UMEÅ UNIVERSITY

Investigating Attitudes of A Persuasive Eco-feedback Design for Digital Tasks

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Abstract

Sustainable development as a research topic is becoming more prevalent across different fields. From a computer science perspective sustainability can incorporate anything from how to develop low-resource-use algorithms to human-computer-interaction oriented applications for behavior change. Eco-feedback systems is the collective term for solutions that can give consumers feedback regarding the environmental impact from their product use. This thesis explores how Persuasive Systems Design (PSD) and eco-feedback can be merged for a digital context, i.e. during the use of computers and software. Two design prototypes were developed where one was considered neutral and the other had PSD applied. As one aim of the thesis was to investigate how different designs affect people and if demographic and personal differences have any effect on the result, these designs were distributed in different questionnaires to measure the persuasive potential and user opinions. Further on, the PSD prototype was used in a usability test and short interview with the intention to gather more opinions in addition to the survey. The results show no significant difference in the response towards the neutral against the persuasive systems design. In total the perceived ease of use and usability score high, meaning the participants regard the design to be easy to use. The response differs greatly when it comes to usefulness and intention to use a similar system in the future. The results of this thesis give an indication of where the user interest is currently at. However, further evaluation and more research is necessary to develop stronger conclusions regarding how different users perceive eco-feedback systems.

Keywords: Sustainable development, Eco-Feedback, Persuasive Systems Design, Human-Computer-Interaction, Monitor systems, Environmental friendly, Persuasive Potential Questionnaire, UTAUT, UX Design.

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1 Introduction

The urgency to take action in order to curb disastrous impacts of climate change has put sustainability goals on the agenda in many industries. The software industry is no exception. In recent years, Human Computer Interaction (HCI) designers have started to address sustainability as a research topic. Much of the existing research revolves around persuasive technology applications aimed to promote pro-environmental behavior in users [1, 2]. Another prominent topic is that of *Eco-feedback design*, a strategy that aims to present users with information regarding e.g., energy use in the household or environmental impact caused by the use of a product [3]. The intention is that by displaying how much resources are being consumed by a certain task and making the users aware of it, they are to adjust their behaviors to benefit the environment [3]. As of now, most of the research in the eco-feedback design field affects residential resource and energy use. These areas include electricity, materials, transportation and water usage[4].

Meanwhile, demands for data has seen a steady growth in the last decade and according to the International Energy Agency (IEA) internet traffic surged by more than 40% in 2020 alone [5]. As a result of Covid-19 pandemic restrictions, video streaming and conferencing along with online gaming and social networking has seen new levels. However, this was a trend even before the pandemic effects added on to it. In Sweden, 86% of the internet users above 12 years old streamed video online in the year 2019, compared to 27% in 2007 [6]. Both the number of internet users worldwide and the number of connected devices are growing steadily which puts increasing demand on digital services and their reliance. This demand has spurred increased hardware efficiency in data centres [7] together with a focus among the biggest actors in the tech industry to purchase renewable energy [8] or relocate servers to a favorable environment [9].

Since data demands grow and different reports [9] suggest that the "cloud" is consuming increasing amounts of electricity, an interest to research user attitudes towards decreasing their "digital footprint" emerged. As stated before, HCI Research has been focusing on pro-environmental behavior in general. By utilizing *Persuasive Systems Design* this project aims to develop new concepts surrounding how persuasive design can be applied to **software use** and investigate the user acceptance of such a design. Persuasive design is applied as a means to make a possibly less enjoyable experience of limiting one's normal internet habits, into one that is more pleasurable and motivated. A prototype of a persuasive eco-feedback solution is proposed and tested in this thesis, by surveying individuals' combination of perceptions and impressions regarding the system.

2 Objectives

The purpose of this thesis is to explore how persuasive design can be applied to create an eco-feedback prototype aimed for digital habits and to research the users perceived persuasiveness and attitudes toward this system. Further on, the objective is to find out if persuasive design and awareness of sustainability issues affects the user response. Persuasive design in the field of behavior change for software sustainability has not received much attention in previous literature, which is why the area is of particular interest. Meeting the goals of the objective is achieved through the aim of answering the following research questions.

The researched target group are Swedish people who do most of their daily work at a computer, i.e. students or office workers. However, it is not an enforced condition to belong to this group in order to participate in the study.

2.1 Research questions

1 How can persuasive systems design be applied to an eco-feedback system designed for digital tasks?

2 What is a users perception of a system designed to give them eco-feedback regarding digital tasks?

   (a) How does applying persuasive system design affect user response towards such a system?

   (b) How do users' varying degree of awareness for environmental issues affect their response towards such a system?

   (c) How are the users' response influenced by different demographic data such as age and gender?

2.2 Hypotheses

Persuasive design hypothesis.

H_0: There is no difference in how people accept the system in relation to persuasiveness.

H_1: There is a significant difference in how people accept the system in relation to persuasiveness.

Sustainability awareness hypothesis.

H_0: There is no difference in the users' attitude to act sustainably in the digital space in relation to the degree to which they act sustainably in their daily lives.

H_1: There is a significant difference in the users' attitude to act sustainably in the digital space in relation to the degree to which they act sustainably in their daily lives.

3 Background

The broad term sustainability covers several different meanings. The following chapter attempts to establish a foundation regarding sustainability definitions and further explore sustainability in the software industry. The chapter introduces the fundamentals of the concept of **Persuasive Design**. Finally, a short introduction to Omegapoint and their view on sustainability is included.

3.1 Defining sustainability

From the UN report of the World Commission on Environment and Development the following famous quote is derived: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [10]. This definition has laid the foundation for *The 2030 Agenda for Sustainable Development* that was adopted by all United Nations Member States in 2015. At the core of the agenda are the 17 Sustainable Development Goals (SDG) defined to contribute to adoption of initiatives that encourage an economical, environmental and socially sustainable future.

Goal number 12: *Responsible consumption and production* is of relevance to this thesis with focus on sustainable consumption. Especially the target goal of 12.8: *By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.* Goal number 9: *Industry, innovation and infrastructure* mentions the need for inclusive and sustainable industrial development, which includes a need for technological solutions for an industry in line with environmental goals. These technological solutions on their own can also achieve environmental goals and focus on energy efficiency for example. There are several aspects of the goals that can relate to the dimensions of software sustainability in one way or another [11].

3.1.1 Sustainable behavior

Sustainable behavior can include all kinds of behavior that ensure an individual's well-being, e.g. getting enough rest each week. For the sake of this project however, sustainable behavior is defined as "behavior that tries to minimize potential harmful effects on the environment" [12], what can also be called pro-environmental behavior. For a behavior change to occur from unsustainable to pro-environmental there are steps defined as the following:

1. Recognition of behaviors to be modified
2. Investigation of influencing aspects
3. Creation and implementation of interventions

4. Assessment of outcomes of interventions

Information systems can contribute at the third step *Creation and implementation of interventions* by striving to benefit sustainable user behavior. It is important however to note that pro-environmental behavior in general is not considered to be pleasant, because it is associated with inconveniences like restrictions or discomfort [12]. There lies a big challenge in getting people to be motivated and excited about saving energy and taking part in other green initiatives [13]. At the same time, other research [14] conclude that acting pro-environmentally can make people feel good. Venhoeven et. al describe how participants of their study [14] had a more positive self-image when voluntarily engaging in environmentally-friendly behavior, compared to when having constraints forced upon them. The importance is in convincing people to go green because of the personal gain or fun it can mean, rather than motivation based upon guilt and shame [13].

For this thesis in particular, it is of particular interest to see how users respond to a persuasive system designed to monitor their energy consumption and act environmentally-friendly in the digital space.

3.1.2 Software sustainability

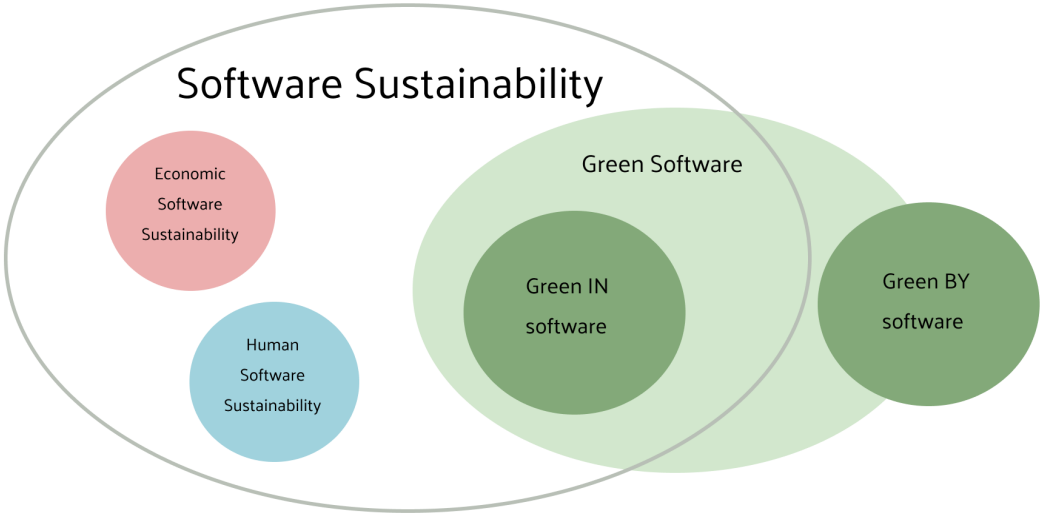


Figure 1: Overview of software sustainability.
Inspired by C.Calero and M.Piattini. [15]

There are many levels to sustainability in the field of software. As seen in Figure 1, three categories similar to the ones mentioned in relation to the SDG can be attributed to Software Sustainability.

- *Human Software Sustainability* - "how software development and maintenance affect the sociological and psychological aspects of the software development

community and its individuals. This encompasses topics such as: Labor rights, psychological health, social support, social equity and livability." [15].

- *Economic Software Sustainability* - "how the software lifecycle processes protect stakeholders' investments, ensure benefits, reduce risks, and maintain assets."[15].

Achieving a sustainable software organization relies on, among other issues, the sustainability of previously mentioned categories. This thesis however, revolves around a third category, the **Environmental Sustainability** of software. Environmental sustainability relates to how software product development, maintenance and use affect the environment, primarily through energy use. There are many different definitions on environmental or green IT, especially considering that the discipline is still in its infancy. One distinction is that of green *in* software or green *by* software [15]. This separation refers to the fact that software has the potential to be sustainable through: (1) sustainable *code*, agnostic of its purpose or (2) the software's *purpose* is to support sustainable goals [16]. With focus on environmental sustainability, the former one could imply that the code is optimized to reduce energy consumption, while the latter might take the form of a smartphone application to help citizens travel more sustainably.

3.1.3 Sustainable human computer interaction

Sustainable human computer interaction (SCHI) can be discerned as trying to achieve sustainability *by* software with an emphasis on the end user. This thesis falls somewhere in between sustainable software research and SCHI by trying to combine a focus on the end user with the environmental impact of software.

3.2 The impact of ICT on the environment

Information and communication technology (ICT) is hugely relevant as the world is becoming increasingly connected and digitalized. The IEA [17] summarizes ICT by the following three segments.

- Data centres - facilities that house connected computer servers that store, process and distribute enormous amounts of data.
- Data transmission networks - transmits data between two or more connected devices.
- Connected devices - "end" devices, consumer electronics, appliances and similar devices with internet connectivity or other means of communication.

Similar to other industries, ICT has a complex effect on the environment. Some scholars argue that the net impact of ICT on the environment is ambiguous, since on one hand, the production, use and disposal of the three categories previously mentioned obviously has a negative environmental impact. On the other hand, ICT can reduce emissions and resource use by e.g. implementing smarter strategies for industrial processes or for the electrical grid [18].

Malmodin et. al [19] estimate in their research that the ICT sector accounts for 1.1-1.4% of the global electricity use. Projecting the emissions of ICT sector is difficult due to the impact of several different factors. Where in the world the energy is being produced and used to sustain the centres greatly impacts the carbon footprint. What can be said for certain is that the impact for each gigabyte of data is steadily decreasing, a trend that is seen due to more efficient networks and energy consumption. However, with the ever-growing increase of data traffic, driven largely by increased consumption of videos, it is of interest to research the user attitudes towards changing habits.

3.3 Persuasive Technology

The study of persuasion on its own has a long history. In ancient Greece thinkers were involved in the topic of *rhetoric*, basically how to persuade and influence listeners through their speeches. The concept of "Persuasive Technology" first emerged in behavior scientist B.J Fogg's book *Persuasive Technology: Using Computers to Change What We Think and Do* [20] as he translated these ancient methods to the computerized world. Fogg defines a Persuasive Technology tool as " an interactive product designed to change attitudes or behaviors, or both, by making a desired outcome easier to achieve". Persuasive technologies can affect users' attitudes and actions by practicing various strategies to attain a desired behavioral change. Applications of persuasive technologies was found to have great potential for users to adopt green information systems in favor of more sustainable habits [12]. There is also the important discussion about whether persuasive tools are unethical by design. Some argue that attempting to change someone's behaviors must be unethical or at least questionable [20], as people question their right to tell someone how to live their life. Others consider good-natured persuasive technology as part of the foundation of ethical leadership [20].

3.4 Omegapoint

Omegapoint is an IT consultant firm with a specialization in secure software development. In recent years they have had a focus on social sustainability through engaging young children and especially girls in technology. Recently they have started to see the importance of shifting to a more holistic view on sustainability and therein lays the environmental aspect. The firm has started to establish a better approach for working towards sustainability on the broader scale and many of the consultants share an interest in the topic. For this thesis the company has helped by providing support in the form of supervision from two IT consultants and other consultants for user testing.

4 Theoretical framework

The theoretical framework establishes essential theory and strategies for development and evaluation during the project. For the design of a persuasive eco-feedback system there are chapters on **Prototyping**, **A/B testing**, **Usability heuristics**, **Persuasive Systems Design** and **Eco-feedback Design**. For the purpose of evaluating a user response the **Unified Theory of Acceptance and Use of Technology** (UTAUT) model and **Persuasive Potential Questionnaire** (PPQ) are introduced.

4.1 Prototyping

In the design process there are many principles and tools to consider for testing and evaluating the user experience. Prototyping of an user interface can be an effective, inexpensive way to determine to test whether the solution actually works for those intended to use it. When it comes to prototyping one can talk about a high-fidelity (hi-fi) or a low-fidelity (lo-fi) prototype. The hi-fi prototypes are usually interactive, made in a prototyping tool and appear like a live system with the content that the final product would have [21]. The lo-fi prototype is usually not interactive and requires a person to display content in real time for the user. The lo-fi prototype is also simpler when it comes to appearance and might consist of black-and-white sketches or wireframes [21]. Depending on what the test is attempting to achieve, different types of prototypes might have different advantages and disadvantages. A hi-fi prototype might have the benefit of freeing up resources so a designer can focus on observing the test instead of keeping up to make the prototype work. They can also reveal problems regarding specific user interface components or workflow. A lo-fi prototype on the other hand takes less time to prepare and the fact that the design looks incomplete might subject the users to less pressure. This can invite the users to speak more freely and possibly give more negative reactions compared to if the prototype looks more polished [21]. Another term for prototype that is used interchangeably in this thesis is “mock-up”.

4.2 A/B testing

A/B testing is the name of a widely used approach for testing and comparing two alternative designs [22]. It is most commonly used in active web sites or applications, by configuring a server to randomly select between two alternatives, the “A” or “B” design to present to the user. Data is then collected on how well the design performs depending on some specific measurements such as where the user clicks or how fast they can perform their tasks. For this thesis a variant of A/B testing is applied by randomly distributing two alternate designs to different participants of the study and measuring their opinions.

4.3 Nielsen's 10 usability heuristics

Nielsen, researcher in human-computer-interaction, developed 10 usability principles that are established among many interaction designers today [23]. These are called heuristics because of their broad, non-specific approach to how interfaces should be designed. The 10 usability heuristics are in short:

1. Visibility of system status - The system should aim to always keep users informed about the current system status, through appropriate feedback at the right time.
2. Match between system and the real world - The system should aim to keep a language that is natural and understandable to the user without having to look up definitions.
3. User control and freedom - Users should be encouraged to explore the system without being afraid of getting stuck or feeling frustrated. By providing easy ways to back out of an action it fosters the feeling of being in control and free.
4. Consistency and standards - The system should aim to be consistent both within the product and possibly within a family of similar products. To what extent is available it should try to follow industry standards to avoid having to force the users to learn something new.
5. Error prevention - Carefully craft the system so that errors are minimized, this could be done by eliminating error-prone conditions or presenting users with confirmation options before they commit to an action.
6. Recognition rather than recall - The system should strive to minimize the load it puts on the user by making elements and actions visible. Any information needed to use the interface, e.g. menus, should be easily retrievable.
7. Flexibility and efficiency of use - The system should strive to achieve a balance between being flexible for the expert user but still cater to the novice ones. Personalizing, short-cuts and tailoring content could be good examples of such flexibility.
8. Aesthetic and minimalist design - Keep the visible system elements relevant, avoid distracting elements and focus on the essentials. The available features should aim to support the user's primary goals with the system.
9. Help users recognize, diagnose, and recover from errors - Express error messages in a clear, understandable way to the user.
10. Help and documentation - Aim for a system that does need further explanation or help to get started, but provide a good documentation and help for the times when it is needed. The documentation should be easy to find and focus on what the user want to achieve.

4.4 Persuasive Systems Design

B.J. Fogg first defined the expression of **Persuasive** technology as "any interactive computing system designed to change people's attitudes or behaviors" [20]. Fogg further defined seven tools for persuasive technology:

1. Reduction - This tool works in a persuasive way by simplifying a complex task for the user. Utilizing this process can help a user increase their self-efficacy and develop a more positive attitude about the behavior.

2. Tunneling - This tool acts persuasive by taking users through a predetermined number of steps in order to complete a task. This approach controls what the user goes through and experiences, which can be an effective way to persuade them or get them to stick to a process.

3. Tailoring - A tailoring technology acts persuasive by giving users a personal and relevant experience. By eliminating large volumes of generic data and rather only keeping what is relevant for the user in a decision, form etc.

4. Suggestion - Providing a suggestion at the right time can have great persuasive power. An example would be to prompt a user to back-up their photos when closing a photography application as this might be a good time to remind them to take such an action.

5. Self-monitoring - This technology works by allowing people to monitor themselves in order to spark a change in an attitude or behavior. By providing users with means to self-monitor and track their performance or status they can become more motivated to achieve goals.

6. Surveillance - Applying surveillance is another common persuasive technology. By monitoring their behavior people can be more likely to act in a certain way, as in when people know they're being watched, they behave differently.

7. Conditioning - This technology revolves around reinforcing target behaviors by usually providing some kind of positive feedback to the user after behaving in a desirable way.

Oinas-Kukkonen and Harjumaa [24] define **Persuasive systems** as "computerized software or information systems designed to reinforce, change or shape attitudes or behaviors, or both, without using coercion or deception". Persuasive systems usually have intentions of the creators to nudge the user in a certain direction. The Persuasive Systems Design (PSD) is a framework suggested by Harjumaa and Oinas-Kukkonen that builds upon the theoretical framework by Fogg but additionally introduces new definitions and techniques for practically developing a persuasive system. PSD revolves around three steps (see Figure 2) for developing and evaluating persuasive systems [24].

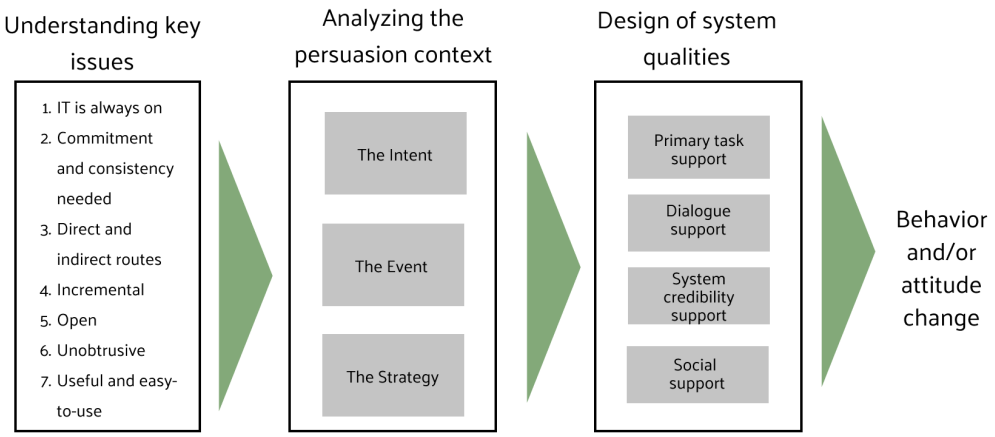


Figure 2: 3 steps for persuasive systems design.
Inspired from Harjumaa and Oinas-Kukkonen

4.4.1 Understanding key issues

The key issues behind persuasive systems that Harjumaa and Oinas-Kukkonen present are summarized in seven principles, see table 1.

Table 1 Issues behind Persuasive Systems

1.	Information technology is never neutral.
2.	People like their views about the world to be organized and consistent.
3.	Direct and indirect routes are key persuasion strategies.
4.	Persuasion is often incremental.
5.	Persuasion through persuasive systems should always be open.
6.	Persuasive systems should aim at unobtrusiveness.
7.	Persuasive systems should aim at being both useful and easy to use.

4.4.2 Analyzing the persuasion context

The persuasion context needs to be carefully analyzed in order to effectively persuade. This analysis includes awareness of the intent of the persuasion, the persuasion event and defining the strategies in use for delivering the persuasion message [24].

4.4.3 Design of system features

The PSD [24] adds on to Fogg's seven tools by categorizing persuasive system principles into primary task support, dialogue support, system credibility support and social support. This third step of the PSD is central to this study as it captures how to go about with the actually design of a persuasive system.

Primary task support is the category of principles that strive to enable the carrying out of the user's primary task, these are most similar to Fogg's seven tools.

Dialogue support captures the design principles surrounding computer-human feedback that help users achieve their target behavior. These include praise, rewards and reminders among others.
System credibility support describes how to design the system to make it more credible as the authors argue credibility enhances the persuasiveness of it.
Social support describes the principles for designing a system that motivates users by utilizing social influence.

Persuasive systems design is of relevance to this study by investigating whether it can leverage the user perception of an eco-feedback design system.

4.5 Eco-feedback design

Eco-feedback is a "design strategy that presents users with information about resource consumption or environmental impact caused by product use" [3]. There is an assumption that better information gives people the means to act in more environmentally friendly ways. However, various studies [25] of purely informational programs have shown that this usually results in only a marginal effect to which they change behaviors. To maximize the potential of information there are some important aspects as to how and when to present it. It should be easy to trust and easy to understand, presented in a way that both attracts attention and is memorable, and disclosed as close as possible (in both time and location) to the choice of relevance [25].

Traditional eco-design techniques focus on reducing resource usage during a manufacturing process. Meanwhile, people's environmental attitudes can be influenced by public campaigns or education programs. Eco-feedback products merge these two methods by trying to influence the user to make green decisions while at the same time reducing the product's environmental impact during the use phase [3].

Figure 3: The EU Commission's official marking to be used on single use products containing plastics from July 3rd 2021.

A typical example of eco-feedback design is usually embedded in a Home Energy Management System (HEMS) that delivers various reports and analyses for energy usage to the household [1]. Another example is the official symbol used by the European Union Commission for single use plastics (see Figure 3), designed to prevent improper disposal of these products.

Eco-feedback design can be viewed as an extension of persuasive technology [25], but it does not inherently have to be persuasive. A HEMS can merely present data for

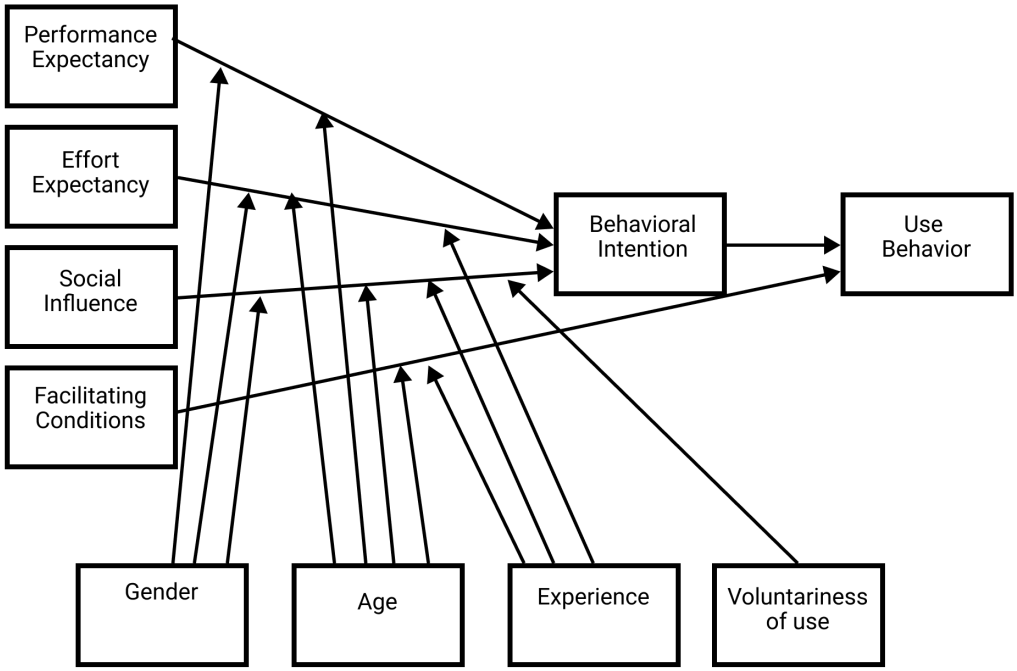


Figure 4: UTAUT model (inspired by Venkatesh et al [26])

the user to raise awareness and leave it up to the user to decide what to do with the information. However, data presentation is close to *monitoring* which Harjumaa and Oinas-Kukkonen include as a persuasive tool.

For this project it is of relevance to discover how eco-feedback design combined with PSD can be applied at a prototyping stage and yield different reactions from the study participants.

4.6 Overview of the UTAUT model

The Unified Theory of Acceptance and Use of Technology (UTAUT) model is a unified model that comes from evaluating and comparing eight different existing models in the field of information technology acceptance [26]. Applying this theoretical model of adoption to this project could help measure different variables' effect on the behavioral intention, where especially age and gender are of interest for the results. A visualisation of the original UTAUT model can be viewed in Figure 4.

4.7 Overview of Persuasive Potential Questionnaire

The Persuasive Potential Questionnaire (PPQ) [27] was developed with the intent of being able to measure potential persuasive effect of prototypes that are not fully functional. PPQ in its original form consists of three dimensions and 15 items. The dimensions are Susceptibility to Persuasion (SP), General Persuasive Potential of the System (GPP), and Individual Persuasive Potential of the System (IPP). In this project it is of interest to extend the items of PPQ to a new questionnaire that is combined with some UTAUT items. In the end, the PPQ items will be the basis for evaluation on how persuasive the study participants found the developed prototype

to be. The original PPQ items can be found in Appendix A.1.

5 Methods and Approach

The methodology of this project is based upon Design Science Research (DSR) [28]. This iterative process is meant to be repeated in a cycle until desirable results are reached. See Figure 5 for an illustration of the DSR process.

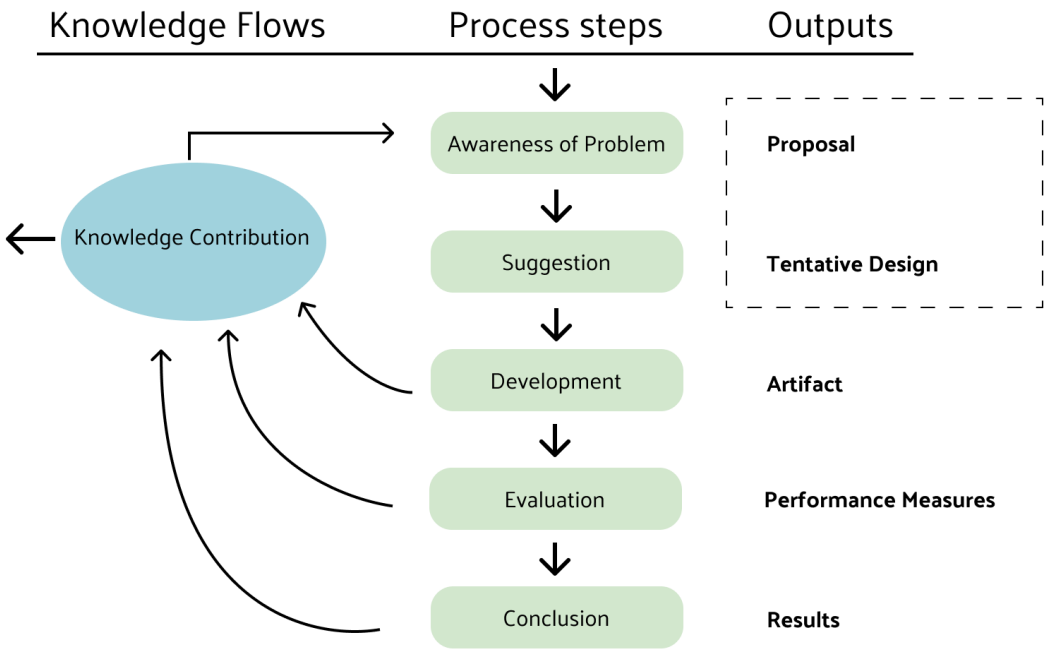


Figure 5: Design Science Research Process Model. Adapted from Vaishnavi, V. and Kuechler, W.

Awareness of Problem

The first step of the DSR process is to gather awareness of the research problem. Translating this phase to this thesis project was doing the initial research surrounding the topic and establishing the motivation behind the objective and proposed research questions. Further on, a short investigation of whether any similar tools are available today was also conducted.

Suggestion

The Suggestion step ties closely together with the previous step. This is the phase where new functionality is envisioned based on the problem awareness. For this

thesis, this step can be boiled down to brainstorming a solution and coming up with an initial idea for a tool that can be evolved and tested in the following phases.

Development

Some variants of the DSR model [29] combine the Suggestion and Development phase into a *Design & Development* phase, and that is the structure followed for this thesis project. The Development step takes the *Tentative Design* further in development and implementation. This step is of high importance in constructing a feasible prototype that fits the aims of the research and can be properly evaluated in the next step. The output *Artifact* could be seen as the proposed eco-feedback design.

Evaluation

Once the Artifact is constructed it should be evaluated according to criteria that were developed in the *Awareness of Problem* phase. For this study it corresponds to experimental evaluation by running a survey and a user test where the artifact is tested on potential users on perceived persuasiveness. Usually, the results from the evaluation phase and any additional information gathered in the steps performed before are fed back to another round of the cycle.

Conclusion

This phase could be the end of one research cycle or the end of a more complete research effort. If it is the end of a research effort then the results should be satisfying the original aims, with reservations for arriving at some loose ends that need further improvement in subsequent projects.

5.1 Literature review

The first phase of the study was done by conducting a literature review. Sources used were mainly collected through databases available through the Umeå University library. The goal of the study was to gather information regarding the topics of "software sustainability", "persuasive systems design", "eco-feedback design" and different models for measuring user acceptance or perceived persuasiveness (UTAUT, PPQ). The knowledge collected was used as a foundation for designing mock-ups and a questionnaire that could answer the research questions.

5.2 Experiment design

The project applied a mixed methods research in two phases, with the main phase being a questionnaire and the second phase being in-person usability tests together with interviews. Both phases revolved around the design proposal that was developed through a theory-driven design approach. The main phase was conducted as an A/B test where half of the respondents saw a neutral design and the other half saw a persuasive design. The intention was that by employing an A/B test, the test results could reveal whether the persuasive design has an effect on the user response.

5.3 Ethics

All participants of both the questionnaire and user test were made aware of their rights through a formal introduction. In the questionnaire this took the form of an introductory written section, see the first page of Appendix B.1. For the user test the participant was personally informed of their rights during the introduction to the study. To comply with GDPR, the participant had to sign an agreement for the handling of their personal data for the duration of the thesis.

5.4 Participants

Participants for the questionnaire survey were mainly gathered through distributing the survey in Facebook groups (Teknikkvinnor), Omegapoint internal communication channels (Slack) and various social media (Swedish page of Reddit). Participants for the user test were gathered through Omegapoint and acquaintances. They were selected on the criteria of working with computers most of the day or being students.

5.5 Pilot study

A first draft of the questionnaire was tested on 6 people, most of them with a background in human computer interaction or computing science. These participants were asked to specifically review the content, report how long it took to complete and give any feedback on how it was structured. The received criticism was on questions that were difficult to understand and typing mistakes. Corrections and some restructuring of the form was made for the final version.

5.6 Questionnaire design

In order to understand the participants acceptance of eco-feedback surrounding digital tasks, parts of the UTAUT model were modified (i.e. only capturing variables affecting behavioral intention) and adopted to a PPQ questionnaire. A dimension of climate change awareness was added to the questionnaire to gather that aspect, as seen in Table 2. In the end, the final model adapted to this study is similar to the one displayed in Figure 6.

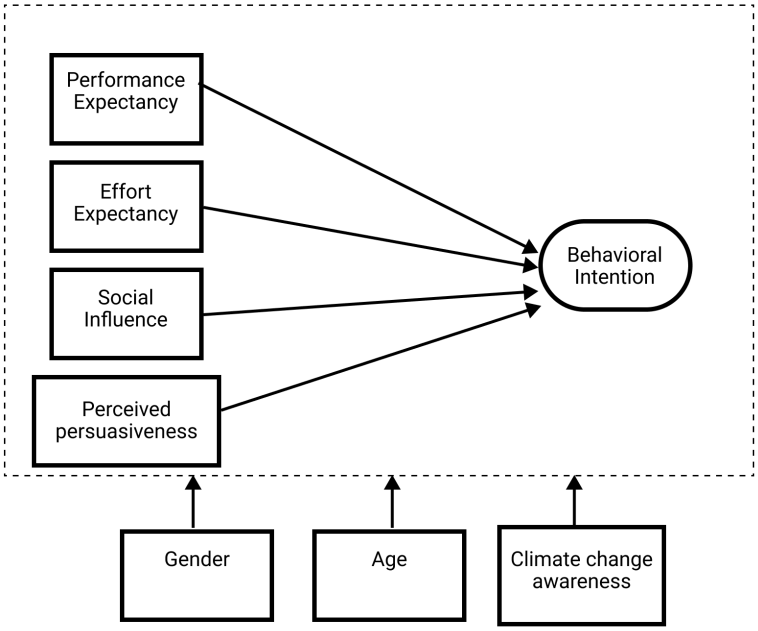


Figure 6: Modified UTAUT model

Table 2 About participant

Measurement factor	**Coding**	**Item**	**Ref.**
Susceptibility to Persuasion	SP_1	What others say brings me to rethink my attitude towards it	PPQ[27]
	SP_2	I do not want to be influenced by others	
	SP_3	Even my friends have difficulties to influence me	
	SP_4	No one can tell me what to do	
Climate change consciousness	CCC_1	I am aware of climate change	CCM[30]
	CCC_2	Current global warming is a natural, not man made phenomenon	
	CCC_3	I'm willing to pay a certain amount to reduce the impact of climate change	
	CCC_4	I recycle most of my household garbage	
	CCC_5	I am concerned about the impact of climate change	

In Table 2 the selected items SP1-SP4 asked the respondents to rate whether they agreed or disagreed with statements regarding susceptibility to persuasion. The items

CCC1-CCC5 asked the respondent to rate how they agree towards climate change and acting environmentally friendly. The items of Table 3 ask the participant to rate each item on a 5-graded Likert scale (1 = Completely disagree; 5 = Completely agree). The goal with this section was to measure the participants' opinions of the usefulness of the system and its potential for them. Lastly, the items of Table 4 gathered the participant's perceived persuasiveness of the system, by providing a 5-graded Likert scale (1 = Completely disagree; 5 = Completely agree), for each of the items.

Table 3 Attitudes towards the prototype

Measurement factor	**Coding**	**Item**	**Ref.**
Performance Expectancy	PE_1	The system would be useful in my daily desktop usage	UTAUT[26]
	PE_2	Using the system could help me get information about the energy use from daily desktop usage	
Effort Expectancy	EE_1	Using the system seems easy to learn	
	EE_2	I think it seems clear and understandable to use the system	
Social Influence	SI_1	If people around me would use the system (or similar), I would also try it	
	SI_2	If my workplace recommends us to use the system (or similar) I would use it	
Behavior intention	BI_1	I would use this system regularly	

Table 4 Perceived persuasiveness items for questionnaire

Measurement factor	Coding	Item	Ref.
General Persuasive Potential	GPP_1	The system makes people change their behavior	PPQ[27]
	GPP_2	The system has the potential to influence people	
Individual Persuasive Potential	IPP_1	This system can help me change my attitude	
	IPP_2	I would use this system as often as possible	
	IPP_3	I think that I would use such a system in the future	
	IPP_4	I will use this system regularly	
	IPP_5	This system does not cause a change in behavior with me	
	IPP_6	This system causes me to do some things differently (potentially)	
	IPP_7	With the help of the system, I will behave differently in the future	

5.6.1 Questionnaire distribution

The research question required distributing one design for half of the respondents and another design for the second half for the A/B test. To achieve this, two unique questionnaires were created with Google Forms with both of them including the items from Table 2, Table 3 and Table 4. The difference between them was the section of screenshots from the Figma prototype that were different depending on whether it was the persuasive or neutral design. See Appendix B.1 for the "neutral" questionnaire.

5.6.2 Survey distribution tool

To ensure an even distribution of the two questionnaires, a lightweight website hosted on Google Firebase was developed. The website included a short introduction to the survey and a button that redirected the user to a Google Forms page (see Appendix A.3 for images of the page). The form that was opened depended on a number that increased by one each time a person clicked the button. An even number opened the non-PSD questionnaire and uneven number the PSD version. This number was stored in Google's Firebase Realtime database, a noSQL cloud database. It was then fetched from the database whenever a user clicked on the button and a function determined where the user was directed.

The website also served as a means to block potential survey participants that accessed the site from a mobile display. The intention behind that was to rule out

that participants used too small devices that would render the prototype text illegible, since it might skew the results or decrease the completion rate.

5.7 User test

The second phase of the study was designed as a user test in a simulated desktop environment. The PSD was tested in this phase, since a response to research question (a) was deemed to be achieved through the survey. This phase aimed to collect further qualitative information around different user attitudes. In addition to that the test also tried to gauge whether the proposed design was understandable and useful to the user.

The test included the following tasks the participant was to complete:

- Open the EcoMeter application and go through the start screen
- Leave it open by minimizing the window
- Open a web browser - navigate to an email page
- Open a video call
- Activate pop-ups in EcoMeter
- Return to browser, navigate to a streaming service (Youtube) and press play on a video
- Return to video call
- Watch statistics from last week
- Close EcoMeter

The participants were asked to perform the tasks on a Surface Laptop (i5 8GB 256GB 2017 model) in the mock-up system. The testing took place in a secluded, quiet area such as an office or group room at Umeå University. The procedure was recorded (given that permission was given during the introduction) through the screen-recording software available in Xbox Game Bar. The recording captured both how the participant interacted with the testing environment and their opinions on its usefulness during and after the test.

5.7.1 Interview

When the tasks were completed, the test was followed up with a brief structured interview, see Appendix A.2 for interview questions. The idea was that without the interview the test would merely be a usability test and by adding the interview the test could provide insights that better align with the research questions. The main goal with the questions was to gather more feedback and thoughts surrounding the use of the prototype and the concept as a whole.

A first iteration of user testing was conducted to measure how well the tasks and questions worked. Timing the test was also important to gather an approximation of how much time the test conductor should ask from upcoming participants.

5.8 Data evaluation

The quantitative data gathered in the questionnaire was analyzed through t-test and Pearson's r to gather if correlations could be found between various variables. These analyses and data visualization was done in RStudio using the R software environment. Qualitative data was analyzed by transcribing the data, coding the input and establishing common theme, a method a.k.a. thematic analysis. The responses were thematically coded using NVivo software and FigJam (Whiteboard tool for Figma).

6 Design and Development of Requirements

This chapter describes theory-driven design process of establishing requirements and creating mock-ups of an eco-feedback system. The first section describes the pre-study work that was completed before the design implementation, i.e. the development of requirements from brainstorming and reviewing similar systems. Finally, the resulting requirements and a brief explanation of how the practical design implementation was done are introduced.

6.1 Developing requirements

Since the prototype was developed from scratch, some sort of theory for how to construct it needed to be established. This process is described further in this section.

The foundational work was achieved through a rather informal process of brainstorming off of ideas that came up during the research phase. The most prominent idea was formed off of a brain storming session with associate professors specializing in cloud computing. This idea stayed relevant throughout the project: "[...] think of a way to let users know how much energy a task is using. How much power will watching this video use? How much power will making this search use?"

Table 5 Requirements from brainstorming

1	Display information regarding digital activities that the user is engaging in
2	Provide the user with feedback regarding how much power different activities use

6.1.1 Extracting requirements from similar solutions

Inspiration for the system was also collected from existing systems such as the Task Manager[31] (Windows 10), Xbox Game Bar[32] and Android battery usage settings. The results from this process can be found in Table 6. In addition to these, a study exploring personalised eco-feedback systems [33] was also reviewed. Any functions that were found to be interesting and relevant for a digital eco-feedback system were documented as follows:

The Task Manager's *Processes* has a real-time function that shows on-going tasks and their respective resource usage. One column displays *power usage* and *power usage trend* based on CPU, Disk and GPU impact on power consumption. The Xbox Game Bar has a performance modal that displays a graph moving with hardware use,

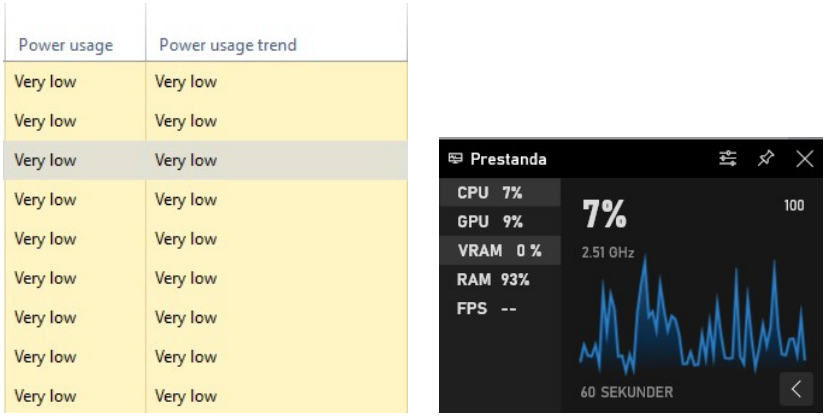


Figure 7: Screenshots from Windows Task manager (left) and Xbox game bar (right)

this small window could be attached and displayed on top of other software. Both of these programs influenced the formation of ideas. Battery usage settings on Android (version 10) and especially the *Power saving mode* that can deactivate and limit background activity that consume a lot of power was also found to be interesting.

Petkov et. al [33] designed several different mock-up screens in an attempt to get insights regarding how different personality types are motivated by different feedback. Four mock-up screens were developed with different values in mind and categorized as egoistic, altrustic, biospheric and social. These screens displayed the users weekly consumption in three sections of feedback content that depended on the category type. The social screen compared electricity usage statistics with that of a neighbor, showed a list of similar households and how the user ranks among them. The biospheric screen compared how the user's energy consumption translated to carbon dioxide emissions and how it would affect polar bear habitats over time. The social aspects and different ways of conveying the impact of energy consumption were highlighted from this study.

Table 6 Requirements from similar solutions

1	Display information (both real-time and historic) regarding the power consumption impact of hardware and software
2	Include an option similar to "Power saving mode"
3	Provide the user with information similar to that of the social (comparisons with other people) and biospheric (display carbon dioxide emissions) screen

6.1.2 Requirements for general user interface design

A few general user interface design requirements were adapted from Nielsen's 10 heuristics. To ensure that the system was designed with a structure for providing a good user experience the requirements of Table 7 were applied.

Table 7 Requirements for general user interface design

1	Aim to use a language and design elements (buttons, menu styles) that users are familiar with
2	Prevent situations that could make the user prone to errors
3	Apply a minimalist design and avoid cluttering with unnecessary visual elements
4	Strive for a flexibility regarding how the system can be used (full window or minimized, personalizing options and similar)

6.2 Resulting requirements

From the brainstorming and review of similar systems it was gathered that the eco-feedback system should be based upon already existing ideas. These existing ideas are often based around battery optimisation or saving hardware resources. Requirements 2 and 3 extracted from similar solutions (Table 6) were found to be effective as parts of the persuasive systems design and therefore excluded from the basic requirements in Table 8. The basics of the new concept should involve an overview of currently running tasks and their impact on the power consumption, but additionally give users an idea of how these numbers affect something larger. Additionally, the system should aim to deliver a good user experience by employing the requirements mentioned in Table 6.

Table 8 Requirements for eco-feedback mock-up

REQ1	Display information regarding digital activities that the user is / has been engaging in
REQ1.1	Display information (both real-time and historic) regarding the environmental impact of above
REQ2	Provide the user with advice regarding how to reduce the environmental impact
REQ3	Give the user an option to take action on environmental impact

6.3 Design implementation

The design implementation was based upon the requirements found in the previous sections. The development of a system mock-up utilized the requirements and included sketching ideas on paper. The environmental impact proved to be difficult to incorporate in the system, but was implied through the focus on energy consumption. The most well-rounded ideas were later translated into lofi Figma frames. Subsequently followed a converging process by striving to define one solution amongst different ideas and formats. Most design proposals were initially done for a mobile format, but the final solution was one intended for desktop use. This decision was made upon the basis that a desktop tool would be more specific to people who are regularly on desktops and part of the target group. The selected idea was further developed in Figma to reach a level of detail that could fulfill all the requirements.

The neutral design was the first one to be developed, by striving to fulfill the requirements in Table 8. Following that, a version that had more elements of PSD applied

was created. The different versions were evaluated by the author together with other students in the HCI field, to eliminate any major usability problems before inserting the prototype into experiments.

7 Results

The following chapter presents results from the design and development phase, along with data collected through the questionnaire followed by a section presenting qualitative results. The key results of this work are briefly enlisted below:

- A design proposal for how to apply persuasive systems design for an eco-feedback system for digital tasks was developed, see Figure 8 for an overview of the system.
- The two different designs produced no measurable difference in the perceived persuasiveness score.
- A higher score on climate consciousness shows a small correlation with the individual persuasive potential.
- Women's critical perception of the system scored slightly higher (more positive) than that of men's.
- A consensus that the system's usability was good could be found.
- The general attitudes towards the system were ambiguous. Many of the responses are diverse with no clear preference expressed. A group of participants rate the relevance and importance of similar system low in comparison to other areas of their lives where the environmental impact is larger. There was a small agreement among participants that they do not want to decrease power from their hardware since it would inflict on their work productivity or enjoyment of games. Others praise the creativity of the solution and are positive towards using a similar system in the future.

7.1 Results During the Design and Development Phase

The neutral design version consisted of a start screen and three pages. The three pages were an overview of current energy use, an overview of the last seven days energy use and a settings page. The PSD design had the same layout of the neutral design with some added features. The system applied principles of the PSD in the following ways:

Primary Task Support

With the primary task being **making it easier to reduce energy use in the digital space**, it is supported by the following:

- **Self-monitoring** - The application in its basic form provides a method for self-monitoring the energy use (Note that this is part of the "neutral" design too).

- **Tunneling** - By giving the option of Eco-mode, the system supports tunneling by eliminating difficult decisions guiding the user towards a specific behavior, i.e. one that can improve their energy use. The modal window that appears when the system detects a high power usage in the background also has some tunneling applied to it.
- **Reduction** - Enabling the user to activate functionality that affects their whole computer interaction - reduces complexity of having to activate it individually.
- **Tailoring** - By providing comparisons and numbers in a context that might be easier to understand, the information can be tailored towards a specific target group.
- **Suggestion** - The systems modal windows are fitting suggestions that might convince the user to act towards energy saving. As the "pop-ups" can be presented as close in context to the task performed, it might be even more beneficial for persuasiveness. They also implement a sort of nudging by making the button towards reducing energy use appear more prominent than the alternative.

Dialogue Support

- **Praise** - By offering praise when the user has performed well e.g., lowered their energy use or performing better than the average user.
- **Liking** - Using a "cute" earth-shaped icon could contribute to better liking of the system, since it could be deemed as more visually attractive.

System Credibility Support

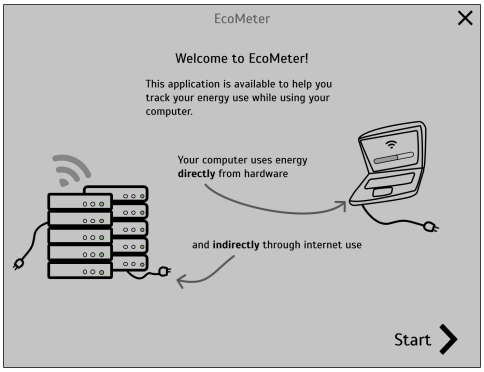
- **Expertise** - The expertise of the system can be expressed through displaying comparisons to real-world situations that offer a better understanding, see the white box in Figure 8c.
- **Surface Credibility** - The credibility is not that strong with the prototype because of its simplicity and the gray scale colors. Instead, the goal was to make use of the lo-fi design to get people's honest opinions. However, depending on the recipient it could instill credibility from a competent look by presenting accurate numbers.
- **Real-world feel** - The system has transparent goals and automatically highlights people behind it through its intentions and presentation for the users.

Social Support

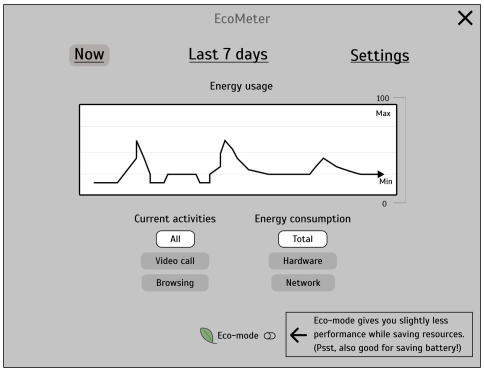
- **Social comparison** - The PSD offers the ability to compare to peers, see the information text and button in Figure 8c. It is not a complete function that is available to try out in the prototype, but is there on the surface.

- **Normative influence** - By receiving a comparison of one's own results to people in the area, the system leverages normative influence to increase the likelihood that a person would be persuaded to improve.
- **Competition** - Similarly to the former point, providing a comparison to nearby people or friends causes the system to act in a persuasive manner. Part of achieving this is attempting to influence the user to adopt a certain behavior through the natural drive to compete.

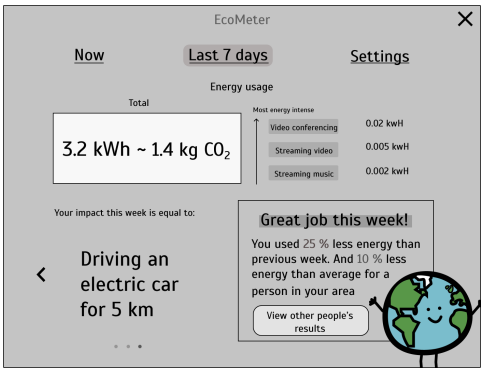
7.1.1 Images of System Design



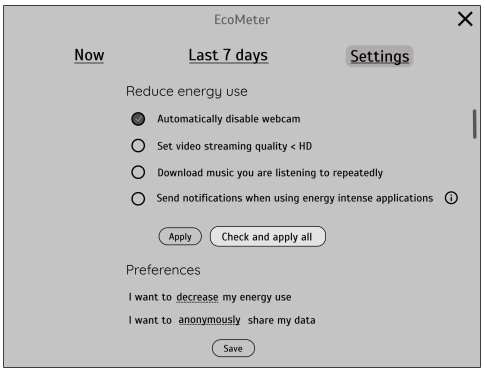
(a) First screen



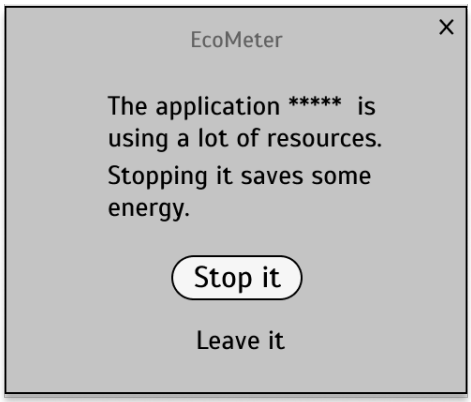
(b) "Now" page



(c) "Last week" page



(d) "Settings" page



(e) "Pop-up"-window

Figure 8: Images revealing the lo-fi design of the PSD system

7.1.2 Desktop simulation

The Windows desktop environment was built as an interactive prototype in Figma. The desktop interface included a desktop view, browser with e-mail, browser with video streaming and a video call view. The "EcoMeter" mock-up was adapted to the simulation.

For the second phase of the study a desktop simulation setting was built in Figma. The PSD was used in the test and developed further to make it fit in better in a Windows environment. The system was built using a combination of pre-made components (other creator), screenshots and animated GIFs (original work by the author). This enabled the ability to quickly build a test environment.

The tasks that were to be performed in the test environment shaped the designing of it. The tasks were oriented around a web browser, the EcoMeter application and a video call service. Figure 9 illustrates the desktop view with the shortcuts for the aforementioned programs. Building the simulation environment in Figma meant that most interactions were limited to facilitate only one specific task. E.g the browser in Figure 10 only allows the participant to use the shortcuts under the search box. A participant who would like to type the address themselves would be unable to due to these constraints.

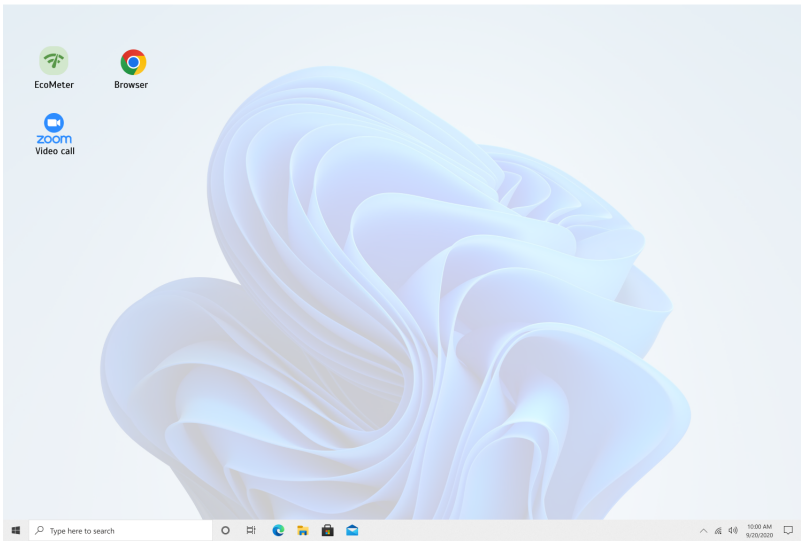


Figure 9: Simulation start screen

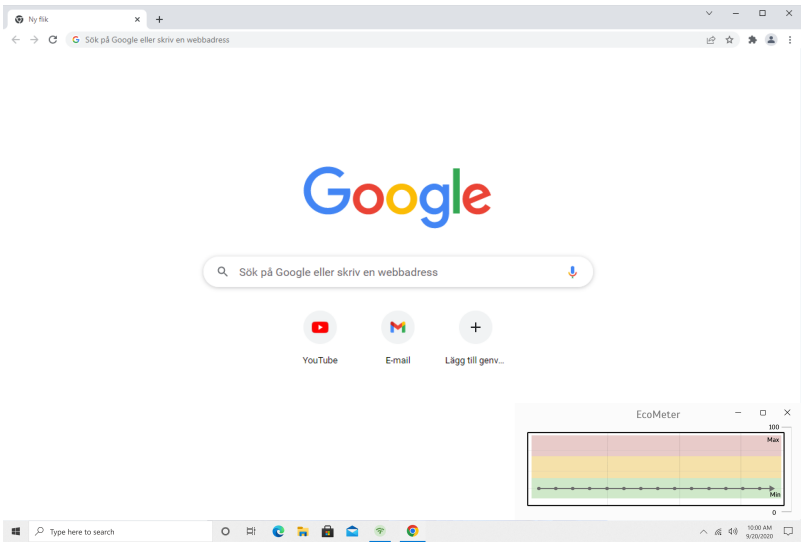


Figure 10: Browser open with the hi-fi EcoMeter in the lower right corner

7.2 Questionnaire results

The questionnaire was distributed and open for participants to take part in from 2022-04-06 until 2022-04-20. The questionnaire had a total of 42 respondents. 19 respondents for the non-PSD survey and 23 for the PSD. See Table 9 for a summation of the demographic information that was collected.

Table 9 Questionnaire participant demographic information

Age	
18-24	5 (12%)
25-34	21 (50%)
35-44	8 (19%)
45-54	8 (19%)

Gender	
Men	27 (64.3%)
Women	14 (33.3%)
Prefer not to say	1 (2.4%)

All items were presented on a 5-point Likert-scale. A 5 represents the *Completely agree* on the scale and 1 *Completely disagree*. Chronbach's alpha (reliability analysis) for responses for items regarding Climate Change was calculated to measure the consistency of the items. A combined total score was calculated for the five items, which meant to represent a climate consciousness score in a participant. A similar approach was taken to the Individual Perceived Persuasiveness items and General Perceived Persuasiveness respectively.

Table 10 Mean items score across the two groups (neutral vs. persuasive)

	Neutral n=19		PSD n=23	
Variables (total score)	**Mean**	**S.D**	**Mean**	**S.D**
Susceptibility to Persuasion	2.5395	0.7133	2.4022	0.6603
Climate Change Consciousness	4.2105	0.5597	4.3652	0.5245
Performance Expectancy (**PE**)	3.3947	0.7920	3.5652	0.9083
Effort Expectancy (**EE**)	4	0.9718	4.2609	0.6720
Social Influence (**SI**)	3.0789	1.1698	3.4130	1.1644
Behavior Intention (**BI**)	2.6316	1.0651	2.8261	1.1541
Individual Persuasive Potential (**IPP**)	2.8596	0.7228	2.9304	0.7923
General Persuasive Potential (**GPP**)	3.1842	1.2271	3.1304	0.9911
"It does not feel important to monitor my digital energy consumption"	2.31	1.0569	2.4348	1.3760
"I like the idea of monitoring the energy consumption from my digital habits"	4	1.1055	3.7826	1.2416

7.2.1 Hypothesis testing

A two-sample t-test with a significance level of $\alpha = 0.05$ and the null hypothesis *the difference in group means is zero* could not verify that the means of any of the scores from Table 10 are different across the groups.

7.2.2 Data visualization

The participants intention to use similar software in the future is visualized in the boxplot in Figure 11. Another score which measures how useful and persuasive the participants found the prototype to be is the total *Individual Persuasive Potential* score. This score distribution across the groups can be viewed in figure 12.

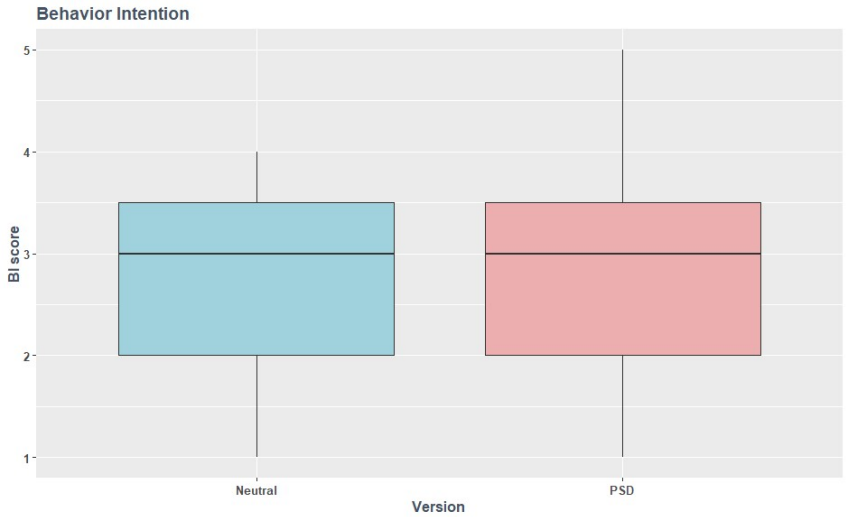


Figure 11: Boxplot of score distribution of *I would use this system regularly* for the neutral and Persuasive Systems Design respectively

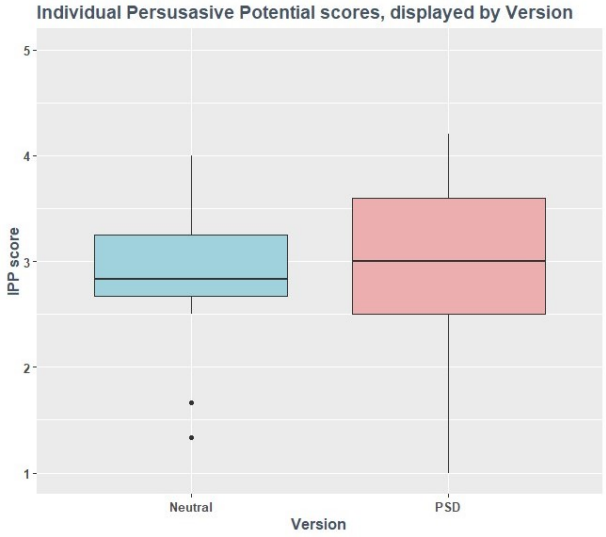
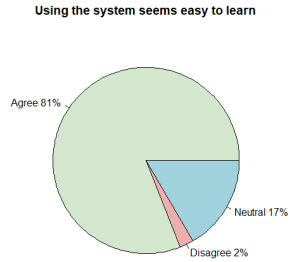
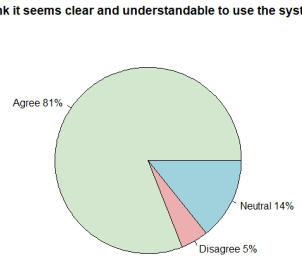


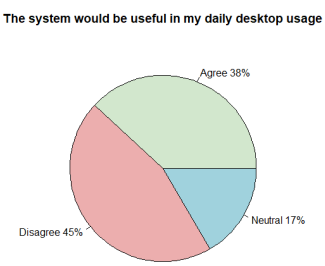
Figure 12: Boxplot of score distribution of total Individual Persuasive Potential (IPP) score for the neutral and Persuasive Systems Design respectively



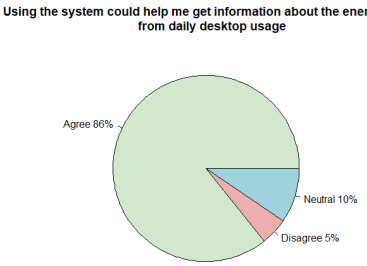
(a) EE1



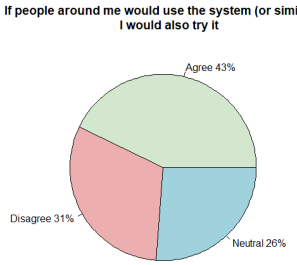
(b) EE2



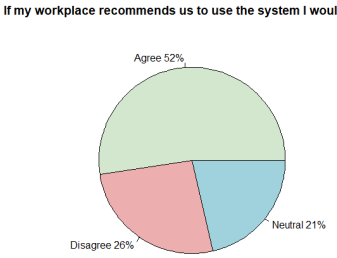
(c) PE1



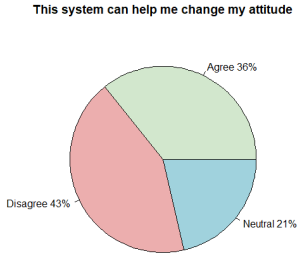
(d) PE2



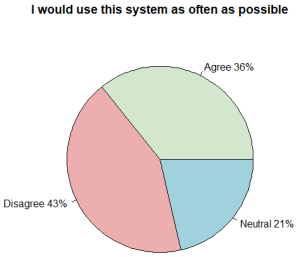
(e) SI1



(f) SI2

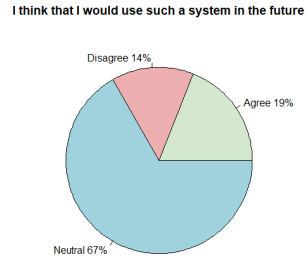


(g) IPP1

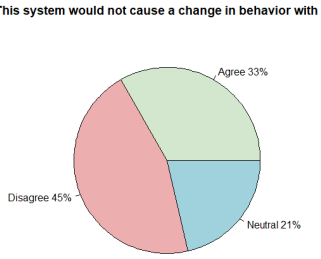


(h) IPP2

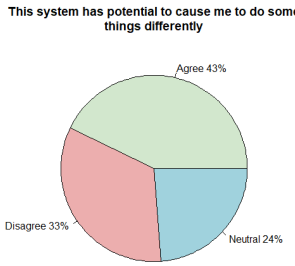
Figure 13: Pie charts revealing acceptance percentage for key items across the complete dataset (1 / 2)



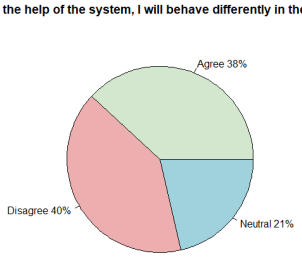
(a) IPP3



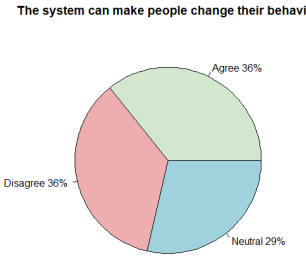
(b) IPP5



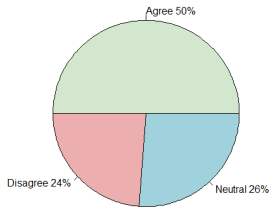
(c) IPP6



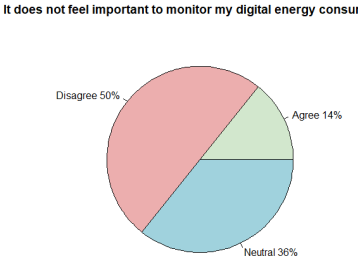
(d) IPP7



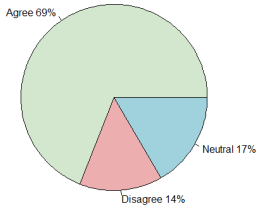
(e) GPP1



(f) GPP2



(g) GOP1



(h) GOP2

Figure 14: Pie charts revealing acceptance percentage for key items across the complete dataset (2 / 2)

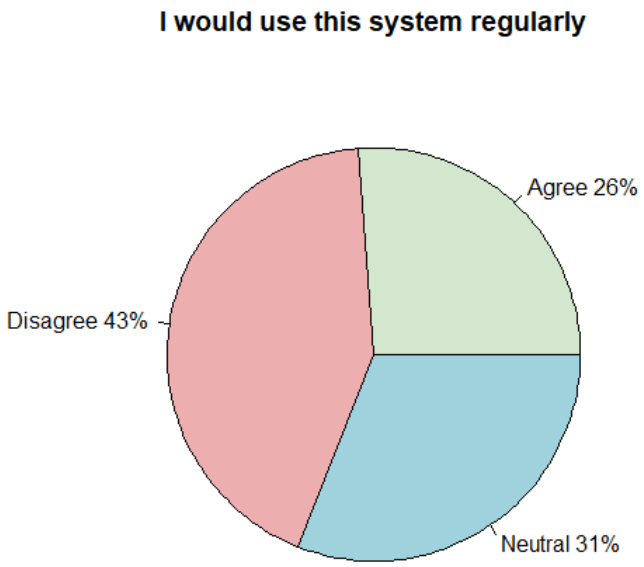
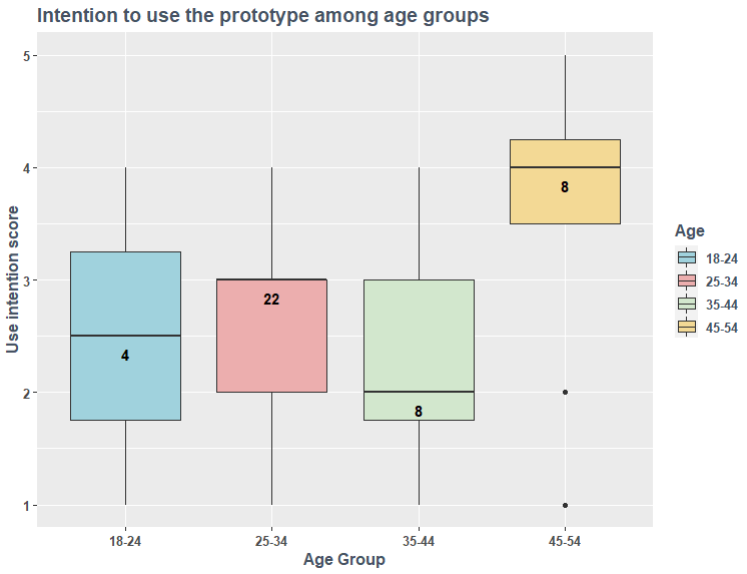
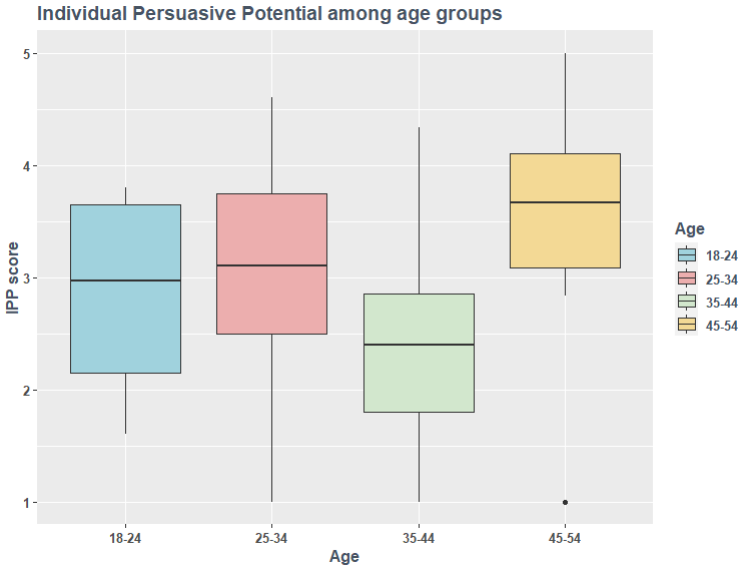


Figure 15: Pie chart revealing acceptance percentage for Behavior Intention item across the complete dataset

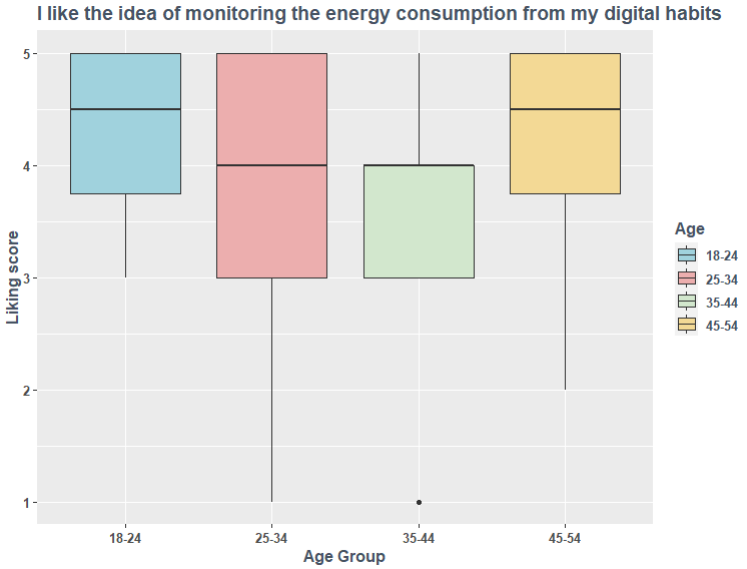
Since the t-test displayed no measured difference between the two different designs, the pie charts (Figures 13, 14 and 15) display results from the complete dataset of 42 participants. The whole dataset is again used for displaying between-group results of gender (Figure 17) and age (Figure 16) and for calculating Pearson's r.



(a) Sample size of each age group displayed in the box

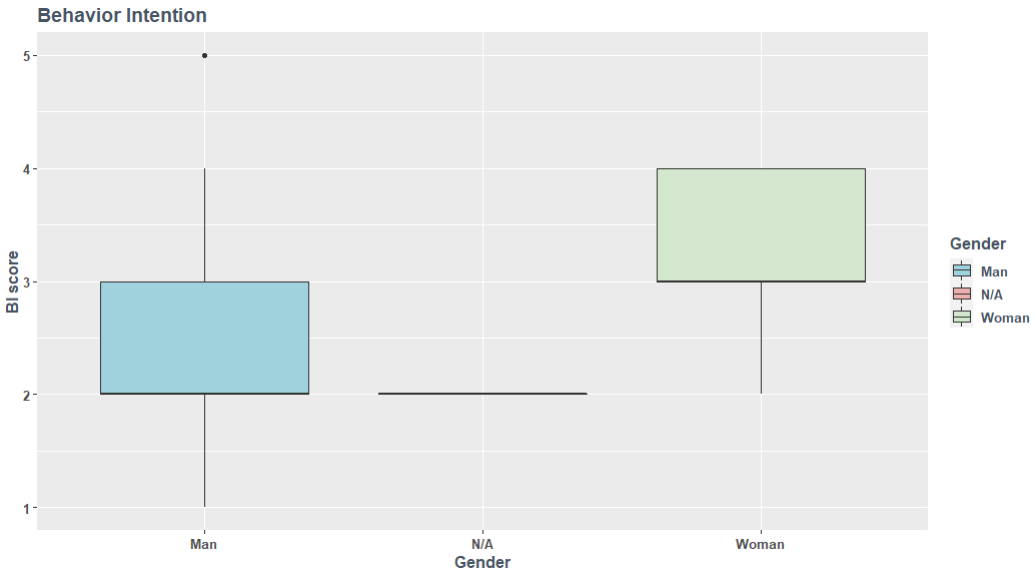


(b)

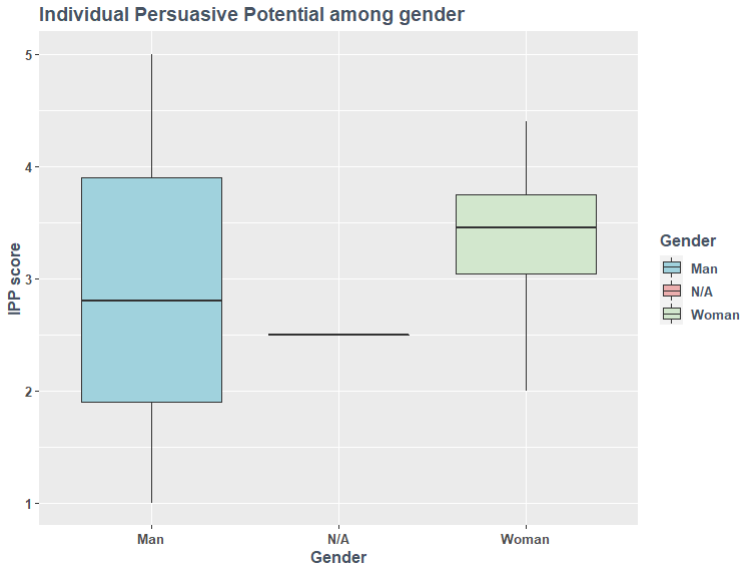


(c)

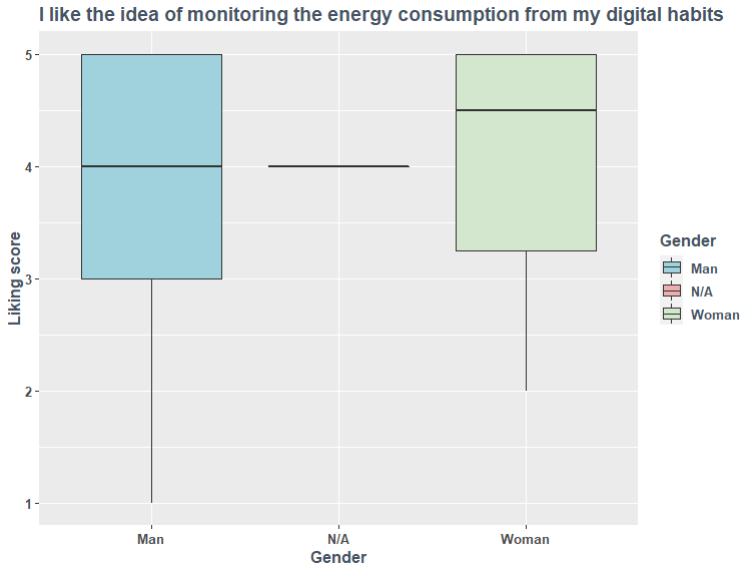
Figure 16: Use intention, Individual Persuasive Potential and how much they like the concept idea across age groups, sample size included in (a)



(a)



(b)



(c)

Figure 17: Use intention, Individual Persuasive Potential and how much they like the concept idea across gender

7.2.3 Pearson's r correlation

Pearson's correlation formula is used to calculate whether there are any linear dependencies between two variables in the data. The value of r can vary between -1 and 1, from a negative to a positive association. An r-score of 0 means that there is no linear trend between the variables.

$$r = \frac{\sum(x - m_x)(y - m_y)}{\sqrt{\sum((x - m_x)^2 \sum(y - m_y)^2}}$$

The formula was applied to the climate change consciousness score against selected scores on how the user perceived the prototype. Results from this can be seen in Figure 18.

Pearson's product-moment correlation between scores	**Result**
Climate Change Conciosuness score → General Persuasive Potential score	0.34
Climate Change Conciosuness score → Behavior Intention	0.52
Climate Change Conciosuness score → *It does not feel important to monitor my digital energy consumption* (reverse-scored)	0.41
Climate Change Conciosuness score → *I like the idea of monitoring the energy consumption from my digital habits*	0.43
Climate Change Conciosuness score → Individual Persuasive Potential score	0.60

Figure 18: Pearson's correlation formula applied with corresponding results

7.3 User test

The user tests were performed during 2022-04-18 and 2022-04-25. The test was conducted with a total of 5 participants, three men and two women. The participant age varied between 21 and 56 (SD = 17.9).

7.4 Qualitative results

The qualitative results are a combination of data from the user test, interview and from an open-ended question from the forms. These are categorized into *usability* and *general opinions* to separate feedback that surrounds using the prototype from thoughts the participants expressed on the concept.

7.4.1 Usability

All five participants completed the tasks within four minutes. One participant was distracted when following the instructions and supervisor intervention was necessary to get on to the next step. Another participant was hesitant when it came to finding how to activate the pop-up setting, however, most of the participants showed some level of hesitation in face of this task. In total, the participants agreed that the

mock-up system and “EcoMeter” prototype were easy and intuitive to use. One participant expressed “There was not an abundance of functionality in the program. [...] not much that I could do by mistake”.

Most participants were focused on performing the tasks and did not acknowledge the visual change in energy consumption. One person acknowledged the change: “I can see how the energy went up when I opened the browser and then down again...”.

7.4.2 General Opinions

Both versions of the questionnaire generated 14 usable responses in the open-ended question field that encouraged participants to share any thoughts that had come up. Of these 14, four could be interpreted as feedback on the questionnaire design, e.g. “Most questions were ‘positive’ but one included a negation, might impact the result”. Another ten of the answers included general opinions or explanations of the participants feelings toward the concept. From the interviews were also gathered opinions that was categorized at the same time. A visualization of the summation of these responses can be viewed in Figure 19. The categories were structured based on how the participant expressed their opinions with themes that overlap to some extent. One participant stated that “Monitoring my personal work computer I have no interest or need for. I do however see the potential in measuring the energy consumption of other equipment around the household [...]”.

When it comes to behavior most participants had a reflection regarding how their own behavior could be affected from using the system. The interview question **Do you think a similar solution could affect your digital habits?** led most participants to a conflicted response, i.e. they were not feeling positive that the system would make them behave differently (stream less video for example). One participant said: “I do not know if it would have changed my habits. You usually have a certain type of use already and I do not know if the program would make me just quit that, but maybe I would become more aware and think twice”.

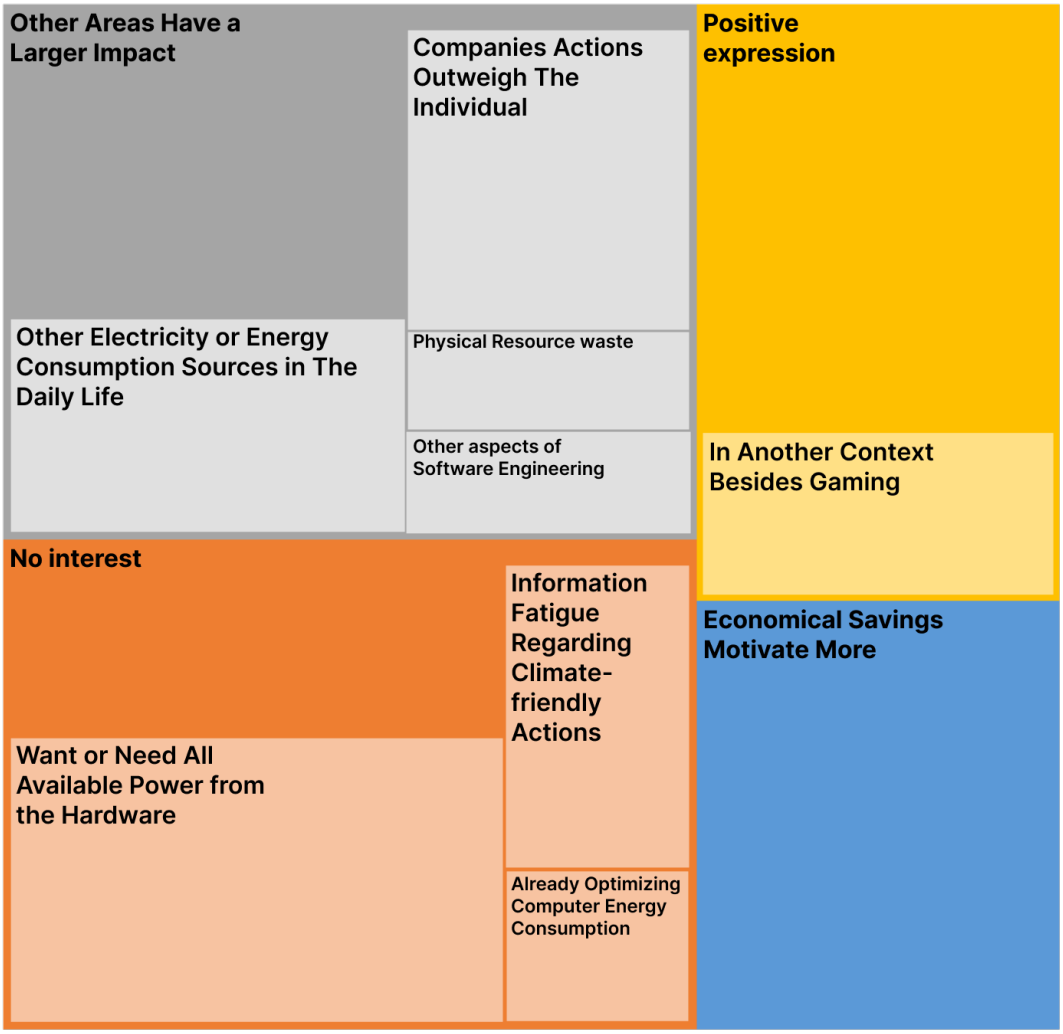


Figure 19: Hierarchy Chart of Codes for *General Opinions Towards Concept*. Different colors represent a theme that was identified within a response and the boxes inside are subcategories that were found in that theme. The size of the boxes are proportioned according to the number of items coded with the theme.

8 Discussion

The discussion chapter serves as a way to relate how the research questions can be responded to with the key-findings of this study. This section also discusses limitations with the persuasive systems design and experiment design.

8.1 Answering research questions

How can persuasive systems design be applied to an eco-feedback system designed for digital tasks?

The proposed design applied persuasive systems design to a new system centered around digital tasks and computer use. The design proposal presented in this thesis provides concrete examples of application of PSD to an eco-feedback system and insights into the PSD process. Hence, the design proposal itself should be considered to satisfy this research question.

What is a user's perception of a system designed to give them eco-feedback regarding digital tasks?

In general, most study participants were positive towards the proposed design and judged the system to be both easy to learn and understandable by default. The usability test did not reveal any large issues with how the users achieve the given task. There is a consensus that the systems works well for what it is intended to do, see Figure 13d. However, when it comes to future use of a similar system or how the users believe the concept could affect their habits in the long term, more people expressed neutrality, uncertainty or negative feelings.

(a) How does applying persuasive system design affect the user response towards such a system?

The research results suggests that the persuasive system design did not affect the user response in any significant way. A t-test across the different variables of the two groups revealed p-values that were all too large (with a 95 % confidence interval) to reject H_0: *There is no difference in how people accept the system in relation to persuasiveness.*

(b) How do users' varying degree of awareness for environmental issues affect their response towards such a system?

To answer this question Pearson's correlation formula was used to calculate the climate change consciousness score and its correlation to other scores. A positive correlation was found on all calculated variables with varying strengths on the linear relationship. None of the variables displayed an exact ($r = 1$) linear relationship but the strongest was the way the climate change score influenced the individual persuasive potential. This could indicate that people who are already aware or worry

about climate change issues would be better persuaded by this eco-feedback system.

(c) How are the users' response influenced by different demographic data such as age and gender?

The sample groups of different age and gender were unfortunately too small to be able to draw any substantial conclusions regarding how these factors affect the response. There are a few trends that can be viewed in the data but these might as well be explained by individual differences rather than actual differences that can be transferred to the different groups. In the data one can see that the 45-54 age group had a higher mean score across all the different variables in Figure 16. Meanwhile, the 35-44 age group had the lowest mean score across the same variables.

For gender, there are some indications in Figure 17 that women were slightly more positive and found the application to be more persuasive. The mean score of *Behavior intention* for women were 3 while for men it was 2. It is important to note however, that the group of women were almost half the size of men, possibly skewing the results.

8.2 Discussion around the negative response

> "Strain at gnats and swallow camels"
>
> *Expression originated in the Bible, in Matthew 23:24.*

A participant expressed in the questionnaire that they picked up a "strain at gnats" feeling from the project. What they likely meant was that they feel like the system focuses on a minor issue, by measuring environmental impact from digital habits, while overlooking what they consider as more important issues. Seen in particular from a Swedish perspective, with a majority of national electricity sources considered green [34], it becomes challenging to motivate sustainable energy consumption behaviors for the computer end-user. The transportation sector is for example a much larger source of greenhouse gas emissions than the ICT sector, based on the fact that fossil fuels still power much of this sector [34]. In total, a handful of people from the study expressed no interest in using the prototype in their daily lives or that they do not want their productivity inhibited by computer resource saving. These expressions could be an indication that some users are keener to act in sustainable ways in other areas of their lives, if at all.

8.3 Limitations

The following section presents some limitations of the thesis, as in constraints with how it was conducted and problems that appeared along the way.

8.3.1 Focus throughout the project

The study started out with a focus on the pure software effects on power usage, e.g., effects from streaming video. However, during the project the focus shifted slightly towards that of (local) hardware power consumption. The shift makes it problematic

to distinguish opinions on the software side of it, but on the other hand that could indicate where the user interest is. This take might come as natural for many of the users since it can be viewed as a more immediate effect for them, in the effects of costs for new hardware and electricity bills etc.

8.3.2 Study design limitations

It can be argued that there were issues with the way the survey was distributed. For example, a known limitation with a survey is that there are no ways of limiting who has access to the survey after distributing it through the channels. In this case, the tool that was supposed to distribute the survey evenly worked well in doing so. Still, there was an uneven distribution in the end (n=19 for the neutral design, n=23 for the persuasive design). This can probably be explained by the fact that people contribute to surveys voluntarily, which means that they do not always finish and submit them. According to the database of the survey website, the button linked to the forms was pressed 61 times. This indicates that almost a third of the initial respondents did not submit a complete questionnaire. Other survey tools might have been able to gather incomplete data, but this is not available in Google Forms. There could be many reasons why people did not complete the survey, e.g., the questionnaire being too complex or time-consuming. In addition, eliminating users on mobile excluded a large group of recipients. There is always the issue with surveys that they are uncontrolled and respondents might want to portray themselves in a certain way rather than reflecting their true opinions, what is known as the *social desirability* bias [35].

Since the study was so broad there were a few issues trying to keep on track as the project progressed. For example, the plan from the beginning was to gather all the data exclusively from the questionnaire. To increase validity an idea was to expand to include a user test and interview. However, the motivation and time necessary for these were not entirely available and therefore they were not completed in the most rigorous way. In the end this might have contributed to an inconclusive result.

8.3.3 Data collection limitations

After what was considered as careful design of the questionnaires it still appeared that one of the forms had a duplicate of one question and the other form had one of the items missing. During one interview it was found that the recording stopped mid-test which rendered that interview more difficult to process even though some notes were taken. These issues are faults that might interfere with the results and does not give a complete picture regarding what was collected. In a longer project with less time constraints, these issues could have been discovered by:

1. having a better structure down for comparing the forms before they were released and
2. establishing a thorough procedure for testing, including various forms of data collection (triangulation) that could make up for similar mistakes

8.3.4 Persuasive design limitations

The fact that the persuasive design did not have any significant impact on whether the study participants found the system to be persuasive or not could have several explanations.

1. The concept on its own could be polarizing depending on opinions and motivations of the participant. People are diversely motivated and a simple system like the one proposed can not motivate all users. As some research suggests [36] providing a "one-size-fits-all" eco-feedback solution might only succeed with informing instead of motivating, depending on the consumer's own goals. The system prototype tried to be persuasive with the goal that everyone should want to lower their energy consumption and decrease any environmental impact. However, it is a large assumption to make as the reality is complex and people have different values and concerns that make up their goals.

2. A questionnaire with images of a simple prototype might not be enough to convey the ways in which the design could act persuasive. There is also no way of telling whether the applied PSD in this case is thorough. Meanwhile, there is no evidence that the *neutral* design is in fact neutral. Some issues with PSD that Oinas-Kukkonen et. al described such as that *Persuasion is often incremental* is problematic when designing a study that tries to gauge the persuasiveness with little to no direct user interaction. Another issue is that they described that PSDs should *aim to be both easy and useful to use.* While a majority of questionnaire participants agreed that they perceived the system to be easy to use, fewer of them (38%) agreed with *The system would be useful in my daily desktop usage.*

3. One explanation could be that applying PSD was not best suited for this project and its potential could not be measured here. PSD could be a way to effectively make users more engaged in an experience and keep them on track for their goals. In the case of this study, the goals of the users are not known or rather assumed to be that they want to act environmentally friendly in all cases. The concept of saving power "in the cloud" is still experimental in the sense that it is not a concept that is already known or actively engaged in in many cases. For another study it might be more appropriate to apply PSD to already existing applications or systems developed closely with users in mind.

9 Conclusion and Future Work

In conclusion, most of the study participants were positive towards the idea of monitoring their digital energy impact. Across the study, a majority of the participants agree that the system seems easy to use, is understandable and works well for conveying a message regarding energy use. The results are diverging more regarding the usefulness, persuasive effect and whether the participants believe that the system has potential to cause a behavior change. No conclusion could be drawn that the design version with Persuasive Systems Design applied, had a larger persuasive impact on a respondent. A small tendency regarding how people who are more concerned or caring for the environment, would be better persuaded by the system, could be seen.

The study found few conclusive results regarding the user perception of a persuasive eco-feedback system design and how it is affected by different demographics. This could indicate that the sample size was too small and more exhaustive research needs to be conducted before drawing conclusions. Supplementary research would be needed to draw proper conclusions regarding the persuasive effect of the system, by for example conducting a more long-term type of experiment.

General user responses suggest that some people do not have an interest for measuring energy consumption from their computer use. It does not align with their productivity goals, what they expect and need from their hardware or views of where the substantial environmental impact is made.

With the broad aim of this thesis, further work in this field might benefit from having a distinct limitation in which area to explore. A behavioral science take on further work could be to delve deeper into what motivations people have for acting sustainably. By involving users early in a design process one can develop and test solutions that have different results for different kinds of people.

A computer science aim could focus around establishing new or identifying technological advancements beneficial for cloud services, block-chain technology or other electricity intense applications. Another idea could be to explore more green *by* software solutions. One take on it could be to make use of machine learning in Home Monitor Systems to save energy. When it comes to the HCI perspective one might consider solutions that leave the decision to users without intrusiveness. A similar system such as the one proposed in this thesis could be tested in a longitudinal study where participants' reactions are measured over time. This might reveal new insights as eco-feedback could be delivered closely with usage of the source. However, regardless of research field, it might be valuable to focus on the larger environmental improvements that can be gained outside the individual's control.

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A Appendix

A.1 Persuasive Potential Questionnaire

SP_1	What others say brings me to rethink my attitude towards it.
SP_2	I do not want to be influenced by others.
SP_3	Even my friends have difficulties to influence me.
SP_4	No one can tell me what to do.
GPP_1	The system makes people change their behavior.
GPP_2	The system has the potential to influence people.
GPP_3	The system gives the behavior of its users a new direction.
IPP_1	This system is exactly what I need to change my attitude.
IPP_2	Thanks to the system I reach my goals.
IPP_3	I will use this system as often as possible
IPP_4	I think that I will also use such a system in the future.
IPP_5	I will use this system regularly.
IPP_6	This system does not cause a change in behavior with me.
IPP_7	This system causes me to do some things differently.
IPP_8	With the help of the system, I will behave differently in the future.

A.2 Interview questions

- How did it feel to use this program?
- Was it easy or difficult to use the program?
- How do you consider it's usefulness for you?
- How do you think the program works for giving you information about your energy consumption?
- Is the program something you could see yourself use (again)?
- What would it take for you to be convinced to use such a program in your life?
- Is there any situation where you would like to use a similar program? Is there any situation where you would NOT like to use a similar program?
- Are you interested in getting to know your digital energy consumption? Why / why not?
- What, if anything, motivates you when it comes to considering the environment?
- Do you think a similar solution could affect your digital habits? Why / why not?

A.3 Survey Distribution Website screenshots

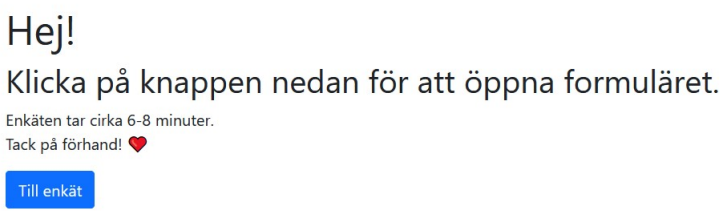


Figure 20: Screenshot of survey distribution website (in Swedish)

Figure 21: Screenshot from survey distribution website on mobile

B Appendix

B.1 Google Form

Digital energy consumption

My name is Stella and I am a student at Umeå university. I'm currently writing my Master's thesis on the M.Sc. program in interaction technology and design. My work is centered around energy consumption of computer software. As a part of the work I have chosen to develop a small sketch of a system and distribute this survey to gain some knowledge on how it is perceived. In the first part of the questionnaire I collect some information about you. In the second part you will see some images from the system sketch, followed by questions on how persuasive it is and whether you would want to use it.

You as a participant are anonymous and none of the submitted information can be connected to you personally. The sole purpose of the collected information is to be used in my master's thesis work. The results of the thesis will be open to the public eventually, but any collected information will be treated confidentially and no later until 2022-08-30. Your participation is completely voluntary and you can choose to discontinue at any point. However, I would really appreciate if you choose to complete the survey once you have started it.

The questionnaire takes around 5-8 minutes to complete. Your contribution will be of great use for my continued work.

If questions regarding the survey or thesis occur, do not hesitate to contact me: stbi0004@student.umu.se

*Required

About you

The following chapter collects some data about you.

1. Gender *

Mark only one oval.

- ◯ Man
- ◯ Woman
- ◯ Prefer not to say
- ◯ Other: _____

2. Age *

Mark only one oval.

- ◯ Under 18
- ◯ 18-24
- ◯ 25-34
- ◯ 35-44
- ◯ 45-54
- ◯ 55-65
- ◯ Older than 65
- ◯ Prefer not to say

3. Regarding persuasion *

Mark only one oval per row.

	Completely disagree	Disagree	Somewhat agree	Agree	Completely agree
What others say brings me to rethink my attitude towards it.					
I do not want to be influenced by others.					
Even my friends have difficulties to influence me.					
No one can tell me what to do.					

4. Thoughts regarding the climate *

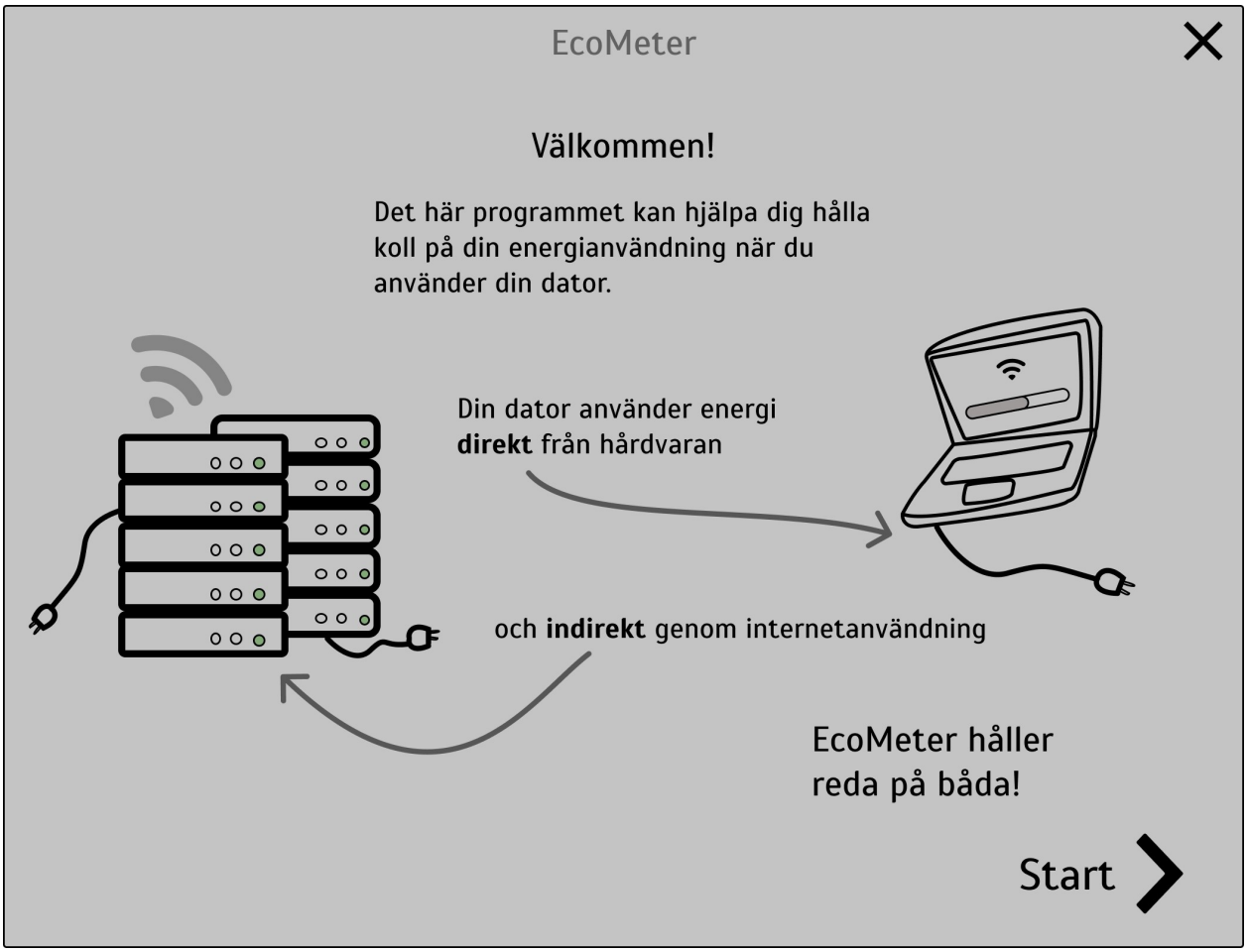
Mark only one oval per row.

	Completely disagree	Disagree	Somewhat agree	Agree	Completely agree
I am aware of climate change					
Current global warming is a natural, not man made phenomenon					
I'm willing to pay a certain amount to reduce the impact of climate change					
I recycle most of my household garbage					
I am concerned about the impact of climate change					

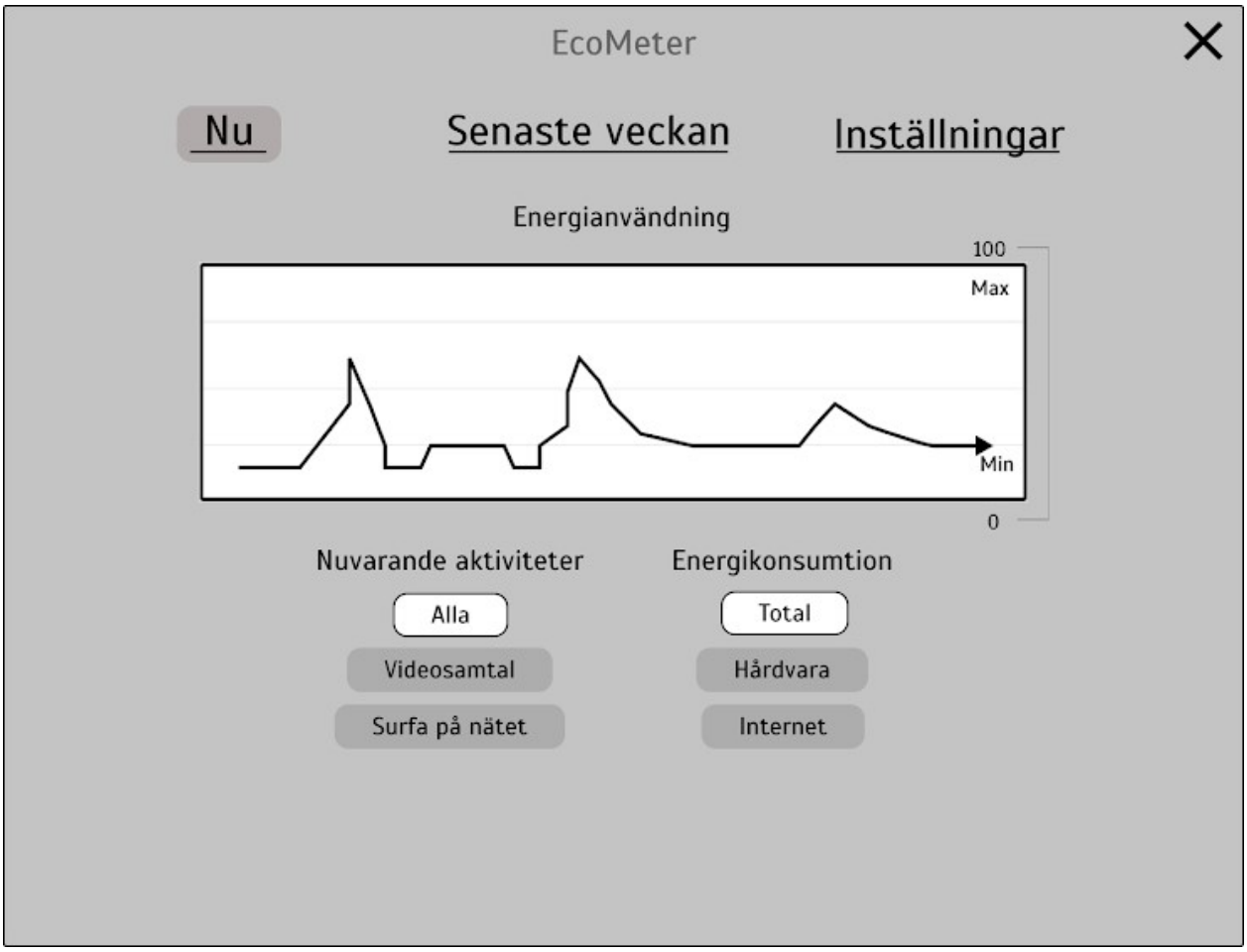
"EcoMeter"

The following chapter introduces a sketch of the system "EcoMeter". This is a basic program that runs on the computer and can help users gain a better understanding of how their energy consumption is affected from computer usage. After this follows questions based on your impression of the images. Respond according to what you think / believe, there are no right or wrong answers.

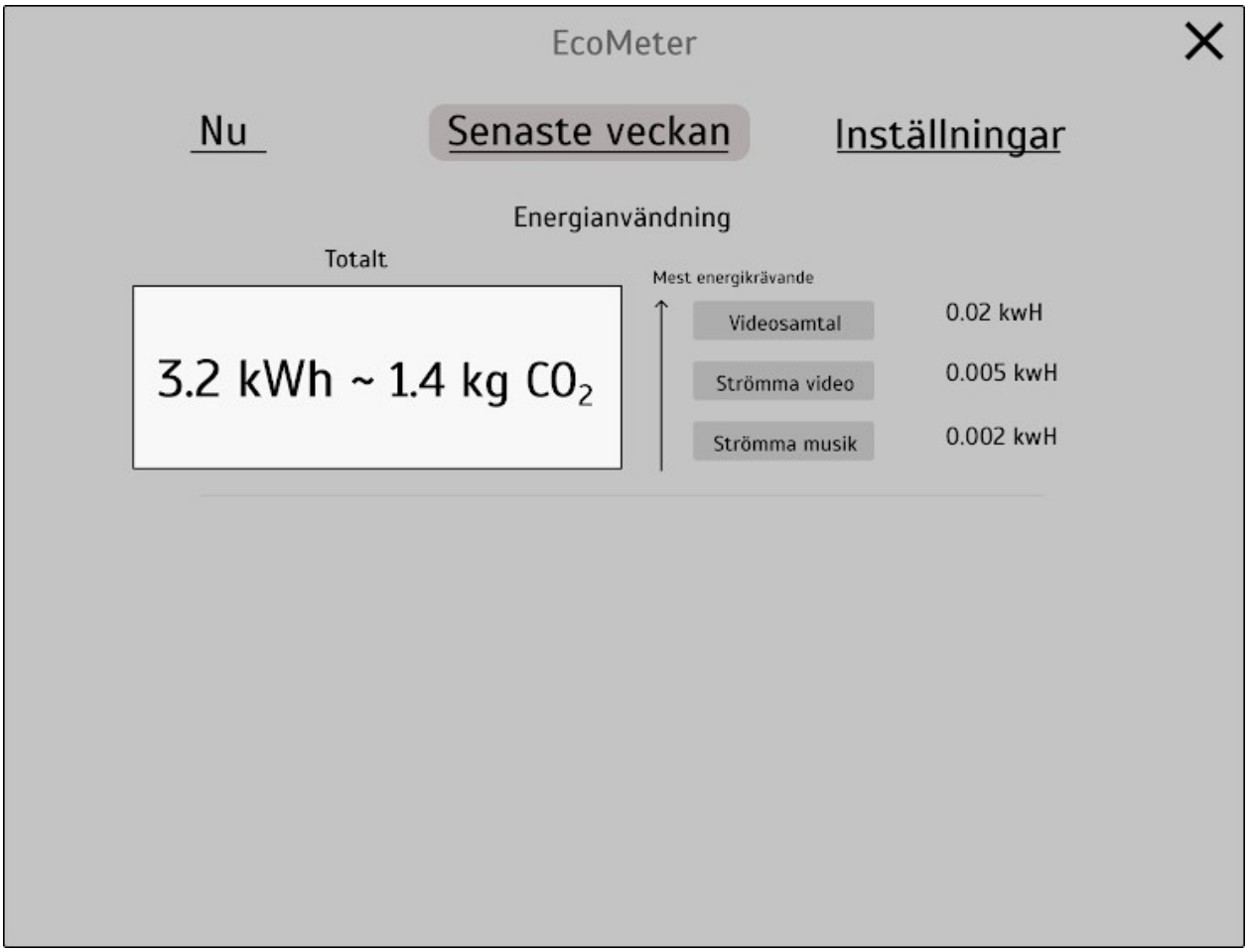
1. Start page


EcoMeter
Välkommen!
Det här programmet kan hjälpa dig hålla koll på din energianvändning när du använder din dator.
Din dator använder energi **direkt** från hårdvaran
och **indirekt** genom internetanvändning
EcoMeter håller reda på båda!
Start

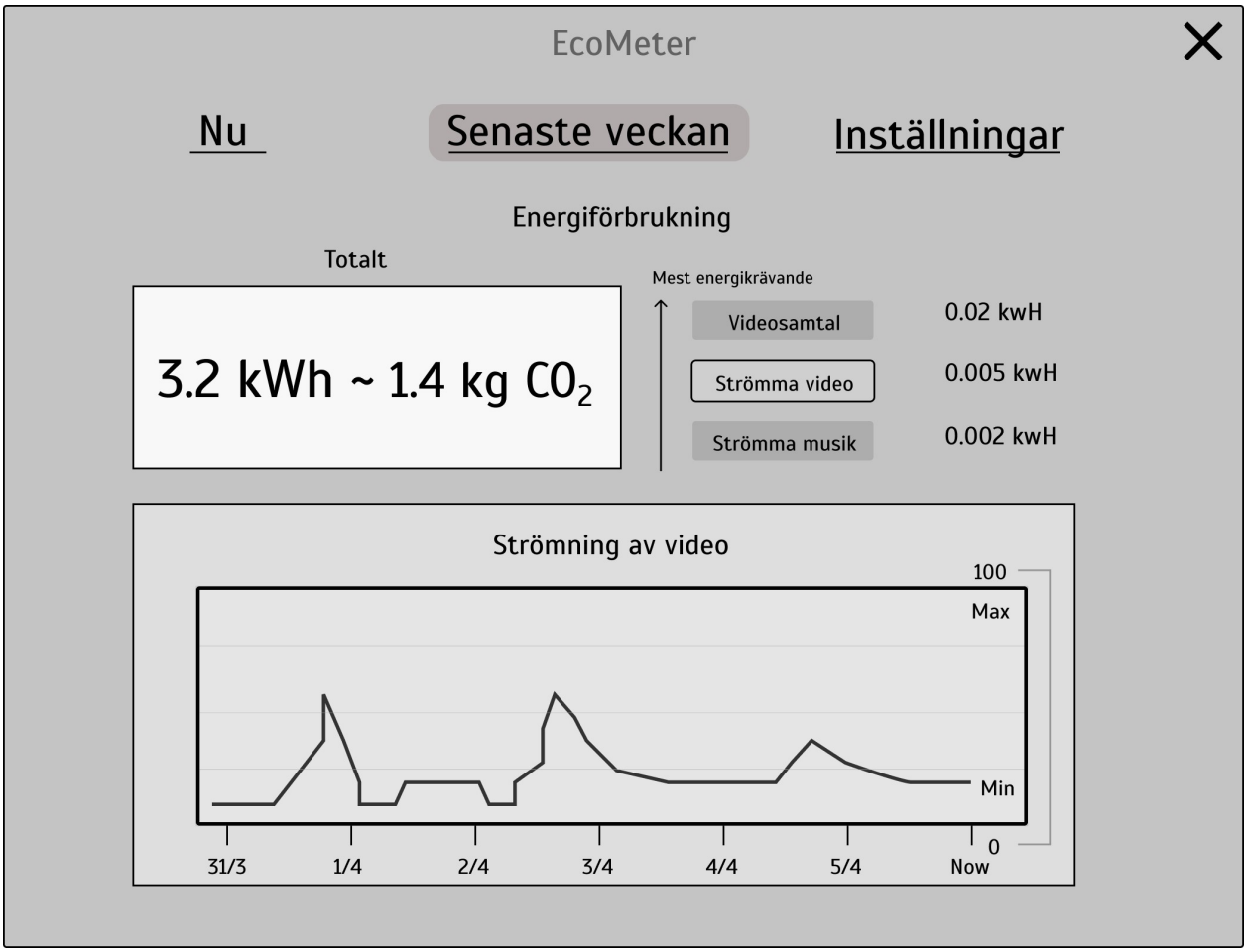
2. Real time supervision



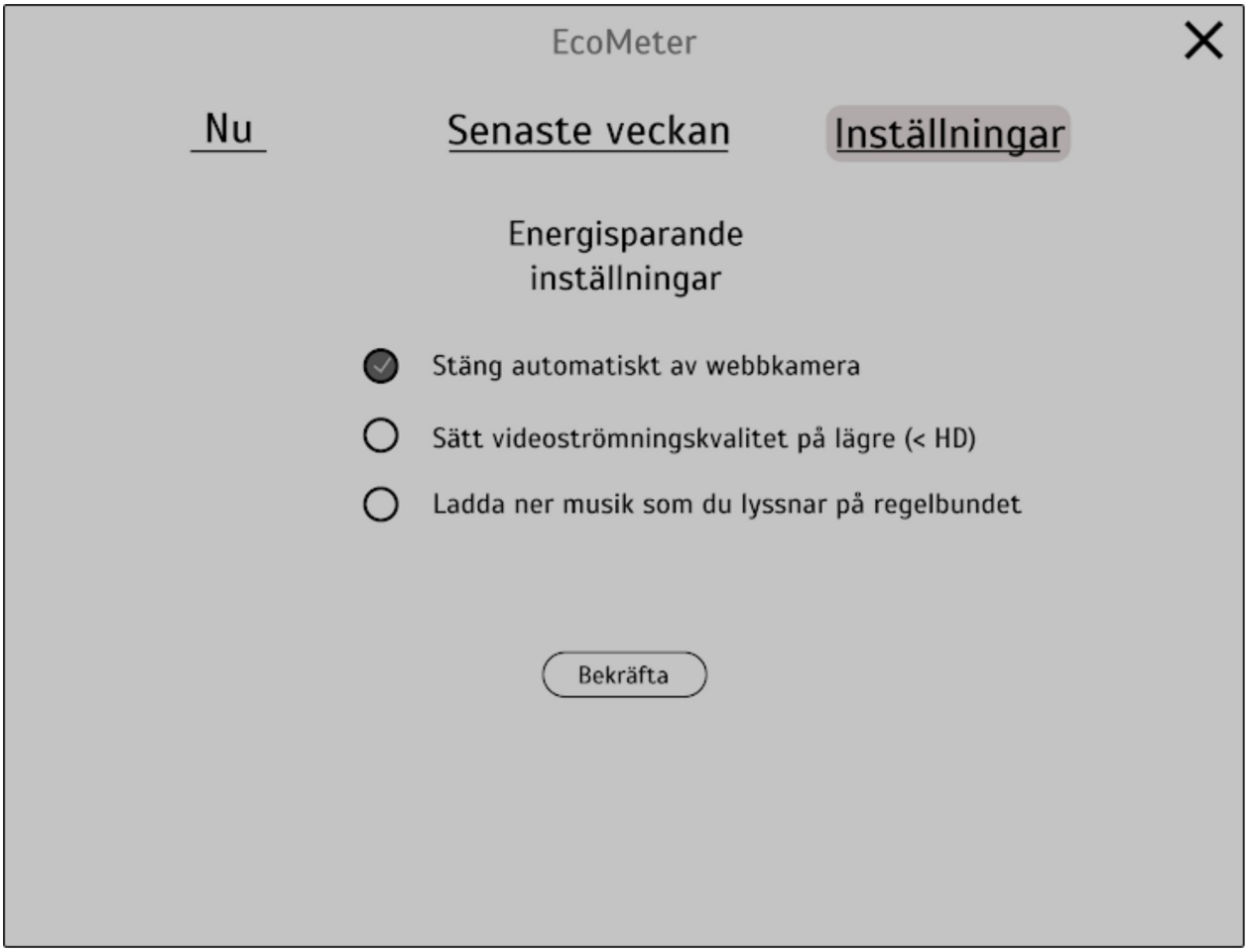
3.1 Summary over last week's energy consumption



3.2 "Video streaming" selected



4. Settings



The following items regard usage of the system

5. The system would be useful in my daily desktop usage *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

6. Using the system could help me get information about the energy use from daily desktop usage *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

7. Using the system seems easy to learn *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

8. I think it seems clear and understandable to use the system *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

9. If people around me would use the system (or similar), I would also try it *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree						Strongly agree

10. If my workplace recommends us to use the system (or similar) I would use it *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

11. I would use this system as often as possible *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

12. I would use this system regularly *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

13. I think that I would use such a system in the future *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

The following questions regard how persuasive or not the system is

14. The system makes people change their behavior *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

15. This system can help me change my attitude *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

16. The system has the potential to influence people *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

17. This system does not cause a change in behavior with me *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

18. This system causes me to do some things differently (potentially) *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

19. With the help of the system, I will behave differently in the future *

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

Opinions on the concept

20. It does not feel important to supervise my digital energy consumption *

Mark only one oval.

	1	2	3	4	5	
Completely disagree	◯	◯	◯	◯	◯	Completely agree

21. I like the idea of supervising the energy consumption from my digital habits

Mark only one oval.

	1	2	3	4	5	
Completely disagree	◯	◯	◯	◯	◯	Completely agree

22. Other

Anything that came up while filling out the form or anything else you want to add? Feel free to submit your thoughts and comments here.