survey and interviews relating to the research question will be covered. The questions relating to RQ1.1 are S10, S11, S13 and S14 from the survey and in addition, I2, I5 and I10 from the interviews. All questions are presented in Table 7.2.

Table 7.2: Green coded questions relating to RQ1.1 and referring to Figure 7.1

Question Nr	Questions
S10	What of the following options do you think would be the hardest to give up entirely? Please choose the option that you think fits best. With non-green energy means any energy source which is not renewable. Non-green energy is typically lower cost.
S11	Below you will find a list of everyday activities. For each of the activities that you do regularly, please indicate your main reason for doing so. Please tick the box on each row that you feel apply on each row. If it is not an activity that you perform, please tick the box "I do not perform this activity"
S13	What of the below actions/incentives would motivate you to decrease your use of digital services? Please choose the option that you find most suitable on each row.
S14	Do you have any other inputs or ideas that you would like to share to increase sustainability in relation to use of digital services?
I2	When you recycle plastic bottles, at least in Sweden, you do it to get your money back and so you have a motivator for recycling. If this were to concern software, should people be motivated to act sustainable in relation to software (or should the motivation come from within)?

Continued on next page

Table 7.2 – continued from previous page

Question Nr	Question
	If so, what do you think could be a good motivator?
I5	Moving on, information about the implications of streaming services and as well software can motivate users to decrease their use, what do you think would be the most important information to provide the users with?
I10	Blocking streaming services is something which has proven to not be a sufficient way to decrease the use of streaming services, is there any other solutions or alternatives that you think too is not sufficient for the purpose of decreasing the impact of software and if so, why?

The first connected question, S10, covers what the respondents would find the hardest to give up entirely. This together with the respondents explanations for their choices constituted a basis to understand what ways could be efficient to affect the end-users.

The next question connected to RQ1.1 was S11 where the connection between the two was based on what reason respondents had or performing certain activities. This was connected to RQ1.1 as this could create a foundation for what would motivate and nudge users into taking more sustainable actions.

S13 was more specific and covered what would motivate the end-users to decrease their use of digital services and thereby covering specific nudges. Thus connected to RQ1.1. S14 was as described in the previous section an open question and open for the respondents to provide any thoughts or information they wanted, thus also connected to RQ1.1.

There was also three of the interview questions connected to RQ1.1. The first connected question was I2. This question concerned what the interview subjects would find as good motivators to act more sustainable in relation to software. What would be motivators, is clearly connected to RQ1.1 as this could be what makes an impact on the end-user for them to change their behaviour.

Further, I5 concerned about what would be the most important information to affect the end-users with. This too was connected to RQ1.1 as this would be the direct information impacting the end-user to change their behaviour.

I10 was the last question from the interviews connected to RQ1.1. To summarise, this question concerned how to more specifically nudge the end-users into a more sustainable behaviour. Just as what would make a change and be a good way to nudge the end-users, what would be a less efficient way is also connected to RQ1.1.

RQ1.1: What types of nudging, as conveyed through software, could make the end-user take a more environmentally sustainable action?

The types of nudging appropriate to make users more aware of the environmental impact of software, i.e., take more environmentally sustainable action, depends on who the end-user is and, hence, on the individual motivators for

that end-user.
Nevertheless, there are nudging that would be useful to impact users' behaviour. These are comparisons, suggestions to watch at another point in time, and inform the user of the impact of their action prior to using the software. Moreover, suggesting the user to not keep things running in the background and downloading during the night are two other suggestions for the user to act more sustainable.
What should be avoided is blocking the digital services. The information provided should be positive and colour coding matching the context should be used.

In this section, the answers to question RQ1.1 has been presented and covered. In the next section of this chapter, the answers to the final research question, RQ2, is presented.

7.1.3 RQ2

In the following section, the answers to the last research question are covered. The last research question is the most general of the three and covers what can be incorporated into the requirements and design process of software engineering to incorporate sustainability. The questions connected to the final research question was the open question previously mentioned, S14, from the survey as well as I7–I9 from the interviews. These questions have all been gathered in Table 7.3.

Table 7.3: Purple coded questions relating to RQ2 and referring to Figure 7.1

Question Nr	Questions
S14	Do you have any other inputs or ideas that you would like to share to increase sustainability in relation to use of digital services?
I7	What do you think could be included in the requirements process of software for it, the software, to be more sustainability concerned and create awareness of its environmental impact with the end-users?
I8	How do you think that software can be designed, to make an impact on the users to decrease their use and thereby impact as well as understand that software too is something having an impact on the environment?
I9	If there were to be a marking/carbon emission stamp on software, what criterion's do you think would be of importance to include, e.g., what should be measured to constitute and make the basis for this marking?

As mentioned in the two previous sections presenting the connection between

RQ1 and RQ1.1 and the survey question S14, this question was open. The question was added to make a possibility for the respondent to add any thoughts they wanted concerning the environmental impact of streaming services and how that could be decreased. As it was open, it collected a large variety of answers and connects to all three research questions.

The first question connected to RQ2 from the interviews were I7 covering what the interview subject would find relevant to include into the requirements process of software to create awareness with the end-user. This question is explicitly connected to RQ2.

Further, I8 was connected to RQ2 in the same way as I7 but instead of focusing on requirements, I8 focused on the design of software and on what measures could be integrated to create awareness with the end-user.

The last question connected to RQ2 was I9. This question concerned what could be included for measuring in software to make a basis for this marking, this with the aim to raise end-user awareness of what is sustainable software and what is not. Therefore I9 is connected to RQ2.

RQ2: What measures can be integrated into the requirements as well as design process of software development to make it possible that when developing software to take sustainability into consideration?

The measures that can be integrated into the requirements and design process of software development to increase sustainability and thereby answer RQ2 has been presented in the checklist in Chapter 6. The checklist is also included on its own in Appendix E.
All of the suggestions on the list are measures that are suggested and based on the survey, interviews, as well as validation of the checklist to decrease the impact on the environment through software.

To conclude, RQ2 concerns what suggestions to include in the requirements and design process. This is provided through a checklist with suggestions on what to *do*, *consider* and *don't do*.

7.2 Implications

The results of the study matter in several ways. They are important both to raise awareness with the end-users, for them to question their behaviour, and foster learning, i.e., be more mindful in their use of software.

Further, there is a chance that increased end-user awareness can lead to end-users, in turn, requiring that companies are transparent with how they fulfil measures to obtain sustainability.

Also, concerning the checklist, there is a possibility for software developed to become more sustainable and at the same time foster learning of end-users. Moreover, with more developers being aware of the importance of sustainability and incorporating it in their day to day work, there will hopefully be a higher awareness of sustainability in software companies. Overall, the results are important to raise

awareness and impact the software engineering field as a whole to become more sustainable.

In this chapter, the results from the survey, the interviews as well as the validation of the checklist has been discussed. the answers to the three research questions have been presented. In the upcoming chapter, potential future work is covered.

8
Future work

In this chapter, we provide recommendations concerning future work. What is presented is both what would have been of interest in connection to this thesis to elaborate and research on further, but, in addition, we present future work which is important in connection to this topic.

8.1 The two facets of sustainability

In this thesis, two perspectives on sustainability have been mentioned. These two were the aspects of considering how software can be developed in sustainable ways and the other was how the end-user could act when using software to decrease the impact on the environment. The latter has been the focus of this thesis. While this aspect has been covered there is still a need to find ways in handling the other aspect of sustainability in relation to software.

How to develop sustainable software remains a challenge, which was pointed out during the interviews. In this thesis, this has been brought forward and understood both through the literature review summarised in Chapter 3, as well as mentioned by several respondents in the interviews. Thus, we suggest further studies focused on sustainable software development, which possibly could be based on the Principles of Green Software Engineering [19].

8.2 Education

The year 2030 is a milestone considering goals concerning sustainability [16]. This can be considered problematic as today, i.e., 2021, there is very limited environmental aspects incorporated into the software development courses at the bachelor and master programs of IT/Software Engineering at Chalmers. During the interviews, it was emphasised by several researchers the importance of newly educated developers having an understanding of the sustainability aspects of software.

To ensure that software developed is sustainable there needs to be knowledge with the developers. The checklist provided in this thesis is considered a step in this direction. However, there is still a need for the individual developer to understand the importance of this for the checklist to be well received in development processes.

If there is an increased focus on incorporating sustainability at the universities, there among Chalmers, there will most likely be an increased awareness with software companies, as the newly educated software engineers will bring this knowledge to the table. Further, there will be a larger end-user awareness as more people will take

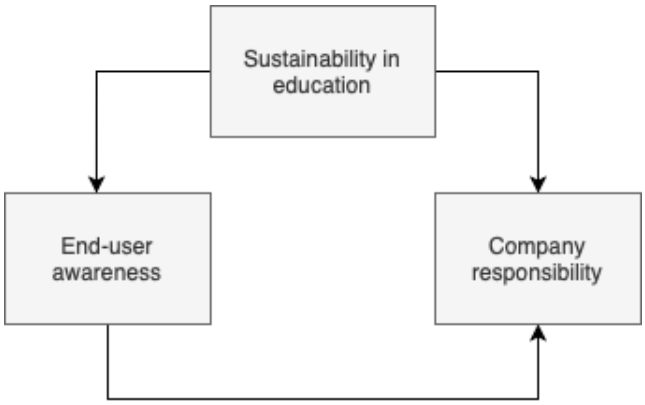

Figure 8.1: The potential impact increased sustainability in education can lead to

part in the knowledge and the impacts. This in turn could lead to higher pressure on the companies, as previously mentioned, to become more sustainable and take responsibility concerning this issue.

8.3 Testing timing of nudges

In this thesis, the types of nudging that would be of relevance to increase the awareness of sustainability with end-users have been investigated. What could have been examined further in this study, if it would have been possible, would have been to make a longitudinal experiment to establish the timing of nudges.

The timing of nudges was mentioned during the interviews and it was suggested that the users should be nudged only once per day and that the users should get a weekly report. This was something that was not examined further and which can be considered to be of interest for further studies as well as a complement to this thesis. This will most likely require extensive user testing through a longitudinal experiment and the question is if a master thesis, limited in scope concerning time, is the most suitable way to do this.

8.4 Developer evaluation of checklist

What would also be of interest for future work and in relation to this thesis would be to test the checklist with developers to see how it works in practice as the checklist only is evaluated through expert opinion.

One of the important aspects raised in this thesis concerning sustainable software development was that much responsibility lies with the software developers. Thus, it would be important to ensure that this list is something they would find useful and convenient to use and update it accordingly.

8.5 Policies for software

Looking at a larger perspective, and with a basis of what the researchers emphasised in the interviews, there seems to be a need for policies concerning software. What could be considered to be of importance in the future is for more policies to be created, to ensure that companies' responsibility is forced rather than wait for it to happen. Such policies would make it possible to force companies to act sustainable. Policies could be of importance to make labels/certifications, to make it easier for the users to make sustainable choices and increase the transparency which already is aimed for by Greenpeace, as earlier mentioned [9].

8.6 Sustainability marking for software

Moreover, in connection to creating policies for software, there could be an interest in evaluating whether a sustainability marking could be of relevance for software. This could be built upon further by taking basis in the Greenpeace transparency report [9]. By using a marking, it would be visual for end-users how sustainable a software is. This is a method that already is used with other products. For instance with coffee, Fairtrade, and with kitchen appliance where there is a marking ranging from A to G describing how energy efficient the appliance is.[1] What would be of importance would be to consider what should constitute the criteria for being marked at a certain level. Here it could be suggested that the Principles of Green Software Engineering could be used and built further upon [19].

In this chapter potential future work in relation to the thesis has been presented. In the next chapter, the threats to validity of the study are covered.

[1] `https://europa.eu/youreurope/business/product-requirements/labels-markings/energy-labels/index_en.htm`

9
Threats to validity

The validity of a study concerns how trustworthy and how correct the conclusions of the study is, as well as the quality of the study. The validity aspects covered in this thesis is based on the paper by Feldt and Magazinius [12]. The four suggested types of validity that are common in software engineering are: Conclusion validity, internal validity, construct validity, and external validity. All of which will be presented below.

One overall threat to validity, which can not be emphasised enough, is that the thesis has been written by one researcher, and by so there is an even larger risk of bias to be introduced. Thus, to mitigate this risk, throughout the thesis, other researchers have been included in the validation of the different steps of the study.

9.1 Conclusion validity

Conclusion validity focuses on the certainty regarding the conclusions. According to Feldt and Magazinius the conclusion validity focuses on "how sure we can be that the treatment we used in an experiment really is related to the actual outcome we observed. Typically this concerns if there is a statistically significant effect on the outcome."

A threat to this study is the ongoing COVID-19 pandemic which possibly could affect the outcome of the survey as well as interview results due to the fact that people are spending more time in their homes and, thus, tend to potentially use streaming services more frequently in the absence of other activities. That said, it has been shown during the pandemic that people tend to form new interests such as baking and reading, as well as spending time outside and, thus, the effects found should still be considered valid and can still have an impact on the end-users.

The risk could however be that the respondents of the survey would find it harder to change their behaviour in regards to streaming services now as the use of streaming services has increased heavily during the COVID-19 pandemic.

9.2 Internal validity

Internal validity concerns whether the treatment of the study relates to the presented outcome [12]. Meaning how sure we can be that the outcome actually is due to the treatment and methods used in the study.

There comes a risk with the choice of subjects for the surveys as well as the interviews, which can be adjusted by making sure that the selection of the subjects

is random, if possible. In the case of this thesis, the selection of respondents on the survey was random (i.e., in the sense that the researcher did not control who would answer the survey).

Another indicated risk concerning the content of the survey was the risk of people answering the survey untruthfully as the subject of sustainability is sensitive to people and they most likely will try and answer in a manner that makes them seem to care for the environment. To try and mitigate this risk, questions in the survey were steered towards facts that the user could provide rather than questions dependent on the users' feelings or questions where the user had to try and prove something.

Another risk concerning internal validity is that there are not enough survey or interview subjects that can participate. This can be addressed as well as minimised by trying to make the survey as well as the interviews as soon as possible in the study, to receive early indications if this is the case. This was not considered a problem in this thesis as the topic of the thesis was broad and something most people could relate to. Thus, the problem to find respondents was not considered an issue.

Moreover, to ensure internal validity, a complete case analysis was performed on the survey data—analysing missing data would otherwise be required, which is both hard and requires extensive experience. However, given the sample size, $N = 295$, for the survey we feel confident that modelling missingness would only have contributed to significantly increasing the uncertainty and not much more.

What in addition can be a threat to the internal validity is that interview respondents are biased. Concerning this matter, we tried to give the respondents as little information as possible, but still ensuring that they had enough information to be able to participate in the interviews.

In addition, the protocols for the interviews and the validation of the checklist was followed to ensure internal validity. The protocol for the interviews can be found in Appendix D.1 and the protocol for the validation of the checklist can be found in Appendix E.

Concerning the validation of the proposed checklist. The plan from the start was to get experts only to validate the checklist. Unfortunately, the response rate was low which was a disappointment. Thus, the validation was made broader and instead focused also on newly graduated software engineers. This then made it possible to get the perspective of future software developers.

9.3 Construct validity

For this thesis, construct validity concerns whether the intended construct is measured. In this particular case, it would concern sustainability.

For the survey, the construct validity was aimed to be fulfilled by basing the survey questions on literature focusing on sustainability. In addition, the survey questions were discussed with and evaluated by sustainability researchers.

For the interviews, the questions were chosen from a large deck of interview questions (described in Chapter 5). This was once again done together with sustainability researchers to ensure that they were targeting what was in line with the

goal and research questions.

For the validation of the checklist there was laid trust in the participants in the validation based on their knowledge within their respective fields and thus for them to be able to understand the suggestions on the checklist and validate them based on their experience. What could have been done to strengthen the validation further and what can be suggested to do to develop the checklist further is to include direct examples to make the suggestions even more clear.

9.4 External validity

External validity is whether the presented finding can be generalised to a situation outside the study [12].

The threat to external validity is that the sample used was not broad enough and, thus, that there is a risk that the findings, as well as the answers to the research questions, do not apply to other people than the ones participating. However, the aim of the study is not mainly statistical generalisability, but rather analytical generalisability, since we followed a case study approach.

Considering the focus on streaming services this was considered as a valid starting point due to the fact that it captures a large number of software users. The checklist targets software overall and the generalisability of the checklist should not be limited by the focus on streaming services but rather it should be considered that it captured a large part of end-user habits which could be derived into suggestions as streaming services are commonly used.

To summarise, the most common types of validity threats, as found in software engineering research, have been presented in this chapter. In the upcoming chapter, the conclusions of the thesis will be presented.

10
Conclusions

The goal of this thesis concerned how it was possible, through software to affect end-users to be aware of their environmental impact when using said software.

The thesis consisted of a literature review, a survey, interviews, while a best practice checklist was put together and validated.

The literature review initialised the study and by so the related work was established. In addition, the literature review i.e., the related work, served as a foundation for the survey to ask specific and relevant questions. The survey was designed based on the related work and sent out to users of digital services. The survey resulted in information on end-users and their behaviour in relation to digital services.

The survey results were investigated further in the interviews where the aim was to deepen the knowledge found and receive new perspectives with the help from five researchers. One of the more important findings from the interviews were that several interview subjects emphasised the need for providing information raising awareness regarding the impact on the environment through the use of software.

As a last step of the thesis, a best practice checklist was put together consisting of ways to affect end-users to decrease their software use. In addition, to foster learning regarding the impact of software on the environment. The suggestions on the checklist is based on the literature, the survey, the interviews, and a final validation step where a focus group provided input.

To summarise, it can be established through both the literature, the survey results, and the interview results that there is a need to increase end-user awareness regarding the impact they have on sustainability when using software. Further, it can be concluded that software should aim to make end-users aware of the CO2 emission and provide information with the most important aspects of the environmental impact of the digital service in question.

Moreover, there are strong indications that there are types of nudging that are both appropriate as well as less useful to make end-users aware of the impact their use of software has. These types of nudging should be individually tailored and could make the end-users take more environmentally sustainable actions.

Overall, it can be concluded that the most important aspect is to, through the provided checklist, try and make the end-users aware that no matter what software they use, it has an impact on the environment.

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A

Survey

A.1 Survey questions

Below follows a table containing all the questions from the survey in their original phrasing. Question 9, 11 and 13 were all matrices and therefore the questions has been split up into several pieces.

Table A.1: Survey questions

Question Nr	Question
Q1	What gender do you identify with the most?
Q2	How old are you? Please choose your age among the options in the list.
Q3	What of the following streaming services have you used more than once for the past month? Please tick as many boxes as you feel apply. If you do not find your streaming service of choice, please specify which one you use in "other".
Q4	What device do you most often use, to watch your media on? The device you use is the one where you load your app from and the main hardware used to watch your videos on.
Q5	How many devices are usually active in your household at the same time streaming video content? Remember that any streams running simultaneous counts. For instance, using YouTube on your phone while watching a stream on the TV. Please give an estimation of what you think, your answer does not have to be exact.
Q6	How many days a week do you estimate that you usually stream content on the previously mentioned streaming services? Please give an estimation of what you think, your answer does not have to be exact.
Q7	How many hours a day, do you estimate that you spend on the previously mentioned streaming services? This also includes background streaming

Continued on next page

Table A.1 – continued from previous page

Question Nr	Question
	such as keeping YouTube on for music or a series on for company. Please give an estimation of what you think, your answer does not have to be exact.
Q8	How concerned do you think we should be of software's impact on the environment?
Q9	How much would you trust information about carbon emission/environmental impact if you heard it from/if it was communicated by any of the below: Please choose the option that you find most suitable on each row.
Q9.1	Family member/friend
Q9.2	Scientist
Q9.3	The government
Q9.4	An energy supplier
Q9.5	An environmental organisation
Q9.6	An application on your phone
Q9.7	Media (news/radio/papers)
Q9.8	The internet
Q10	What of the following options do you think would be the hardest to give up entirely? Please choose the option that you think fits best. With non-green energy means any energy source which is not renewable. Non-green energy is typically lower cost.
Q11	Below you will find a list of everyday activities. For each of the activities that you do regularly, please indicate your main reason for doing so. Please tick the box on each row that you feel apply on each row. If it is not an activity that you perform, please tick the box "I do not perform this activity".
Q11.1	Walk/cycle to work
Q11.2	Public transport
Q11.3	Turn off lights I'm not using

Continued on next page

Table A.1 – continued from previous page

Question Nr	Question
Q11.4	Recycle
Q11.5	Following a vegetarian diet
Q11.6	Turn off your computer overnight
Q11.7	Take as short showers as possible
Q11.8	Buy second hand
Q12	Whose main responsibility do you think it is that streaming services are sustainable? i.e. reducing the environmental impact of streaming services
Q13	What of the below actions/incentives would motivate you to decrease your use of digital services? Please choose the option that you find most suitable on each row.
Q13.1	Notifications informing me about my daily CO2 emission
Q13.2	Information regarding the implications of the use of digital services in relation to emissions
Q13.3	Setting goals in relation to emission to motivate a decreased use of digital services
Q13.4	There is nothing that could motivate me to decrease my use of digital services
Q13.5	Logging my use of digital services to see my behaviour over time and get suggestions on how to improve
Q13.6	Streaming services being blocked by an app after a certain amount of CO2 emission
Q13.7	See the CO2 impact of video streaming related to other activities having impact on CO2
Q13.8	Suggestions to use streaming services at another point in time, which could result in lower CO2 emission

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Table A.1 – continued from previous page

Question Nr	Question
Q14	Do you have any other inputs or ideas that you would like to share to increase sustainability in relation to use of digital services?

A.2 Survey question alternatives

The below table relates to the one in the previous section - here all of the alternatives for each of the questions is presented in the original phrasing.

Table A.2: Survey question alternatives

Question Nr	Alternatives
Q1	Female/Transfemale, Male/Transmale, Non-binary
Q2	15–99
Q3	Netflix, HBO Nordic, Prime Video, CMore, Viaplay, Disney+, SVT Play, Apple TV+ Discovery+, YouTube, hayu, Draken Film, Mubi, TV4 Play, RakutenTV, Other
Q4	TV, Computer, Smartphone, Other
Q5	None, 1 device, 2–3 devices, More than 4 devices
Q6	0 days a week, 1–2 days a week, 3–4 days a week, 5–6 days a week Every day of the week
Q7	0 hours per day, Less than 1 hour, 1–2 hours per day, 3–4 hours per day 5–6 hours per day, More than 7 hours per day
Q8	Not concerned, Somewhat not concerned, Neutral, Somewhat concerned Concerned
Q9.1	Don't trust, Somewhat don't trust, Neutral, Somewhat trust Trust, N/A
Q9.2	Don't trust, Somewhat don't trust, Neutral, Somewhat trust Trust, N/A
Q9.3	Don't trust, Somewhat don't trust, Neutral, Somewhat trust

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Table A.2 – continued from previous page

Question Nr	Alternatives
	Trust, N/A
Q9.4	Don't trust, Somewhat don't trust, Neutral, Somewhat trust Trust, N/A
Q9.5	Don't trust, Somewhat don't trust, Neutral, Somewhat trust Trust, N/A
Q9.6	Don't trust, Somewhat don't trust, Neutral, Somewhat trust Trust, N/A
Q9.7	Don't trust, Somewhat don't trust, Neutral, Somewhat trust Trust, N/A
Q9.8	Don't trust, Somewhat don't trust, Neutral, Somewhat trust Trust, N/A
Q10	Driving a car, Flying, Streaming video, Eating meat, Buying non-green energy Buying new clothes, Don't want to specify
Q11.1	To save money, To protect the environment, Health, Habit, Moral obligation Other, I do not perform this activity
Q11.2	To save money, To protect the environment, Health, Habit, Moral obligation Other, I do not perform this activity
Q11.3	To save money, To protect the environment, Health, Habit, Moral obligation Other, I do not perform this activity
Q11.4	To save money, To protect the environment, Health, Habit, Moral obligation Other, I do not perform this activity
Q11.5	To save money, To protect the environment, Health, Habit, Moral obligation Other, I do not perform this activity
Q11.6	To save money, To protect the environment, Health, Habit, Moral obligation Other, I do not perform this activity
Q11.7	To save money, To protect the environment, Health, Habit, Moral obligation Other, I do not perform this activity
Q11.8	To save money, To protect the environment, Health, Habit, Moral obligation Other, I do not perform this activity

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Table A.2 – continued from previous page

Question Nr	Alternatives
Q12	The streaming platforms, End-users of the streaming platforms, Energy producers Energy providers, Policy makers (e.g. politicians), Other
Q13.1	Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree Agree, Strongly agree, N/A
Q13.2	Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree Agree, Strongly agree, N/A
Q13.3	Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree Agree, Strongly agree, N/A
Q13.4	Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree Agree, Strongly agree, N/A
Q13.5	Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree Agree, Strongly agree, N/A
Q13.6	Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree Agree, Strongly agree, N/A
Q13.7	Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree Agree, Strongly agree, N/A
Q13.8	Strongly disagree, Disagree, Somewhat disagree, Neutral, Somewhat agree Agree, Strongly agree, N/A
Q14	Open Question

B

Bayesian analysis

B.1 Models

In the below table a summary of all the models are presented. All of the survey variable, outcomes as well as predictors has been included. The significant predictors are mentioned in the rightmost column of the table. If none of the predictors were significant, the cell corresponding to the outcome is marked with N/A.

Table B.1: Description of models from the survey

Outcome	Predictors	Significant
Concern	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender, HoursADay
Trust_Family	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	N/A
Trust_Scientist	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender
Trust_Government	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender, ActiveDev
Trust_EnergySupp	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Age
Trust_Environmental	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Age, Gender
Trust_Application	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender
Trust_Media	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender
Trust_Internet	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	N/A
GiveUp	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Driving a car, Flying, Eating meat
Act_WalkCycle	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Walk/cycle to work, Public transport Turning off lights I am not using, Take as short showers as possible
Act_PublicTransport	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Walk/cycle to work, Public transport Recycle

Continued on next page

Table B.1 – continued from previous page

Outcome	Predictors	Significant
Act_TurnOffLights	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Walk/cycle to work, Public transport Recycle
Act_Recycle	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Walk/cycle to work, Public transport
Act_Veggie	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	N/A
Act_Computer	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Take as short showers as possible
Act_Showers	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	N/A
Act_SecondHand	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Walk/cycle to work, Public transport
MainResp	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Walk/cycle to work, Public transport Turning off lights I am not using, Take as short showers as possible
Motivate_Notif	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender
Motivate_Information	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender, HoursADay
Motivate_SetGoals	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	HoursADay
Motivate_Nothing	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	DaysAWeek, HoursADay
Motivate_LoggingUse	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender, HoursADay
Motivate_Blocking	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	N/A
Motivate_Impact	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Age
Motivate_Suggestions	Age, Gender, NrOfSub, Device ActiveDev, DaysAWeek, HoursADay	Gender

B.2 Outcomes

The following table shows a summary of the outcome variables from the Bayesian models covered in Chapter 4.

Table B.2: Description of outcomes from the survey

Variable	Value	Description
Concern	Not concerned, Somewhat not concerned Neutral, Somewhat concerned, Concerned	How concerned the respondent is with software's impact on the environment
Trust_Family	Don't trust, Somewhat don't trust Neutral, Somewhat trust, Trust, N/A	How much a respondent trust a source of information
Trust_Scientist	Don't trust, Somewhat don't trust Neutral, Somewhat trust, Trust, N/A	How much a respondent trust a source of information
Trust_Government	Don't trust, Somewhat don't trust Neutral, Somewhat trust, Trust, N/A	How much a respondent trust a source of information
Trust_EnergySupp	Don't trust, Somewhat don't trust Neutral, Somewhat trust, Trust, N/A	How much a respondent trust a source of information
Trust_Environmental	Don't trust, Somewhat don't trust Neutral, Somewhat trust, Trust, N/A	How much a respondent trust a source of information
Trust_Application	Don't trust, Somewhat don't trust Neutral, Somewhat trust, Trust, N/A	How much a respondent trust a source of information
Trust_Media	Don't trust, Somewhat don't trust Neutral, Somewhat trust, Trust, N/A	How much a respondent trust a source of information
Trust_Internet	Don't trust, Somewhat don't trust Neutral, Somewhat trust, Trust, N/A	How much a respondent trust a source of information
GiveUp	Driving a car, Flying, Streaming video Eating meat, Buying non-green energy Buying new clothes	What alternatives the respondent would find hardest to give up
Act_WalkCycle	To save money, to protect the environment, health, habit, moral obligation other, I do not perform this activity	Respondents reason for performing a certain activity
Act_PublicTransport	To save money, to protect the environment, health, habit, moral obligation other, I do not perform this activity	Respondents reason for performing a certain activity
Act_TurnOffLights	To save money, to protect the environment, health, habit, moral obligation other, I do not perform this activity	Respondents reason for performing a certain activity
Act_Recycle	To save money, to protect the environment, health, habit, moral obligation other, I do not perform this activity	Respondents reason for performing a certain activity
Act_Veggie	To save money, to protect the environment, health, habit, moral obligation other, I do not perform this activity	Respondents reason for performing a certain activity
Act_Computer	To save money, to protect the environment, health, habit, moral obligation other, I do not perform this activity	Respondents reason for performing a certain activity
Act_Showers	To save money, to protect the environment, health, habit, moral obligation	Respondents reason for performing a certain

Continued on next page

Table B.2 – continued from previous page

Variable	Value	Description
	other, I do not perform this activity	activity
Act_SecondHand	To save money, to protect the environment, health, habit, moral obligation other, I do not perform this activity	Respondents reason for performing a certain activity
MainResp	The streaming platforms, end-users of streaming platforms, energy producers, energy providers, policy makers, other	Whose main responsibility is it that streaming services are sustainable
Motivate_Notif	Strongly disagree, disagree, somewhat disagree neutral, somewhat agree, agree, strongly agree, N/A	What would motivate the respondent to act more sustainable
Motivate_Information	Strongly disagree, disagree, somewhat disagree neutral, somewhat agree, agree, strongly agree, N/A	What would motivate the respondent to act more sustainable
Motivate_SetGoals	Strongly disagree, disagree, somewhat disagree neutral, somewhat agree, agree, strongly agree, N/A	What would motivate the respondent to act more sustainable
Motivate_Nothing	Strongly disagree, disagree, somewhat disagree neutral, somewhat agree, agree, strongly agree, N/A	What would motivate the respondent to act more sustainable
Motivate_LoggingUse	Strongly disagree, disagree, somewhat disagree neutral, somewhat agree, agree, strongly agree, N/A	What would motivate the respondent to act more sustainable
Motivate_Blocking	Strongly disagree, disagree, somewhat disagree neutral, somewhat agree, agree, strongly agree, N/A	What would motivate the respondent to act more sustainable
Motivate_Impact	Strongly disagree, disagree, somewhat disagree neutral, somewhat agree, agree, strongly agree, N/A	What would motivate the respondent to act more sustainable
Motivate_Suggestions	Strongly disagree, disagree, somewhat disagree neutral, somewhat agree, agree, strongly agree, N/A	What would motivate the respondent to act more sustainable

B.3 Predictors

The following table shows a summary of the predictors variables from the Bayesian models covered in Chapter 4.

Table B.3: Description of predictors from the survey

Variable	Value	Description
Age	15–99	Age of the respondent
Gender	Female/transfemale, Male/Transmale	Gender of the respondent
NrOfSub	0–16	The number of subscriptions a respondent has
Device	TV, Computer, Smartphone, Tablet, Other	The device the respondent uses
ActiveDev	None, 1 device, 2-3 devices More than 4 devices, Other	The number of active devices a respondent has
DaysAWeek	0, 1–2, 3–4, 5–6, 7	How many days a week the respondent stream content
HoursAWeek	0, <1, 1-2, 3-4, 5-6, 7<	Hours a week a respondent stream content

C

Detailed survey results

Below, all of the outcomes from the survey are described. The information details on what predictors affected the outcomes as well as what of the options on each question that was most popular.

C.1 Survey results

Outcome - Concern
The first outcome analysed was Concern. By looking at the summary of the likelihood it could be established that both the variable Gender as well as the HoursADay has a significant negative impact on the outcome. Looking at the gender as the first predictor a negative significant impact means that an increased value on gender (in this case we only have two alternatives, female/transfemale as well as male/transmale) will decrease the value on the outcome, and thus the concern. This means that women are more concerned about the impact of software on the environment. Moving on to the next significant predictor, the same negative relationship holds. The larger the value on HoursADay, the smaller the value on the outcome, Concern, is. In this case, it means that the more hours a day the respondent's stream content, the less concerned they seem to be about the impact of software on the environment. The predictor ActiveDev seem to have a negative impact on the outcome and Age, DaysAWeek, as well as Device, have a positive impact on the outcome. This seems to result in, that a lower value on both age, how many days a week you use streaming services as well as what device you use will lead to a higher value on the outcome, e.g. you being more concerned about the software impact on the environment.

Most of the respondents answered that we should be **somewhat concerned** about software's impact on the environment.

The next outcome analysed is divided into several outcomes, where the question concerned how much you would trust certain persons or instances in the communication of information regarding environmental impact.

Outcome - Trust_Family
For the first of the outcomes, the trust of family members and friends were considered. Neither of the predictors used could be established to significantly affect the outcome. That said, the Device predictor seemed to have a negative impact on the outcome. The more devices you use, the less you trust your family members or friends communication about environmental impact.

The most chosen answers among the respondents was **neutral** as well as **somewhat trust** concerning this question.

Outcome - Trust_Scientist Moving on to the next outcome, Gender was a significant predictor. The relationship was once again negative, meaning that category 1, female/transfemale, would have a higher trust within scientist whereas category 2, male/female, would have less trust with scientists communicating about environmental impact or carbon emission. Age as well as the number of active devices did have a negative impact on the outcome, but not statistically significant. What could be seen is tendencies where a higher age, as well as more active devices, would lead to a lower trust with scientists. The device of choice that the respondent would use mostly would on the other hand tend to affect the outcome positively. The use of particular devices show tendencies towards a higher trust in scientists.

The majority of the respondents answered on the scale that they would **trust** a scientist communicating information about environmental impact and carbon emissions.

Outcome - Trust_Government

How much the respondents trust the government is affected negatively by how many devices the respondents keep active as well as what gender the respondent identify with, both of these predictors are significant. With this being the case it means that a higher number of active devices decrease the trust of the government as well as previously mentioned, a higher gender category will be more likely to not trust the government in their communication regarding environmental impact. Moreover, HoursADay, how many hours you on average make use of streaming services seem to have a slight negative impact on the outcome, not significant, but still it looks to have an effect. The more hours a day a respondent stream media the less trust they have with the government in their communication concerning environmental impact. The opposite holds for the number of subscriptions a respondent have, if the respondent has fewer subscriptions they tend to trust the government more.

Most of the respondents answered that they would, on the scale ranging from don't trust to trust, that they would **somewhat trust** the government in their communication about the environmental impacts.

Outcome - Trust_EnergySupp

For the next outcome, the communication on environmental impact from energy suppliers was considered. Here, age was a significant predictor and affected the outcome negatively. This means that the higher the age of the respondent, the less the respondent would tend to trust the information about environmental impact coming from an energy supplier. The same goes for gender and how many days a week the respondent will use streaming services with the only difference being that the latter two did not have statistical significance. How many subscriptions the respondent have did yet again affect the outcome in a positive manner and fewer subscriptions tend to reflect a higher trust with energy supplier in regards to communication on environmental impact.

When it came to the answers to this question, most of the respondents answered that they were **neutral** or that they would **somewhat trust** energy suppliers on the information they would communicate.

Outcome - Trust_Environmental

The next outcome concern the communication of carbon emission and impact done by an environmental organisation. The outcome described is significantly negatively

impacted by both age and gender. Where it means that the higher the age as well as the higher the gender category the lower the value on the outcome, e.g. the lower trust in the communication from environmental organisations. The amount of active devices the respondents keep has the same impact on the outcome as previously described but is not significant.

For this question, the majority of the respondents claimed that they would **somewhat trust** an environmental organisation in their communication on their work - meaning the impact on the environment as well as carbon emission.

Outcome - Trust_Application

Moving on to whether information about carbon emission and environmental impact would be trusted if it were to be communicated through an application the gender was once again significant negatively. This means that there is a higher trust in the communication from an application with women than with men. If the age is higher as well as if streaming services are used all days a week independently, the trust in an application to communicate on environmental impact is lower.

Whether an application couldn't or could be trusted with communicating information about environmental impact could be established by the answers from the question, where the majority of the respondents answered that they were **neutral**.

Outcome - Trust_Media

Furthermore, the trust of media's communication of environmental impact was considered and analysed. Yet again the gender was significant and has a negative impact on the outcome which as earlier described mean that there is a significant tendency for women to trust media more, whereas men trust media less when they present information on carbon emission. What also seems to affect and have an impact on the outcome is a higher age, a large number of streaming service subscriptions as well as a large number of active devices, where this leads to lower trust in media communication of environmental impacts.

Most of the respondents answered that they would **somewhat trust** the media in their communication.

Outcome - Trust_Internet

The last outcome concerning trust is whether the respondents would trust information about carbon emission as well as the environmental impact if it was found on the internet. In this case, none of the predictors had a significant impact on the outcome of trusting the internet, but both age, gender, what device is being used, how many subscriptions the respondent has as well as how many active devices are used and how many days a week streaming content is carried out had a negative impact on the outcome, so with all of them increasing, the trust in the internet concerning information on the environmental impact is lowered.

Whether the respondents would tend to trust the internet could be acknowledged by the main part of the respondents answering that they were **neutral** concerning whether they would not trust or trust the information about environmental impact communicated on the internet.

Outcome - GiveUp

Following the outcomes concerning whether to trust certain communication through different types of channels came a question and thereby an outcome concerning what of 6 different habits/actions that would be hardest to give up entirely. These 6 were;

driving a car, flying, streaming video, eating meat, buying non-green energy and buying new clothes.

In this case, driving a car as well as streaming video and eating meat were significant factors. When it comes to streaming video age is a significant factor and concerning eating meat the significant factors were—NrOfSub and HoursADay.

The most answered option was **driving a car**, which the majority of the respondents felt would be the hardest to give up.

Outcome - Act_WalkCycle

The next set of outcomes concerned what certain actions were due to a specific reason. For instance, if you walk or cycle to work, is that due to habits, moral obligation, to protect the environment etc. The first of the outcomes concerned why the respondents choose to walk or cycle if they perform the action.

For this outcome the options—To save money, To protect the environment, Health as well as not performing the action, were all significant. The significant factor for protecting the environment was DaysAWeek, meaning that how many days a week the respondent watched streaming services affected whether they did walk/cycle to protect the environment. Whether the respondents did walk/cycle due to health reasons was affected by the predictor's age and DaysAWeek. The last significant factor was as mentioned not performing the action which was too affected by Age and DaysAWeek.

Most of the respondents answered that they performed this activity due to **health** reasons. Almost 50% of the ones performing the activity agreed on this.

Outcome - Act_PublicTransport

Moving on to the outcome concerning the action of using public transport. The question here was as before for the respondents to state the reason for why they use public transport. In this case To save money, To protect the environment, as well as Habit, was the two significant parameters. The parameter To protect the environment was affected by the predictor Age, Gender and Device. Whereas Habit was affected by the predictor's Gender and Device. This means that if the respondents choose public transport to protect the environment, that is affected by their age, their gender and what device they use to watch streaming services.

Many of the respondents did not make use of public transport. Of the ones using public transport, it was both due to the possibility to **save money** as well as due to **habit**.

Outcome - Act_TurnOffLights

The next outcome, which concerns people turning off the lights saving money, protecting the environment and habit is the significant factors. What in turn affected the respondents to do so was the predictor's age, gender as well as hours per day.

Concerning turning off lights, the respondents on this question would do this **to protect the environment.**

Outcome - Act_Recycle

The next outcome which was analysed concerning actions was the reason for peoples recycling patterns. The significant factor, in this case, was To save money, To protect the environment, with no significant predictors.

Recycling was an action performed by more than 70% of the respondents to protect the environment.

Outcome - Act_Veggie
This outcome concerns the reason for the respondent to follow a vegetarian diet. In this case, none of the factors was significant.

An equal amount of respondents answered that following a vegetarian diet was due to **health** reasons as well as **to protect the environment**.

Outcome - Act_Computer
The next outcome analysed was the reason the respondents had for shutting off their computer during night time. To save money as well as I do not perform this activity was significant. In the case of not performing the activity Gender as well as the NrOfSub, a respondent had an impact on the outcome.

Turning the computer off was an action done due to people having a **habit**.

Outcome - Act_Showers
None of the factors was in this case significant. Meaning that there is nothing that can be said about this particular outcome with statistical significance.

Most of the respondents did not take as short showers as possible. The ones performing the activity did this **to protect the environment**.

Outcome - Act_SecondHand
The last action which has been considered is what the reason behind buying second hand was. When it comes to buying second hand, saving money as well as protecting the environment was significant factors. What affected protecting the environment was the gender as well as the number of subscriptions the respondent had.

Buying second hand was for those who performed the activity due to protecting the environment.

Outcome - MainResp
Whose main responsibility it is whether streaming services are sustainable is the next outcome from the survey. In this case, saving money, protecting the environment, health, as well as habit, were all significant factors affecting the outcome.

The responsibility of streaming services being sustainable was agreed on by more than 60% to lie with the streaming services.

Outcome - Motivate_Notif
Moving on to the next cluster of outcomes motivation was considered. The first outcome covered whether notifications informing the respondent of their daily CO2 emissions would motivate them to decrease their use of digital services. Here, the gender was significantly negative and thus, the higher category on the gender predictor is less likely to be motivated by notifications. Along with this predictor, age, active devices as well as hours per day had the same negative effect on the outcome but was not significant. Most respondents answered that they somewhat agree, that notifications would motivate them to decrease their use of digital services.

Whether it would be possible to be motivated by notifications was answered by the majority of the respondents, on a 7 point scale ranging from strongly disagree to strongly agree, as **somewhat agree**.

Outcome - Motivate_Information
The next outcome considered information regarding the implications of the use of digital services in relation to emissions. In this case, gender as well as hours per day were significant factors and affected the outcome negatively. The gender of the respondents as well as the more hours a day the respondent streamed content,

would decrease the trust they would have in information regarding the implications of the environmental impact of streaming services. In addition to this, age, as well as the number of active devices, does to have a negative impact on the outcome and affect it negatively just as the gender and the hours a day content is streamed. What affected the outcome positively slightly is the predictor DaysAWeek which then shows that the fewer days a week the respondent's stream content, the more they tend to feel that information about the implication of streaming services would motivate them to decrease their use of these.

If information regarding the implications of the use of digital services was considered by the bulk of the respondents as **somewhat agree** to be motivating.

Outcome - Motivate_SetGoals

The outcome concerning setting goals in relation to emission to motivate a decreased use of digital services was only affected negatively by how many hours a day the respondents use streaming services. If the respondents use streaming services a high number of hours a day, then they will be less likely to set goals to decrease their use. Another factor, which is not significant, but still affects the outcome negatively is the gender of the respondent where male/transmale respondents tend to feel that setting goals would motivate them less than what women/transwoman feel it would.

The outcome concerned as mentioned whether it would be motivating to set goals with the aim to decrease the use of digital services and by so hopefully as well decrease the impact on the environment, the most of the respondents were **neutral** as well as **somewhat agrees** to this outcome.

Outcome - Motivate_Nothing

The next outcome which was analysed was whether nothing could motivate to decrease the respondents use of digital services. In this particular case, how many days a week the respondent used streaming services had a negative impact on the outcome, meaning that if the respondent used the streaming service a high number of days every week it would mean that they strongly disagree with that there is nothing that could motivate them to decrease their actions, on the other hand, how many hours a day the respondent used the streaming services affected the outcome in a positive manner and that translated means that the fewer hours the respondent used the streaming services of their choice, the more sure they would be that nothing could motivate them to use streaming services less.

That nothing could motivate the respondents was established to be false. The mass of the respondents answered that they did **disagree** with the given statement. Meaning that the majority of the respondents were optimistic and thinking that there could be factors that could motivate them to decrease their impact through streaming services.

Outcome - Motivate_LoggingUse

Logging the use of digital services to see behaviour over time and get suggestions on how to improve was the next considered outcome. Here gender as well as how many hours a day the respondent used to stream content affect the outcome negatively, once again that means that male/transmale respondents do not think that logging their use would motivate them to decrease their use of digital services as much as female/transfemale respondents do. Another factor that is also affecting the outcome but is not significant is how many active devices the respondents have at

the same time, the more active devices the respondents have the less convinced they are that they will be motivated to decrease their use of streaming services by logging the use. The age of the respondent, the number of subscriptions as well as what device is used tend to have a positive impact on the outcome which means that younger respondents, respondents with fewer subscriptions as well as respondents using certain devices seem to be more motivated by logging their use of streaming content with the goal to decrease this action.

Somewhat agree was the most common answer among the respondents on the considered outcome. Logging the use could be an option to motivate a decreasing use of digital services.

Outcome - Motivate_Blocking

As a result of the next part of the analysis, the outcome concerning streaming services being blocked by an app after a certain amount of CO2 emission was considered. Here it seemed that several of the predictors were significant. Both age, gender, how many active devices the respondent keep, how many days a week the respondent stream media as well as how many hours a day streaming services are used have a negative impact on the outcome. This means that the older the respondent, the less they think they could be motivated by streaming services being blocked. The same tendency goes for gender, female/transfemale respondents are more likely to think that they could be motivated by streaming services being blocked. In addition, if the respondent has a higher number of active devices they are considered to be less motivated by streaming services being blocked for them. The days a week has the same effect on the outcome, more active devices seem to result in less motivation of blocking.

Whether blocking the digital services would be an option could be established to be negative, as the main part of the respondents on the question **strongly disagreed** that this would be a motivating option.

Outcome - Motivate_Impact

When looking at the question of the CO2 impact of video streaming related to other activities having an impact on CO2 the age seem to be significant as well as have a negative impact on the outcome. This means that the older people are, the less motivated they would be to see the impact of streaming services in relation to another activity that impacts the environment. Gender has the same negative impact, but is not significant, here the difference between the two genders are not that large, but still there is a tendency that female/transfemale respondents are more likely to be motivated by seeing the impact related to other types of impact on the environment. Not only gender has this effect on the outcome but also the number of subscriptions a respondent has. The amount of devices that the respondent has is also something that has a slight effect on whether they are motivated by seeing the impact in relation to other activities with environmental impact. What device that the respondents use to stream content on has an impact on the outcome too. Respondents using a computer, a smartphone or a tablet are all more motivated by seeing impacts related to each other than respondents streaming on their TV.

Somewhat agreeing was the most answered option among the respondents on the outcome in question. Meaning the seeing the impact of the digital streaming services in relation to other activities which impacts the environment can be estab-

lished to be somewhat useful to decrease the use of the streaming services.

Outcome - Motivate_Suggestions

Suggestions to use streaming services at another point in time, which could result in lower CO2 emission is only significantly impacted by gender. This factor is negative and once again as it is negative it shows that female/transfemale respondents are more likely to be motivated by the outcome which in this case is suggestions on watching streaming services at another point in time, rather than male/transmale respondents that do not seem to be as motivated by this. What also has a negative impact on this outcome is the number of subscriptions a respondent keep as well as how many active devices the respondent has. The more subscriptions and the more active devices, the fewer suggestions on watching at another point in time will motivate the respondent. What device the respondent uses is once again a positive impact on the outcome, and that means that respondents using the options of devices such as smartphones, tablet and computers are more motivated to get suggestions on watching at another point in time in comparison to respondents watching on their TV.

The majority of the respondents answered that they **agreed** that suggestions to watch streaming services at another point in time would motivate them to decrease their use.

D

Interviews

D.1 Interview questions

Table D.1: Interview questions

Question Nr	Question
Q1	To introduce the subject, I would like to start the conversation talking about recycling which is something people do without any thought today; how do you think can it be made natural to act sustainable concerning software?
Q2	When you recycle plastic bottles, at least in Sweden, you do it to get your money back and so you have a motivator for recycling. If this were to concern software, should people be motivated to act sustainable in relation to software (or should the motivation come from within)? If so, what do you think could be a good motivator?
Q3	If we move on to the information that possibly can be provided to the end-user for them to act more sustainable and be aware that software has an impact on the environment. How do you think that information about sustainability can be trustworthy, if communicated through an app?
Q4	How, with the use of an app, do you think that information about sustainability can be provided without the receivers of the information being overwhelmed? (In addition, how often do you think it would be suitable to provide the end-users with information?)
Q5	Moving on, information about the implications of streaming services and as well software can motivate users to decrease their use, what do you think would be the most important information to provide the users with?
Q6	In the previous conducted survey there was signs that age and gender was two factors showing a difference in how people felt about sustainability in terms of what would motivate them to decrease their use of software e.g. streaming services, how do you think that the less motivated group should/could be motivated?
Q7	What do you think could be included in the requirements process of software for it, the software, to be more sustainability concerned and create awareness of its

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Table D.1 – continued from previous page

Question Nr	Question
	environmental impact with the end-users?
Q8	How do you think that software can be designed, to make an impact on the users to decrease their use and thereby impact as well as understand that software too is something having an impact on the environment?
Q9	If there were to be a marking/carbon emission stamp on software, what criterion's do you think would be of importance to include, e.g., what should be measured to constitute and make the basis for this marking?
Q10	Blocking streaming services is something which has proven to not be a sufficient way to decrease the use of streaming services, is there any other solutions or alternatives that you think too is not sufficient for the purpose of decreasing the impact of software and if so, why?
Q11	Is there anything you would like to add on the subject?

E

Checklist

This appendix consist of the validation questions used for the validation of the checklist together with the finalised checklist.

E.1 Validation questions for checklist

In this section the questions used for the validation is included. The questions has previously been presented in Chapter 6.

- **Question 1:** Is anything on the checklist redundant? If so, why?
- **Question 2:** Is anything on the checklist missing? If so, what? And why?
- **Question 3:** What problems do you see that this checklist could contribute in solving/be a part in solving?
- **Question 4:** On a scale from 1 to 10, how useful do you think this checklist is? If below 5, how do you think it could be improved?

E.2 Finalised checklist

Below, the finalised checklist is presented. The below is the same version of the checklist as presented in Chapter 6.

Checklist

Do:

- **Information:**
  - Provide information on how to improve/decrease impact – i.e., recommended course of action *(survey, interviews)*:
    - Provide the users with information on the impact of the current activity *(survey, interviews)*:
      - Comparison with other well know actions, such as keeping a light bulb on *(survey, interviews)*
      - Comparison with other people in the community/friends/-family *(literature, interviews)*

        * Suggest the users to only use, for instance streaming applications, when really needed/wanted with the aim to make them reflect on their behaviour *(interviews)*
        * Suggest the user to watch at another point in time *(survey, interviews):*
            · o When the electricity is cheaper *(literature, interviews)*
            · o When the electricity is greener *(literature, interviews)*
        * Inform the user prior to their action of choice what the impact is. For instance, what impact this movie has in comparison to something else *(survey, interviews)*
        * Suggest the user to not keep things running in the background when not using it *(literature, interviews)*
        * Suggest the user to download during night *(interviews)*
    - Make the incentive concerning software use positive, rather than negative *(survey, interviews)*
    - Make the feedback based on the user's individual motivators (*survey, interviews)*
        * Suggestions on what has been used previously and worked for others:
            · Motivation based on earning money *(interviews)*
            · Motivation based on planting tree's/helping the environment *(interviews)*
            · Motivation based on seeing the action in the community *(literature, interviews)*
            · Motivation based on earning points/rewards *(interviews)*
        * Use colour coding for feedbacking the users, with the appropriate colours for the context *(interviews)*

- **Settings/Default settings:**
    - Set the default settings to be the ones with the lowest environmental impact. For instance, set the default settings for streaming services to be lowest quality *(literature, interviews)*

Consider:

- **Customisation:**
    - Make it possible for the users to customise how they see the information concerning impact on the environment *(interviews)*
- **Information:**
    - Type of information:

    - Suggest the user to download frequently used content *(interviews)*
    - Suggest the user to consider their behaviour when having software running on more than one screen *(interviews)*
  - Design the software to become a coach rather than telling the user what to do *(interviews)*

- **Settings:**
  - Suggest the users to set a daily limit for themselves, which cannot be changed immediately *(interviews)*
    - Possibility to, in relation to this suggest another action/activity *(survey, interviews)*
    - Possibility to, in relation to this foster learning and provide information concerning the impact *(survey, interviews)*
  - Suggest the users to put in reminders for when they want to be interrupted in their use of software/streaming services *(interviews)*
    - Possibility to question the user if the current activity is how they want to spend their time *(interviews)*
  - Suggest the users to set goals to decrease their use of digital services *(survey)*
  - Make updates of the software to be scheduled during night time

- **Motivation:**
  - Make it possible for the user to log their use of the software in question *(survey)*

Don't:

- **Information:**
  - Do not tell the user what to do or not to do *(literature, interviews)*
  - Do not present CO2/kilowatt hours without making a comparison with other well-known activities (such as light bulb, driving a car etc.). *(interviews)*
  - Do not provide the user with negative feedback about their habits/actions *(literature, interviews)*

- **Motivation:**
  - Blocking:
    - Do not block the users from the software *(survey, interviews)*
    - Do not decide on a certain number of hours the users are able to use the app for *(interviews)*