AALBORG UNIVERSITY
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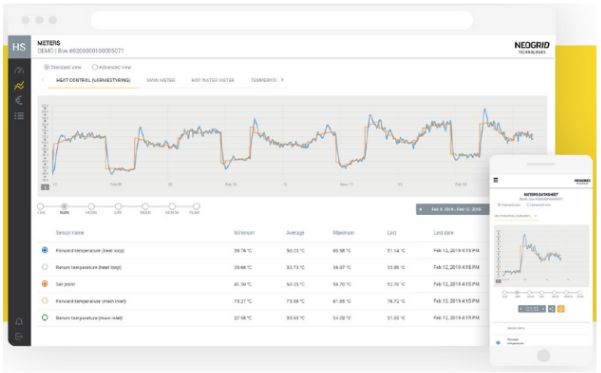
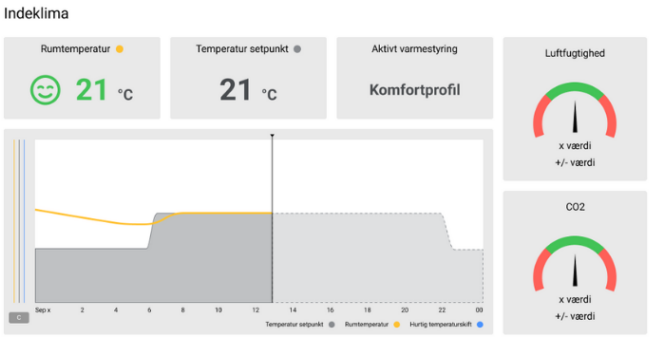
NEOGRID
TECHNOLOGIES

THE PRACTICE OF ENERGY CONSUMPTION

A TECHNO-ANTHROPOLOGICAL STUDY OF PRACTICING ENERGY CONSUMPTION ACTIVITIES AND UNDERSTANDING ENERGY CONSUMPTION FEEDBACK VISUALIZATIONS





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Abstract:
The purpose of this master's thesis is to examine how energy consumption feedback can be visualized in the most understandable way, and how people's everyday practices influence their relation to energy consumption. An Aalborg-based company, Neogrid Technologies, is used as a case when investigating how energy consumption can be visualized. To obtain insights into how energy consumption feedback visualizations are understood, and also how people's everyday practices are influencing their practices of energy consumption, interviews are performed with users of Neogrid's smart heat management solution PreHEAT. All the empirical data is qualitatively gathered through 11 semi-structured interviews. The theoretical approach in the master's thesis is Kirsten Gram-Hanssen's perspective on practice theory, and the qualitative empirical data is analyzed with inspiration from Jennifer Attride-Stirling's thematic analysis approach using thematic networks. The findings are presented as the three Global Themes: 1) Reasons for monitoring energy consumption, 2) Energy consumption practices and 3) The app and its visualizations. The master's thesis concludes that people's understanding of visualized energy consumption data differs with the majority liking numeric and analogue displays showing both numbers and graphs. Furthermore, it is found that the most important practice of people's indoor climate is having a comfortable home, which sometimes conflicts with the act of reducing energy consumption.

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1.0 Introduction

1.1 The Sustainable Development Goals

The Sustainable Development Goals (SDGs) are seventeen goals that to date are the most ambitious global development agenda the world has ever adopted (figure 1). Since the SDGs were formulated by the United Nations (UN) in 2015, environmental sustainability has become of significant interest to world leaders (Tchatchoua, Boulus-Rødje, & Mitchell, 2023; United Nations Development Programme & Globale gymnasier, 2023). Together, the SDGs serve a shared blueprint for a future that is more sustainable. The SDGs build on and incorporate three categories of sustainability; environmental, societal, and economical. The goals deal with several aspects related to sustainability, such as social and environmental effects and gender equality, industry, poverty reduction, ensuring access to healthcare for all, conservation of biodiversity etc. (Hansson, Cerratto Pargman, & Pargman, 2021). The UN members have agreed on taking action and achieving the SDGs by 2030 (United Nations Development Programme & Globale gymnasier, 2023).

Figure 1 – The seventeen Sustainable Development Goals [1]

Some SDGs have become the catalyst for business leaders worldwide to include environmental sustainability in their companies, which has led to a proliferation of technological solutions, which will help support an easier green energy transition (Tchatchoua et al., 2023). These advances in the development of sustainable technologies have made, for example, domestic energy consumption data easily accessible to users (Foster, Lawson, Blythe, & Cairns, 2010; Froehlich, Findlater, & Landay, 2010; Herrmann, Brumby, Cheng, Gilbert, & Oreszczyn, 2021; Strengers, 2011). When energy consumption data is easier for the users to access, this support people to achieve a more sustainable living, by reducing their environmental impact through technologies (Prost, Mattheiss, & Tscheligi, 2015; Tchatchoua et al., 2023).

Inspired by Hansson, Cerratto Pargman and Pargman's article *'A Decade of Sustainable HCI - Connecting SHCI to the Sustainable Development Goals'* (2021), I see it as relevant for this master's thesis to identify how the examined topic can be connected to the SDGs. It is interesting to look at the SDGs since they often constitute an established framework for global agreements that drive both politics and actions on local, regional, national, and global

[1] United Nations. (2023). *United nations - sustainable development goals.*https://www.undp.org/sustainable-development-goals

levels. The authors of the article apply the SDGs as a framework to classify and distinguish between different kinds of sustainability in sustainable human-computer interaction (SHCI) research. Hansson et al. conclude that the majority of the research within the field of SHCI has a strong focus on SDG 12 *'Responsible consumption and production'*, which they argue might be considered a problem. They see a tendency, that the research regularly proposes solutions which imply that sustainability can be interpreted as a matter of negotiation. By negotiation, they refer to either decreasing or shifting individual resource consumption in homes by informing users and implementing technologies such as eco-feedback and/or eco-visualizations (Hansson et al., 2021). While the greater part of SHCI research frames sustainability as an issue that simply can be solved by informing individuals, some researchers also question the focus on information and implementation of technologies like eco-feedback to be the solution. Other researchers start from a theoretical perspective when examining topics in relation to SDG 12. Some researchers use practice theory in studies regarding energy consumption (Hansson et al., 2021).

1.2 Energy Consumption Feedback Technologies

There is an ongoing and growing trend regarding providing householders with energy consumption feedback (Martin, 2020; Martin, 2022). With energy consumption feedback technologies, the aim is to rise awareness and persuade people to change their energy consumption behavior (Jensen, Kjeldskov, & Skov, 2018; Prost et al., 2015). When consumers receive feedback on their energy use, it is commonly argued as an effective approach to reduce energy consumption in buildings (Foulds, Robison, & Macrorie, 2017). Through these feedback technologies, companies aim to enhance householders' understanding of, and control over, their energy consumption (Martin, 2022). The conventional way of communicating energy feedback has always been paper bills. However, bills are usually not designed with the consumer's experience in mind, and often the information on paper bills is intricate to understand (Chiang, Natarajan, & Walker, 2012). Herrmann et al. (2021) express their opinion about bills metaphorically:

> *"Conventional energy bills have been likened to buying groceries in a store where products are sold without price tags and billed via monthly statements. If customers do not know how much they spend on individual items, how can they possibly hope to economize?"* (Herrmann et al., 2021).

Energy consumption feedback technologies are clearly more user-centered, and they typically include numerical or graphical information regarding energy consumption, energy generation, or price. The data is more detailed, diverse, and personalized than the energy data on conventional energy bills (Hargreaves, 2018; Martin, 2020).

1.3 Visualization and Understanding of Energy Data

Both the concept and the implementation of energy consumption feedback technologies can in various ways be rather problematic. There are two factors that potentially can influence consumers' (mis)understanding of energy data feedback. The first factor is a poor understanding of how to read and understand data visualizations, and the second factor is poor knowledge about energy in general (Herrmann et al., 2021; Martin, 2020). How the energy feedback is presented to the consumers and how the consumers understand the meaning of such feedback depends on a large scale of the design of the display interface. In the article *'A laboratory test of the efficacy of energy display interface design'* from 2012, the authors Chiang, Natarajan and Walker divide user interface design into three categories: numerical, analogue, and ambient displays. Numerical displays (figure 2) are providing detailed and quantitative information, which in theory enables quick and clear readings to be made. Numbers are commonly used when describing energy consumption, since the majority of consumers may find these easy to comprehend. Analogue displays (figure 3) are a visualization of energy consumption without numbers instead using graphs, charts, bars, dials, and column gauges. These are often considered more simple to read and interpret compared to the numerical displays. Ambient displays (figure 4) provide an overall indication of a situation, such as a green color to show if the results are good. Sometimes these make use of peripheral vision and do not require any detailed attention from the consumer. There is no text or numbers shown on the display. Instead, it is exclusively pictures, colors, sounds, or flashing lights that inform the consumer about their energy consumption (Chiang et al., 2012).

Figure 2 – Numerical displays[2] *Figure 3—Analogue displays*[3] *Figure 4—Ambient displays*[4]

The second factor that might result in misunderstanding of energy feedback, is limited knowledge about energy as a concept (Herrmann et al., 2021). A problem for many consumers is that there are a lot of terms associated with energy, that might seem difficult to understand. Especially the distinction between energy (kilowatt-hour) and power (watt) is a source of great confusion for many. Commonly to energy consumption feedback technologies is that there frequently is a (perhaps implicit) assumption that consumers need such information, like kilowatt-hour and watt, in order to manage their energy consumption. When using these terms, there is a risk of what Martin calls an *information vacuum* (Martin, 2020). When consumers do not know how to interpret and use the energy consumption feedback, there can be some consequences. These consequences can be shown as a lack of interest from consumers because the energy feedback is too confusing and unrelatable (Hargreaves, 2018). For energy consumption feedback technologies to have the hoped impact on consumers, there is a consensus in research that it needs to address people's daily routines and practices (Chiang et al., 2012; Hargreaves, Nye, & Burgess, 2010; Herrmann et al., 2021; Martin, 2022; Prost et al., 2015; Royston, 2014; Strengers, 2011; Tchatchoua et al., 2023).

[2] Chiang, T., Natarajan, S., & Walker, I. (2012). A laboratory test of the efficacy of energy display interface design. *Energy and Buildings, 55*, 471-480. doi:10.1016/j.enbuild.2012.07.026
[3] Chiang, T., Natarajan, S., & Walker, I. (2012). A laboratory test of the efficacy of energy display interface design. *Energy and Buildings, 55*, 471-480. doi:10.1016/j.enbuild.2012.07.026
[4] Chiang, T., Natarajan, S., & Walker, I. (2012). A laboratory test of the efficacy of energy display interface design. *Energy and Buildings, 55*, 471-480. doi:10.1016/j.enbuild.2012.07.026

1.4 Routines and Practices surrounding Energy Consumption

Hargreaves, Nye and Burgess (2010) argue that energy typically is *double invisible* to consumers. First, energy is an abstract force entering households through hidden wires. Second, most energy-consuming behaviors are part of routines and practices which might make it difficult for people to connect their behaviors to the energy they consume (Hargreaves et al., 2010). People are typically not approaching their behavior rationally when they are consuming energy. Consumers do simply not have a direct interest in energy consumption, but it is just something that happens when they perform activities in their everyday life (Gram-Hanssen, Hansen, & Mechlenborg, 2020; Strengers, 2011; Tchatchoua et al., 2023). For example, Royston (2014) are arguing that people understand the temperature in households not only in terms of degrees, radiator settings, or kilowatt-hours, but mostly through their own experience. She emphasizes that experience-based know-how must influence the development of technologies that help people monitor and manage heat in households. It is shown in several pieces of research, that thermal comfort is the most significant determinant of a household's energy consumption. Furthermore, people see thermal comfort as the most essential factor when talking about a satisfactory indoor environment. Various forms of experience-based know-how are influencing people's way of managing heat within the home. It can be the know-how for which temperature gives the individual comfort, an understanding of how heat flows or how to monitor radiators (Royston, 2014). Therefore, it is important to understand and recognize that the primary challenge facing energy consumption feedback is how to translate people's everyday energy consumption practices into design requirements (Chiang et al., 2012; Gram-Hanssen et al., 2020; Royston, 2014; Strengers, 2011; Tchatchoua et al., 2023).

2.0 Study context

The contribution of this master's thesis is a field study investigating the design criterias for a web application that visualize people's heat consumption. The thesis is a collaboration with Neogrid Technologies (from now on referred to as Neogrid). A presentation of the company will be given later in section 2.1. My aim is to study different types of visualizations of energy consumption and explore if the user's understanding of the data varies based on which type of visualization is used. Furthermore, I also examine if and how people's everyday practices are influencing their understanding of energy consumption. As a

techno-anthropological master's student I have worked with Neogrid on several occasions. The first project I worked on in association with them was on my 7th semester, where my group and I examined, the problem statement: *"How is the use of PreHEAT a collaborative practice in housing associations?"*. After this project I thought it could be interesting to look more into user engagement and involvement of the PreHEAT users. Neogrid gave me the opportunity to be an intern with them on my 9th semester where I studied the aforementioned. There has always been a curiosity from both mine and Neogrid's side to explore if the users were interested in an application where the users were able to get feedback on their heat consumption and the PreHEAT system in general. And if so, which requirements the users have for this application. This curiosity has been the starting point for defining the focus of my master's thesis.

2.1 Neogrid Technologies and the PreHEAT system

Neogrid is an Aalborg-based clean-tech company. It is founded by the two civil engineers Henrik Lund Stærmose and Per Dahlgaard in March 2010, and the focus of the company is on developing smart heat management solutions. Neogrid endeavors to contribute with efficient and sustainable heat management. In this process they have developed PreHEAT. PreHEAT is a system which is an intelligent and self-learning prognosis-based technological solution. The system can be implemented in different settings like private households, housing associations, shopping malls and offices. With PreHEAT it is possible to secure better energy use, since it is learning to reduce and utilize heat smarter. Neogrid states that by implementing PreHEAT, it is possible to reduce 10-20 percent of heat consumption. The PreHEAT system's main function is to provide a baseline for the flow temperature in the building. To provide this flow temperature baseline, Neogrid monitors a diverse set of factors such as weather forecasts and indoor climate (*Neogrid technologies - om os.*). It is a way of automizing monitoring, since PreHEAT continuously is keeping an eye on the building's consumption patterns throughout the day. Based on the data on the consumption patterns combined with the weather forecast, PreHEAT automatically regulates and dynamically optimizes the flow temperature (Neogrid Technologies, 2023).

2.1.1 Neogrid and the Sustainable Development Goals

According to Neogrid, their work can be related to five out of the seventeen SDGs; SDG 7 '*Affordable and clean energy'*, SDG 9 *'Industry, innovation, and infrastructure'*, SDG 12 *'Responsible consumption and production'*, SDG 13 *'Climate action'*, and SDG 17 *'Partnerships for the goals'*. The purpose of Neogrid's prognosis-based, intelligent and innovative PreHEAT solution, is to help buildings become more energy-efficient and flexible in when to consume energy. In this way, they are better at integrating energy from renewable resources (SDG 7 and 9). When the PreHEAT system is helping buildings become more energy-efficient, it is also an important step towards a more sustainable energy system, since the technology helps reduce CO2-emissions (SDG 13). An essential component for PreHEAT to function at its best, is to make users aware of their energy consumption (SDG 12). And lastly, in order to achieve the SDGs, Neogrid is collaborating with several partners, both nationally and internationally (SDG 17) *(Neogrid Technologies, n.d.)*.

This master's thesis's primary focus is related to SDG 12 *'Responsible consumption and production',* but it is not solely focused on informing users about their energy consumption to help reduce their consumption. It is essential for this study to also reflect on how the users' everyday life is, and which energy-consuming activities they are practicing.

2.1.1 The current PreHEAT Web App

One of Neogrid's main problems is that building owners and occupants have a very limited understanding of buildings as energy systems. This limited understanding is something Neogrid sees as an obstacle for them to have informative communication with the users of PreHEAT. They already have an online web app (figure 5), which their customers can access. Neogrid describes the online web app dashboard in their brochure about PreHEAT as follows:

"The PreHEAT Dashboard gives you easy and manageable insight into system operation and consumption, with key numbers, KPI, and benchmarking of comparable buildings. Manageable consumption data is visualized in intervals from five minutes up to a year – and PreHEAT is of course smart enough to detect unintentional consumption. In other words, you as a customer save money and gets a more energy-friendly building" (Neogrid Technologies, 2023). [5]

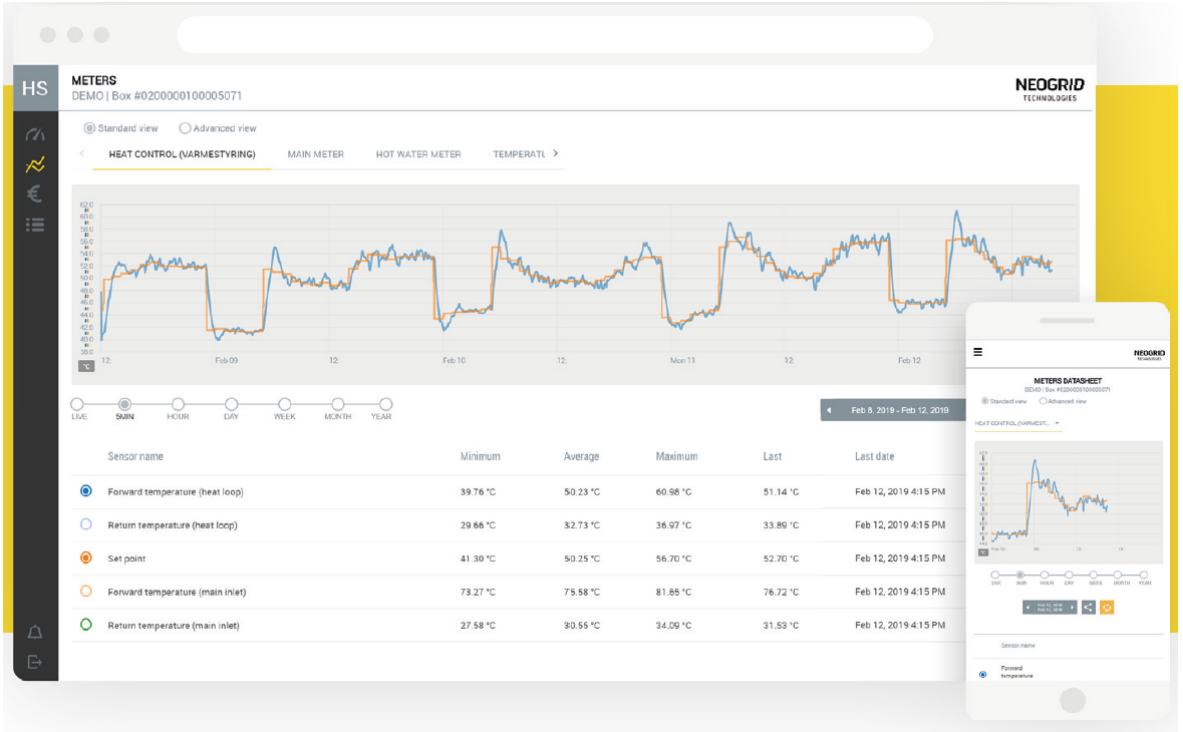


Figure 5 – Screenshot of one of the dashboards in the PreHEAT web app[6]

This online web app is developed by Neogrid with the intention of giving their customers to get an insight into the consumption data. But being in the field for quite some time and talking with several users of PreHEAT, it has become clear to me, that the majority of the users do not understand, and therefore do not use the online web app. The visualization and the information are simply too advanced for laypeople to understand. Therefore, this study will examine how energy consumption data can be visualized in the most understandable way, and also which data users find relevant in a PreHEAT web app.

[5] Translated from Danish: *"PreHEAT Dashboard giver dig nem og overskuelig indsigt i systemdrift og forbrug, med nøgletal, KPI og benchmarking af sammenlignelige bygninger. Overskuelige forbrugsdata visualiseres fra 5 minutters interval og helt op til et år - og PreHEAT er selvfølgelig klog nok til at opdage utilsigtet forbrug. Du sparer, med andre ord, penge og får en mere energivenlig bygning" Neogrid Technologies. (2023). PreHEAT - brochure*

[6] Neogrid Technologies. (2023). *PreHEAT - brochure*

3.0 Problem statement

Previous research show that if an energy consumption feedback technology, such as a PreHEAT web app would be, to influence people to reduce their energy consumption, it is essential to address people's daily practices as well. Therefore, this master's thesis will examine the following problem statement:

> *"How can energy consumption feedback be visualized in the most understandable way, and how are people's everyday practices influencing their relation to energy consumption?"*

4.0 Methodology

The following chapter will describe, discuss and reflect upon the methodological approaches of the study.

4.1 Interviews

This study has exclusively collected empirical data qualitatively. Feedback given directly from engaged and interested individuals is fundamental to research. When researchers ask themselves what a new tool should do, or if a proposed design does what it should do, the best way of finding out is by asking the users. Qualitative interviews are an approach that goes deep but not broad in the investigated topics. Direct conversations with a selected number of participants can provide insightful perspectives on the topic of interest. Surely, it is important to consider what to ask, how to ask, and who to ask, since these considerations can determine the difference between wasted time and valuable insight. Furthermore, reflections on the structure of interviews can have a significant role on the outcome (Lazar, Feng, & Hochheiser, 2017).

4.1.1 Participants

When selecting which kind of participants are usable for the study, there are different things to take into consideration. First, it is necessary to reflect upon if the participant should be a current or a potential user of the proposed technology that is under investigation. In different cases, different kinds of interviewees can have diverse views on the investigated topic, and

therefore, it is essential to include representatives from each type of user category. This will probably help to ensure that the empirical data are not missing significant perspectives (Lazar et al., 2017). In some studies, it can be interesting to interview an expert in the area. Experts have scientific reflections on topics that users do not have. When interviewing experts, it is particularly essential that the interviewer has thoroughly familiarized herself with the subject, and should know the terms used in the specific scientific area. This preparation from the interviewer will most likely provide a more insightful interview (Kvale & Brinkmann, 2008).

Since this study is solely about the PreHEAT web application, the interviewees are current users of PreHEAT. The access to the field has been through Neogrid, which has given me the contact information of several of their users, this being either the janitors from housing associations where PreHEAT is implemented or private householders. Then it has been my responsibility to contact these users to see if they had an interest in participating in this study's interviews. To get a diverse set of interviewees, there are both interviews with people living in rented units and people owning their own houses.

Furthermore, I was invited by Neogrid to a meeting in Voerladegaard, where Neogrid together with other partners is participating in an EU project. The EU project is called 'H2020 SUSTENANCE', and has the overall purpose of setting up sustainable energy systems, to get the outcome of carbon-neutral energy communities (Sustenance Project, 2023). In Voerladegaard there are 20 test families, who all have heat pumps in their private households. The PreHEAT system has been implemented in these 20 test families' heat pumps. On the 16th of March 2023, there was a meeting, where the test families could ask questions about the project, and some employees from Neogrid made some presentations as well. Here, I had the opportunity to present myself and the aim of my master's thesis for the test families, in the hope of finding interviewees. Luckily, five people were interested in getting interviewed.

Additionally, there has been an expert interview with one of the employees at Neogrid. The employee, Kim, at Neogrid, is an interaction designer. Kim has worked with the design of the web app and has both methodological and theoretical insights from his education towards how to create an understandable user interface. Therefore, it was interesting for me to hear about which thoughts have formed the basis for the PreHEAT web application.

All in all, the empirical data in this master's thesis emerge from 11 interviews with users and one expert interview. In some interviews, there were two informants, and therefore the qualitative data contains 15 informants. These informants will be introduced below.

Name	**Age**	**Profession**	**Number of people in the household**	**House owner/renter**
Bo	60s	Pensioner	One adult	Renter
Karsten	40s	Engineer in the energy sector	Two adults and three children	Owner
Lars	60s	Early pensioner	Two adults	Renter
Michelle	60s	Early pensioner	Two adults	Renter
Malene	20s	Student	Two adults	Renter
Kenneth	20s	Student	Two adults	Renter
Morten	50s	Consultant in a union	Two adults and one child	Renter
Lillian	50s	Early pensioner	Two adults and one child	Renter
Niels	30s	Carpenter	One adult	Renter
Bente	50s	Early pensioner	Two adults	Owner
Klaus	50s	Landscape architect	Two adults	Owner
Kalle	40s	Chief within gas trade in the energy sector	Two adults and three children	Owner
Nicklas	80s	Pensioner	Two adults	Owner

Majken	70s	Pensioner	Two adults	Owner
Rasmus	50s	Road engineer	Two adults	Owner

4.1.2 The structure of the interview

There is a continuum that stretches over how much structure there is in an interview. This continuum goes from fully structured to semi-structured and lastly to unstructured. A *fully structured interview* has a rigid script with questions in a predetermined and well-defined order. Here, it is not possible to go out of the script and ask other questions than the ones in the predefined interview guide. A fully structured interview has its pros and cons. For example, it is important that the interviewer follow the interview guide, and if the interviewee makes some statements that could be interesting to follow up upon, this is just bad luck. Requests for clarifications or asking additional questions are not seen as appropriate, since the primary motivation for the fully structured interview is to ensure that every interviewee is asked the same questions. A *semi-structured interview,* on the other hand, makes the room for clarification and additional questions. These interviews have, as fully structured interviews, a predefined interview guide with predefined questions. The primary motivation for semi-structured interviews is to reflect on the interviewee's comments and to get an insight and understanding of their thoughts. Lastly, an *unstructured interview* is simply just based on a list of topics and maybe an initial question for the interview. Hereafter, the interview goes in the direction that the answers from the interviewee is leading (Lazar et al., 2017).

Every interview in this study is conducted as a semi-structured interview. In this way, it has been possible to keep the interviews on the same track and ensured that every interesting topic has been discussed. The elements from the semi-structured interview have made it possible to follow a predefined interview guide (Appendix 1), but also get the interviewees to elaborate and explain their answers when relevant.

4.1.3 Types of Questions

A general thing to keep in mind when drafting questions for an interview is, that they should be kept short and simple. Kvale and Brinkmann (2008) argue that there are five different types of questions which can be used in interviews. *Initial questions* are open and yet relevant to the topic. These will provide spontaneous, insightful descriptions where the interviewee

explains their thoughts and reflections on the relevant topic. *Follow-up questions* can help to expand the interviewee's answer and show the interviewee that the interviewer is interested in what she is saying. Furthermore, follow-up questions can contribute to getting the answers more specified. *Direct questions* are where the interviewer directly asks about a specific topic. *Indirect questions* can be used if the interviewer is interested in knowing what the interviewee thinks is another's opinion. Answers to indirect questions sometimes reveal a part of the interviewees' opinions as well. *Interpretive questions* can be necessary to use, to be sure, that the interviewer is interpreting the answers correctly (Kvale & Brinkmann, 2008).

The interviews conducted for this study are including all five types of questions. They all start with initial questions, followed by direct and indirect questions. I, the interviewer, had prepared some follow-up questions which could be asked if necessary. Lastly, both some spontaneous follow-up questions and interpretive questions were asked in the interview if needed.

An example of an initial question used in this study is the first question I, the interviewer, asked the informants: *"How do you usually monitor your energy consumption?"* To this question, some follow-up questions were prepared: *"Reading on the meter, looking at the energy bill, have installed an app (ex. Watts)."* These different kinds of ways to monitor the energy consumption were to make sure, that the informants understood the question, and furthermore to lead them in the right direction, if they did not know how to answer the question. An example of a direct question from the interview guide could be: *"Do you think about which activities you perform in your everyday life, that use a lot of energy?"* With the follow-up question: *"If so, are you trying to change those activities?"*. If the informants did not understand what kind of activities I was talking about, I had written some examples down in the interview guide, such as cooking, showering and laundering. Lastly, the interpretive questions were of course not a part of the interview guide. These came up, if I had to make sure, that I understood the interviewees answers correctly. An example of this, was when I interviewed an informant named Bente. We were discussing her understanding of a visualization, and before we went further in the interview, I needed to be sure, that I interpreted her statements correctly. Therefore, I asked her: *"Well, as I understand it, you think that this overview actually is reasonable clear and easy to interpret?"*.

4.1.4 The Think-Aloud Technique

When interviewing, it is important, that the interviewer is not too intrusive when the interviewee is thinking. It can simply get the interviewee confused or distracted if she needs to relate to the interviewer when reflecting on things asked in the interview. Therefore, the think-aloud technique can be very useful. This is a useful way to get an insight into, what is happening in the interviewee's head. This technique is used when the interviewee is silent, and the interviewer would like to know what is going on in their head, and what they are thinking. The think-aloud technique simply is to get the interviewee to say out loud everything she is thinking so that her thought process is externalized (Sharp, Rogers, & Preece, 2019).

The think-aloud technique will be used as an exercise in the interviews, to fully understand what the participants are focusing on when looking at the visualized energy consumption feedback. It is assumed, that when people tell by themselves what they look at and how they interpret it, it will be easier to get an insight into their (mis)understandings of the interface.

To give the reader an understanding of, how I, the interviewer, encouraged the informants to talk about the prototypes of the app, a quotation from the transcription of the interview with Bente will be shown here:

> *"I have some different screenshots from the app. What I would like to hear is if you just talk completely freely about what you think, when you see the screenshots. What do you notice first? Is there something you think makes perfect sense, and is there anything you do not understand at all? Simply just all your thoughts about it."*

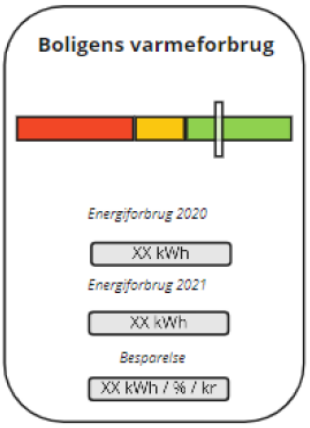
4.2 Prototypes

Often, it is difficult for users to explain what it is they want in technologies, but when they see something specific and get it in their hands, they can quickly tell what they do not want. Sharp et al. (2019) describe prototypes as follows:

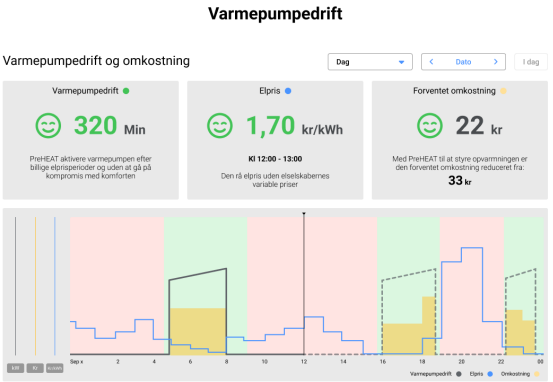
> *'Prototyping provides a concrete manifestation of an idea—whether it is a new product or a modification of an existing one—which allows designers to communicate their ideas and users to try them out' (Sharp et al., 2019).*

Prototypes can be in the form of diverse things; from a paper-based storyboard to a very complex piece of software, or a piece of metal. A *low-fidelity prototype* is a prototype that does not look like the final product and does not have the same functions as the final product. It may be in different materials, such as paper instead of on an electronic screen, and therefore only represent the functions and not perform any of them. On the other hand, *A high-fidelity prototype* looks like a final product and usually shows more functionality. Prototypes are simulating scenarios for how to use the technology, and in this way, help users to understand its usability. Prototypes are especially beneficial when discussing or evaluating ideas regarding technologies, they are a simple form of visual communication among users and a constructive way for designers to explore and investigate design ideas. The purpose of prototypes can vary from testing a product to clarifying some vague requirements to getting users to test and evaluate, or checking if a particular design is adaptable to the rest of product development (Sharp et al., 2019).

In this study, two different prototypes with two different purposes have been used. First, paper-based mock-ups were produced (Appendix 2). These mock-ups exemplify how to visualize energy consumption data in an application. These low-fidelity prototypes have been used in the interviews, to get an understanding of how users interpret energy data easiest, and also what kind of visualization users do not understand or think is irrelevant. They show the intended buttons and functions in the application, their positioning, color, and labelling, and also the overall shape of the device. An example of how the low-fidelity prototypes looks like, is seen to the right. The prototype is illustrating a household's energy consumption compared with last year's energy consumption, and a color scale to visually show the users, if the development in their energy consumption is positive or negative.



The second kind of prototype (Appendix 3) used in this study is a high-fidelity prototype of how the web application might look. This one is more detailed and shows data in several ways. For the interviews, I presented screenshots of dashboards from the web app. Since it was screenshots, it was of course not possible for the interviewees to navigate in the web



application, and therefore it was mostly the visualized design that was the topic of interest. An example of how the high-fidelity prototypes looks like, is seen to the right. The prototype is illustrating the key numbers and a graph in relation to the user's heat pump operation.

4.3 Methodological quality criteria

When collecting empirical data, some methodological decisions need to be made. Before entering the field, and starting to conduct data, there are some thoughts the researcher is required to have reflected upon. Should the empirical data be treated statistically, are the methodological approaches reliable, and has the method helped produce the intended data? (Sharp et al., 2019).

4.3.1 Reliability

The reliability of a method tells something about how the results will be produced on another occasion, but under the same circumstances. Is it possible that another researcher who follows the exact same procedure will get the same results (Sharp et al., 2019)? Since this is a strictly qualitative study, it is difficult to secure high reliability. Individuals interviewed about the same topic will always have different opinions and statements, and even if interviewing the same person, some diversity will probably occur. However, an attempt has been made to have a high degree of reliability in the study. First, in the semi-structured interviews, the same interview guide has been followed. Furthermore, when evaluating the prototype this is under a controlled setting, where the researcher has some predefined tasks for the interviewee to perform.

4.3.2 Validity

The validity of a method is concerned with whether the method measures what it is planned to measure. It is important to consider if the chosen methods are examining the exact problem that is intended. Furthermore, the validity of a study is also about the generalizability of the results. The generalizability is among others influenced by the representation of participants (Sharp et al., 2019). The validity of the study is high due to the semi-structured interviews. The predefined questions secure, that the information given in the interviews is relevant. However, the generalizability of the study might lower its validity. A consequence of qualitative empirical data is, that due to pragmatic obstacles, the number of participants will

not be as high, as if the empirical data were conducted through, for example, a quantitative questionnaire. Furthermore, it is not possible to have a completely random selection of participants, and therefore the results might be difficult to generalize.

5.0 Theory

The following chapter will introduce practice theory, which is this master's thesis' theoretical approach.

5.1 Practice theory

It is widely known and acknowledged that a global transition toward a more low-carbon society is essential (Mechlenborg & Gram-Hanssen, 2020). When working towards a low-carbon society, it is often discussed how to improve the energy performance in buildings. Almost 40 percent of all global energy consumption is somehow related to buildings. In most countries, regulations of building energy are shown as codes and energy labels, which are based on hypothetical calculations of the energy performance of the building. Gram-Hanssen and Georg (2018) argue in their article *'Energy performance gaps: promises, people, practices'* that even though these energy labels are widely used, there are seen notable differences between the hypothetical (i.e. anticipated or promised) and actual energy performance, once the buildings are inhabited by people (Gram-Hanssen & Georg, 2018). Therefore, to reduce energy consumption it is important to look at households and how energy is consumed since it is expected that a substantial reduction is possible in households. A crucial element of sustainable everyday lives is household's energy consumption, and for that reason, it is pertinent to understand the daily routines and the use of technologies that are closely related to energy consumption (Gram-Hanssen, 2009; Gram-Hanssen, 2010a; Mechlenborg & Gram-Hanssen, 2020). An essential aspect of energy consumption in households is that the consumed energy is a part of the performance of people's everyday practices, such as cooking, laundering, and heating up their homes. Energy consumption is not something the average consumer has a direct interest in, but is something happening when they perform everyday activities that are significant to them. This has an influential effect on understanding how energy consumption, and the often linked technologies, are integrated into the everyday lives of households (Gram-Hanssen et al., 2020). To get this understanding, this master thesis will use practice theory to examine people's perception of

energy consumption, and furthermore link it to the PreHEAT web app. This study will mainly be inspired by Kirsten Gram-Hanssen and her view on practice theory, but since she is inspired by other practice theorists, it is of course essential to get an overview of these.

5.1.1 What is a practice?

Gram-Hanssen's work is mainly inspired by practice theory as formulated by Theodore R. Schatzki (1996) which emphasizes that body and things (or technologies) are essential for understanding practices (Gram-Hanssen, 2009; Gram-Hanssen, 2010a; Gram-Hanssen, 2010b; Gram-Hanssen, 2011).

Schatzki emphasizes that there is no universal common understanding of the definition of practice theory since there are several contributions originating in philosophy, cultural theory, social sciences, and science & technology studies (STS). The common denominator is that every kind of practice theory sees practices as the most important for understanding the social, whereas other theories might emphasize language, actions, structure, or systems in their definition of the social (Gram-Hanssen, 2009). Schatzki defines a practice as follows:

> *"A practice is a temporally evolving, open-ended set of doings and sayings linked by practical understandings, rules, teleoaffectice structures, and general understandings" (Schatzki, 2002)*.

A practice is thereby a set of doings and sayings, and also a manner of understanding and describing these sets. Doings and sayings can be hierarchically divided. They can be seen individually at a basic level, when there is a collection of doings and sayings it forms a level of *tasks*, and lastly, at a higher level, several tasks can form *projects*. Normally when people are performing a practice, they will carry out a set of both hierarchically organized doings and saying, tasks, and projects. Practice theory acknowledges practices as social, and thereby an important aspect is, that when performing a practice, people coexist with other people socially. It is not only coexisting with those they interact with (e.g. when practicing laundering, it is often other family members). They also coexist with other people who are performing the same practice (e.g. the majority of people in Western societies share the same laundering practices (Gram-Hanssen, 2009).

5.1.2 Four elements holding practices together

In his definition of practices, Schatzki (2002) proposes four elements of what hold doings and sayings in practices together. These are *practical understandings, rules, teleoaffectice structures, and general understandings* (Gram-Hanssen, 2009). Several practice theorists, which are influenced by Schatzki's work, include these four elements somehow (Gram-Hanssen, 2010a). Kirsten Gram-Hanssen is also inspired by these four elements when analyzing people's everyday life, but has reformulated the names of the elements, composed some of them, and added a new element. In this master's thesis, it will be the four elements developed and defined by Gram-Hanssen (2010a) there will be the foundation for the analysis. The four elements holding a practice together are:

- *Practical understanding, embodied habits, know-how*
- *Rules, knowledge, language*
- *Engagements, meanings*
- *Products, things, technologies*

In the following section, these four elements will be explained. It is important to understand, that even though these four elements are different ways of holding a practice together, all four elements are equally important for understanding practices (Gram-Hanssen, 2009).

5.1.2.1 Practical understanding, embodied habits, know-how

The first element holding a practice together is '*practical understanding, embodied habits, know-how'*. The most essential about this element is people are able to know what to do, and how to identify and react to specific situations. It is routinized bodily and mental activities which are carried out by practitioners. When performing these routinized bodily or mental activities, the practitioners respond to the patterns that constitute the specific practice and furthermore contribute to sustaining and developing the practice. It is a capacity the practitioner possesses and is underneath the action of the practice (Gram-Hanssen, 2009; Gram-Hanssen, 2010a).

5.1.2.2 Rules, knowledge, language

The second element holding a practice together is '*rules, knowledge, language'*. By rules, it is meant rules about how to do things. It is not only explicit rules such as what is legally

allowed and what is not, but implicit rules and tacit knowledge is included as well. It can for example be the practitioner's knowledge of technical stuff. As tacit knowledge, things like cultural myths can be essential to include in this second element, since these can have an influence on how the practice is being practiced (Gram-Hanssen, 2009; Gram-Hanssen, 2010a).

5.1.2.3 Engagements, meanings

The third element holding a practice together is '*engagements, meanings'*. This is about how practitioners are goal-oriented, and how they are engaged. The meaning and engagement are often accumulated through the practitioner's actions. Regularly this element is influenced by normative views or moods in society, and therefore it is frequently seen, that the meaning and engagement are not individual, instead, they probably follow general norms (Gram-Hanssen, 2009; Gram-Hanssen, 2010a).

5.1.3.4 Products, things, technologies

The fourth element holding practices together is *'products, things, technologies'*. This fourth element is an element Gram-Hanssen has developed herself. She has seen through several studies of people's practices in everyday life and has concluded that technologies and things typically take part in performing and structuring practices (Gram-Hanssen, 2009; Gram-Hanssen, 2010a). Technologies are not only seen as inevitable for holding practices together, but they are also seen as an important element for bringing changes into practices (Gram-Hanssen, 2011).

5.1.3 New technologies develop new practices

Gram-Hanssen acknowledges that there is a co-evolution between new technologies and new practices. Her inspiration for this acknowledgment comes from Elizabeth Shove and Mika Pantzar's article *'Consumers, Producers and Practices'* from 2005 (Gram-Hanssen, 2009; Shove & Pantzar, 2005). In this article, Shove and Pantzar study Nordic Walking and argue that two well-known things, a pair of sticks and the practice of walking, have been developed into a new practice of Nordic Walking. They state that artifacts are acquired and used to accomplish practices, but that it is not enough to show that these artifacts are symbolically and materially situated and mediated in existing cultures. It is influential to be able to understand and describe how practices change when they co-exist with new artifacts or

technologies. Practices and technologies are closely intertwined, and Shove and Pantzar focus on two points of this intertwined co-existence. Firstly, innovations in practices are ongoing. Practice, whether they are new or not, requires a form of continual reproduction to exist. People have to perform the practice if the practice has to 'be', and what the practice become depends on who does it and on when, where, and how the practice is done. Secondly, both practitioners and producers of artifacts are equally important for the practice. After all, it is the practitioners, who are the performers of the practice, and therefore crucial for the practice to happen (Shove & Pantzar, 2005).

It is not just an obviousness that when introducing new artifacts or technologies, a new practice will be developed. It is important to look at how people relate to these new technologies in the different consumer phases of acquisition of the technology, using the technology, and disposing of the technology. Furthermore, it is not exclusively about the practitioners getting used to new technologies and being able to use them. Both the practitioner and the technology may change over time, and this might result in use patterns that were not anticipated. In this appropriation of new technologies, there are two processes; internalization and externalizing. *Internalization* is the first step in the process of appropriation, and it is where the technology is singled out and given a place in the practitioner's life. In the beginning, internalization is a cognitive adoption, since it is required some skills and know-how from the practitioner to use the technology properly. This cognitive adoption is often an ongoing process, simultaneous with the relationship between the technology and practitioner going through a transformation. There is a process from an objective understanding of the technology to a subjective understanding. The appropriation process will not only change the relation between the technology and the practitioner, but it will also change the practices. Over time these practice becomes routine, and sometimes the practitioners might even stop to reflect on the technology since it just become a part of the practice. The second part of the appropriation process is the process of *externalizing*. Here, practitioners show other people how, when, and where they use the new technology. In this way, the practitioners might be involved in the development of the practice, since other people might find the usage interesting (Gram-Hanssen, 2009).

5.1.4 Practice Theory and Energy Consumption

Gram-Hanssen argues that combining practice theory and energy consumption in households might be complicated in some ways. The difficult element is that in a household's energy

consumption, a multiplicity of practices is revealed. It is not a practice alone to consume energy, but rather an element or a consequence for several practices. Furthermore, from a practitioner's point of view, energy consumption is often a rather unnoticed and uninteresting element (Gram-Hanssen, 2009; Gram-Hanssen, 2011). Practices in everyday life, that contribute to a household's energy consumption, might include cooking practices and laundering practices, but also the practice of making a home, which is meant to keep a comfortable temperature and lightning, as well as cleaning, decorating, maintaining, and furnishing the home. All of these practices might be more significant for people performing them, than thinking about the element of energy consumption. Therefore, Gram-Hanssen argues, that it is relevant to analyze a household's energy consumption with practice theory. People perform practices for different reasons in their everyday lives and with different purposes. These practices imply or are followed by energy consumption. That being the case, to understand energy consumption is it significant to focus on the several practices people perform (Gram-Hanssen, 2009).

6.0 Coding and analysis strategy

When analyzing the conducted qualitative empirical data in this master's thesis, it will be done with inspiration from Jennifer Attride-Stirling's (2001) approach of thematic analysis by using thematic networks. This approach is relevant for the study both due to epistemological and theoretical reasons. The scientific theoretical approach in this study is hermeneutics. The basic ideas in the hermeneutic approach are, that people always will have a preconception. A preconception can be divided into three categories; language, conception, and personal experience. By *language,* it is meant that the language of an actor is a part of her preconception. People understand the world through the concepts their language makes available. By *conception*, it is meant the assumption an actor has about the world, It can be assumptions about how the society is, or assumptions about other people and themselves. Lastly, by *personal experience*, it is meant that it is obvious that different people have different personal experiences. These experiences are often rooted in their awareness of how things in the world are. The ontological aspect of hermeneutics is, that the understanding of the world must be understood based on the stories and actions of social actors. The epistemological, and therefore how to interpret the understanding of the world, can only be found through the use of the *hermeneutic spiral*. The hermeneutic spiral is the connection

between what is interpreted, the preconception, and the context in which it must be interpreted. All interpretation consists of constant movements between what the researcher has to interpret and the context in which it is interpreted, or between what the researcher has to interpret and her own preconception (Gilje & Grimen, 2002). Especially for epistemological reasons, a thematic analysis using thematic networks will be a perfect match in this study. When interpreting how the users of the PreHEAT web-app understand the app, it is important for me as a researcher to both be aware of the interviewees preconceptions and also remember the concepts and terms Kirsten Gram-Hanssen's practice theory contributes with.

6.1 Thematic Analysis using Thematic Networks

In the following section, the technique of thematic analysis and thematic networks will be presented. Attride-Stirling argues that even though more and more researchers use exclusively qualitative empirical data, there are missing some general guidelines for how to analyze the textual empirical material that qualitative researchers collect. If qualitative research is to capitulate meaningful and useful results, it is important to analyze the data in a methodical manner. Therefore, she has written down a step-by-step guide where she presents the analytical process of qualitative data, which this master's thesis uses. She defines her methodological approach as: *'(...) thematic analyses can be usefully aided by and presented as thematic networks: web-like illustrations (networks) that summarize the main themes constituting a piece of text* (Attride-Stirling, 2001). Furthermore, she argues that:

> *'The technique provides practical and effective procedures for conducting an analysis; it enables a methodical systematization of textual data, facilitates the disclosure of each step in the analytical process, aids the organization of an analysis and its presentations, and allows a sensitive, insightful and rich exploration of a text's overt structures and underlying patterns* (Attride-Stirling, 2001).

Thematic networks are an analytical tool that aims to explore the understanding of qualitative empirical data.

6.1.1 Thematic Networks

Thematic networks are web-like networks, which in the end may help the researcher go from qualitative empirical text to an actual interpretation. It systematizes the extraction of three categories of themes: *Basic Themes, Organizing Themes, and Global Themes.* These themes help break up the qualitative text and find the explicit rationalizations and their implicit significations. *Basic Themes* is the lowest-order theme that is extracted from the textual data. These are simple premises that are characteristic of the data. In order to make sense, Basic Themes need to be seen in the context of other Basic Themes. When several Basic Themes are seen as a whole, they represent Organizing Themes. *Organizing Themes* is the middle-order themes, which are clustering Basic Themes into similar issues. Organizing Themes are more abstract, and are summarizing the principal assumptions in the Basic Themes. A group of Organizing Themes will together form a Global Theme. *Global Themes* are the super-ordinate themes that include the principal metaphors in the qualitative data as a whole. They present an argument or an issue or reality which is seen in the data. When creating a thematic network, it starts with the Basic Themes and works towards the middle to the Global Themes. When presenting thematic networks, they are graphically web-like networks, and the reason for this is to remove any thought of hierarchy between the themes. There is an interconnectivity between all three categories of themes. An example of how a thematic network could look is presented below (Figure 6):

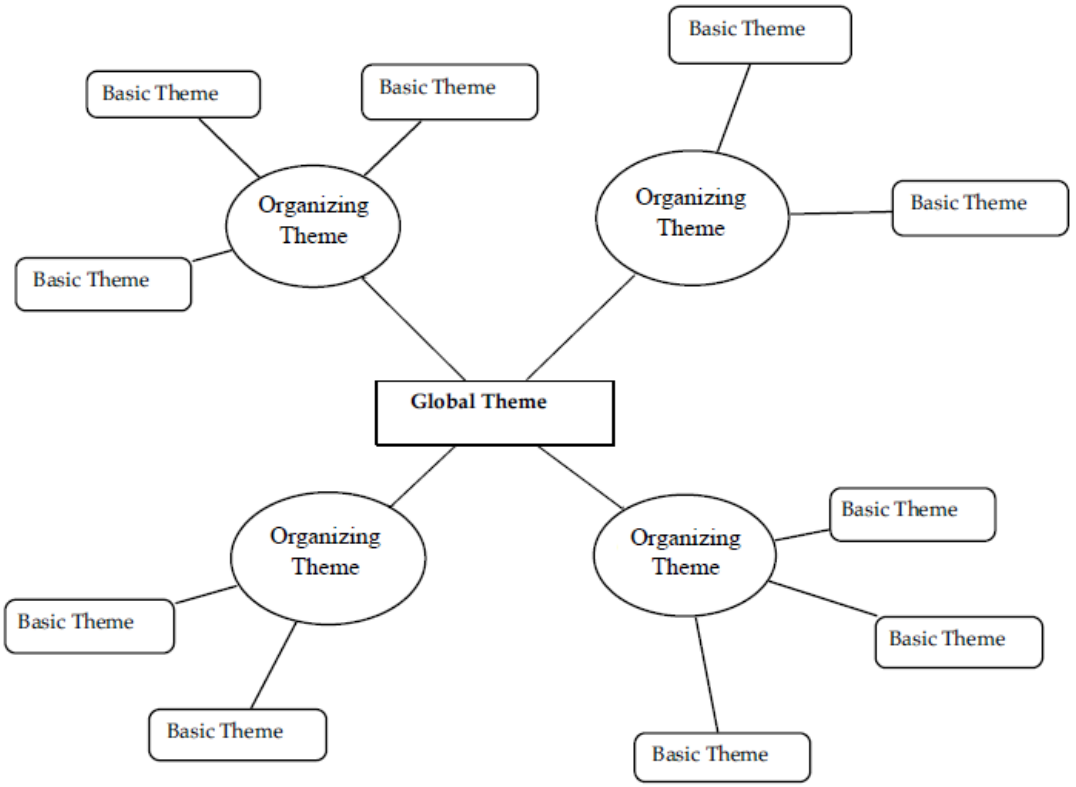


Figure 6: Structure of a Thematic Network [7]

6.1.2 How to do a thematic networks analysis

There are six steps in a thematic networks analysis, and these are as follows: *1) Coding the material, 2) Identifying themes, 3) Constructing the thematic networks, 4) Describe and explore the thematic networks, 5) Summarize the thematic network and 6) Interpret patterns*.

In step 1 *'Coding the material'* the data is to be reduced. There are several ways of reducing data, but it tends to be on the basis of theoretical concepts and interests, on the basis of outstanding issues, or even on both. When reducing, or coding, the data, it is the researcher trying to pick out meaningful and manageable parts of the qualitative data. This can be quotations, passages or single words. In step 2 *'Identifying themes'* the codes will be divided into themes by extracting the prominent, common or significant themes in the codes. This step requires a lot of interpretative work from the researcher. In step 3 *'Constructing the networks'* is the step where the thematic networks will be created. Here, both Basic Themes,

[7] Attride-Stirling, J. (2001). Thematic networks: An analytic tool for qualitative research. *Qualitative Research, Sage Publications,*

Organizing Themes and Global Themes are identified, and the thematic networks visualized in non-hierarchical, web-like illustrations. In step 4 *'Describe and explore the thematic networks'* it is the phase where the thematic networks will be described and explored, and the researcher dig deeper into the understanding and meaning of the qualitative data. In step 5 *'Summarize the thematic networks'* the thematic networks will be presented in a fulfilling summary, where the main themes and patterns that are characterizing it will be underlined. Lastly, in step 6 *'Interpret patterns'* is where the summaries of the networks and the concepts from the relevant theory is used to explore the significant themes, patterns, concepts, and structures that are found in the qualitative data. The aim with the last step is to make a thematic analysis, where the researcher answers the research questions of the study and the theoretical interests underpinning them. This will be done by using arguments which are grounded in the patterns that appeared in the exploration of the qualitative data (Attride-Stirling, 2001).

6.2 Thematic networks and analysis in this study context

In the following section, the six steps in a thematic analysis with thematic networks will be described in relation to this study. The thematic analysis will be based on the 11 conducted qualitative interviews.

6.2.1 Step 1: Coding the Material

Step 1 in the coding phase is where the empirical data is reduced. The way of reducing the data is by extracting parts of the qualitative data out, such as quotations, entire passages or single words (Attride-Stirling, 2001). Before it was possible to start the coding process, I wanted to transcribe the qualitative interviews. When the interviews are transcribed, it is much easier to comprehend the massive amount of information. Therefore, the 11 interviews were transcribed, and then Step 1: 'Coding the material' could begin. Before looking at the transcribed interviews, I wanted to reflect on which kind of information that could be interesting to give attention when reducing the data. The four theoretical concepts from Kirsten Gram-Hanssen's practice theory '*practical understanding, embodied habits, know-how'*, '*rules, knowledge, language', 'engagements, meanings'* and *'products, things, technologies'* were, of course, important aspects of this phase. Furthermore, passages or citations about outstanding issues such as the informants opinions of technologies, interest in

energy consumption and their understanding of different visualizations were also extracted. The process in Step 1 was simply to go through every transcription once at a time, while hearing the recorded interview, and then extract these fascinating citations, passages, or words. Each time a citation, passage, or word was extracted from the transcription, I gave it a headline, so that it was easier to manage the massive amount of extracted parts. The headlines are also what could be called codes. These, in total 42, headlines (or codes) were afterward written down on yellow post-it notes, to get an easier overview of the different kinds of information.

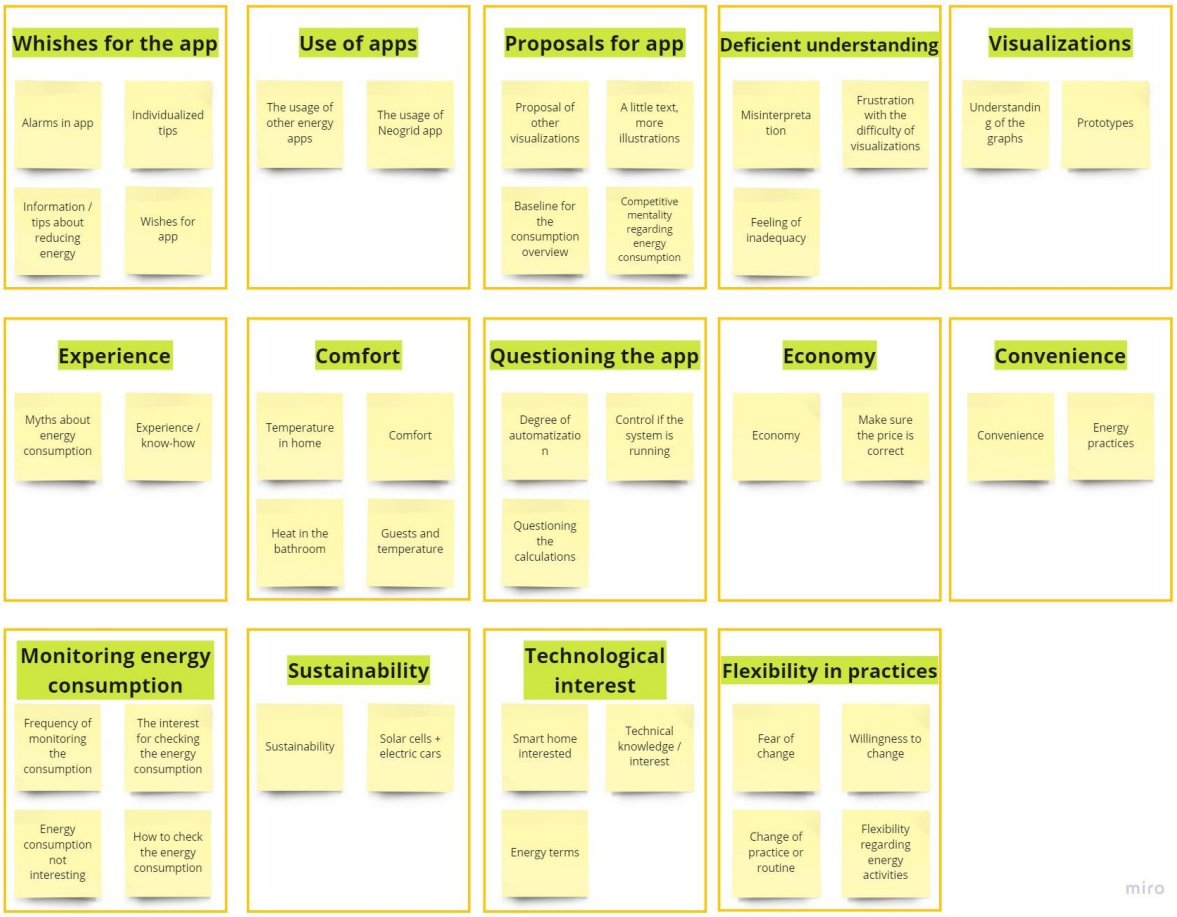
6.2.2 Step 2: Identifying themes

In step 2 of the coding process, the codes are divided into themes. It is an interpretive part of the work to extract these significant, prominent and common themes in the codes (Attride-Stirling, 2001). After seeing the codes that were created in step 1 of the coding process, I realized that I might have taken an advance to step 2. There has already been some interpretive work of the data since the headlines were not only for just one passage or citation from the text but rather a more overall headline for several passages or citations. Therefore, these headlines might already be characterized as

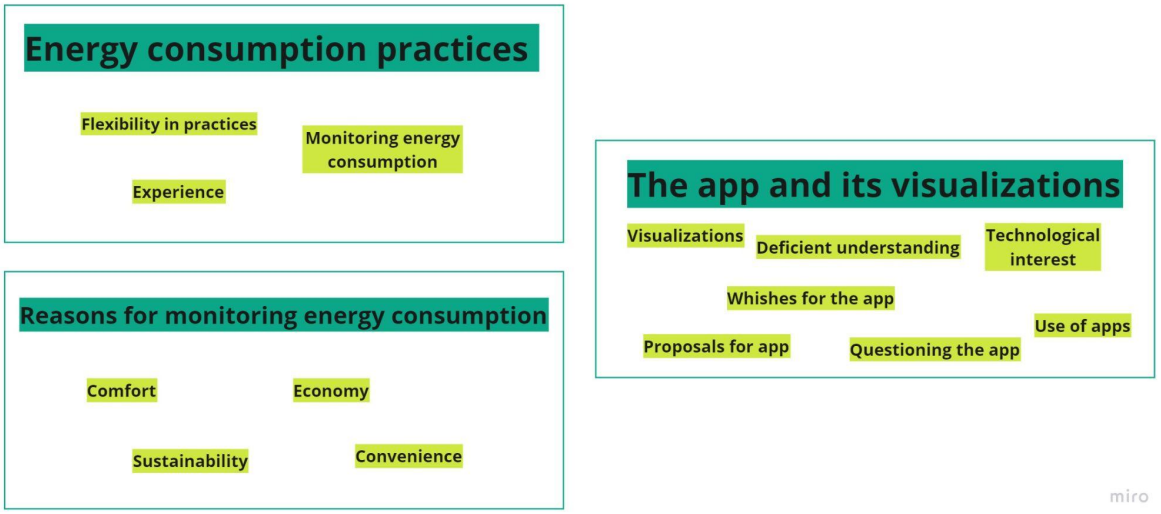
themes. The themes on yellow post-it notes were digitalized, to get a more simple overview. During the next four steps in the coding process, I will rely on the digitalized post-it notes.

6.2.3 Step 3: Constructing the thematic networks

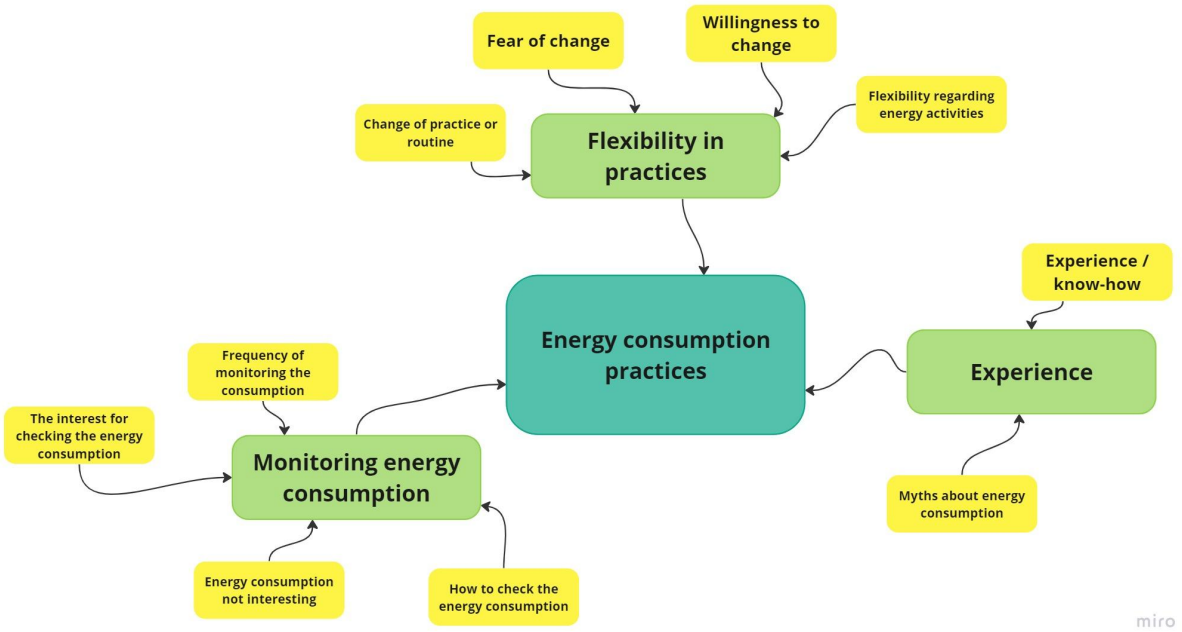
The next step in the coding process is Step 3, where the thematic networks will be constructed. In the non-hierarchical and web-like thematic networks, both the Basic Themes, Organizing Themes, and Global Themes will be identified and presented (Attride-Stirling, 2001). First, the Basic Themes were identified. The Basic Themes are the 42 themes identified in Steps 1 and 2, and therefore these already are identified. Second, the Organizing Themes were identified. When a cluster of Basic Themes is seen together, they represent Organizing Themes. The Basic Themes in the clusters may have some similarities, and therefore I went through the Basic Themes to connect related themes. The 42 Basic Themes were reduced to 14 Organizing Themes, which can be seen below. The Organizing Themes were also given a title, in which characterize all the containing Basic Themes.

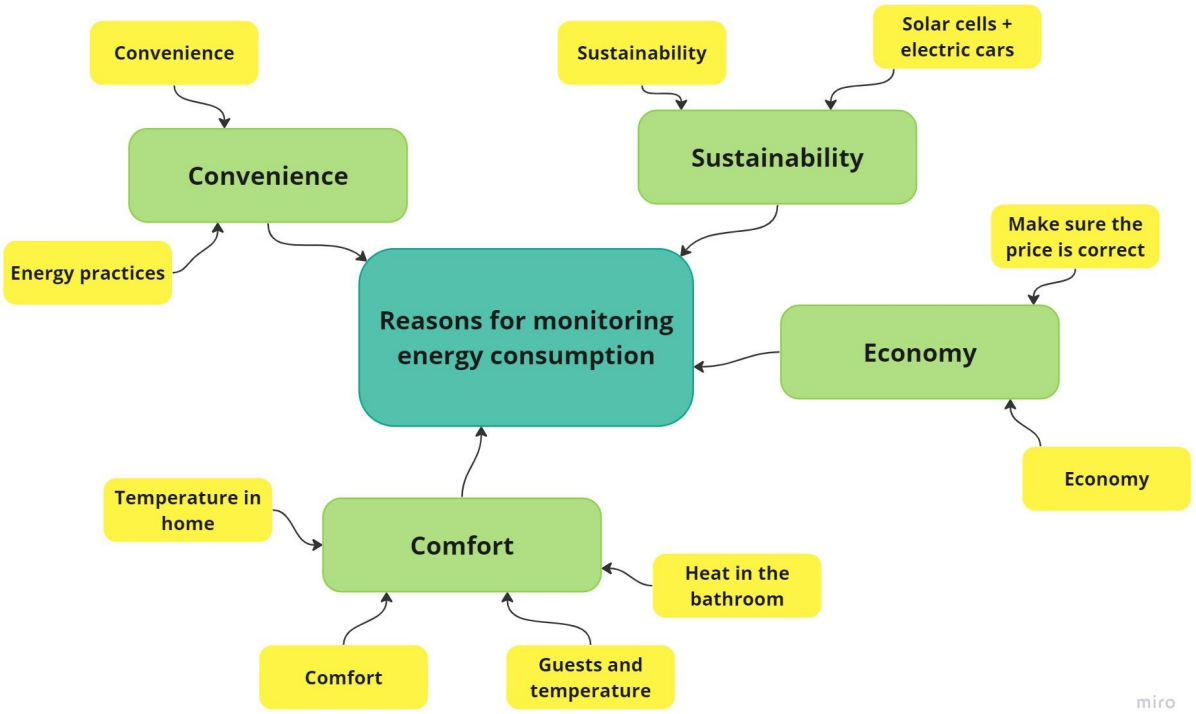


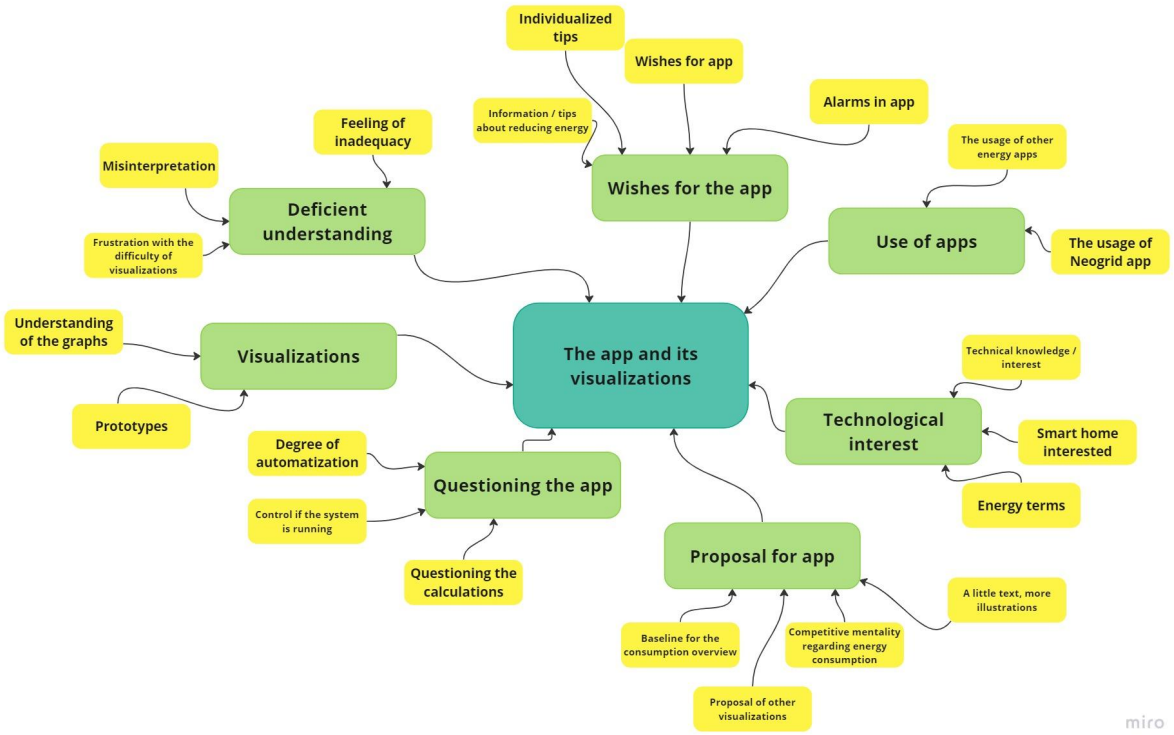
Third and lastly, the Global Themes were identified. These super-ordinate themes present either an argument or an issue seen in the qualitative data. To identify the Global Themes, the Organizing Themes were clustered into groups with similar assumptions. The 14 Organizing Themes were reduced to three Global Themes, which are shown below with titles.



Now, both the Basic Themes, Organizing Themes, and Global Themes have been identified from the qualitative data, and the thematic networks can be constructed. Since three Global Themes have been identified, the thematic analysis in this master's thesis will be based on three thematic networks, illustrated below.


Fear of change
Willingness to change
Flexibility regarding energy activities
Change of practice or routine
Flexibility in practices
Experience / know-how
Energy consumption practices
Experience
Frequency of monitoring the consumption
The interest for checking the energy consumption
Monitoring energy consumption
Myths about energy consumption
Energy consumption not interesting
How to check the energy consumption
miro

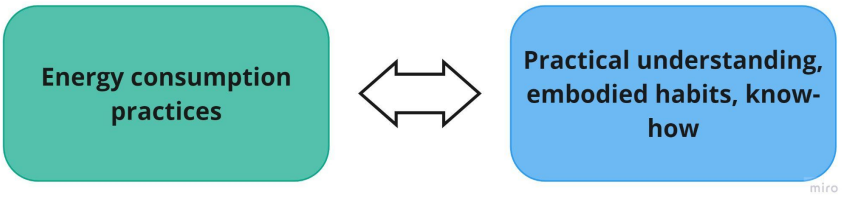

Convenience
Sustainability
Solar cells + electric cars
Convenience
Sustainability
Make sure the price is correct
Energy practices
Reasons for monitoring energy consumption
Economy
Economy
Temperature in home
Comfort
Heat in the bathroom
Comfort
Guests and temperature
miro



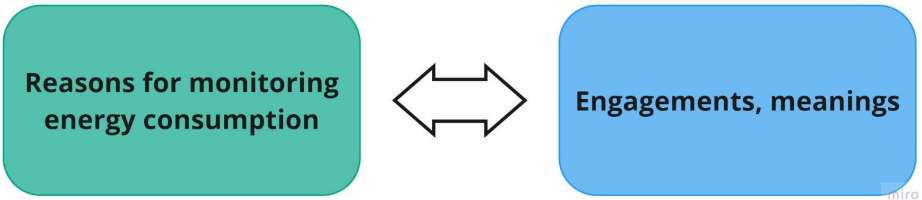
6.2.4 Step 4: Describe and explore the thematic networks

In step 4 of the coding process is it relevant to describe and explore the thematic networks (Attride-Stirling, 2001). The describing part of the thematic networks will not be done in this section, since I think it fits better to do in the analysis section (section 7.0 Analysis). But exploring the thematic networks has a significant influence, in my opinion, on how to combine the qualitative empirical data with the theoretical concepts of practice theory. Therefore, in this step, I will take a deeper look into the thematic networks and see if and how it is possible to incorporate the four theoretical elements of holding a practice together, that Kirsten Gram-Hanssen works with (2009; 2010a).

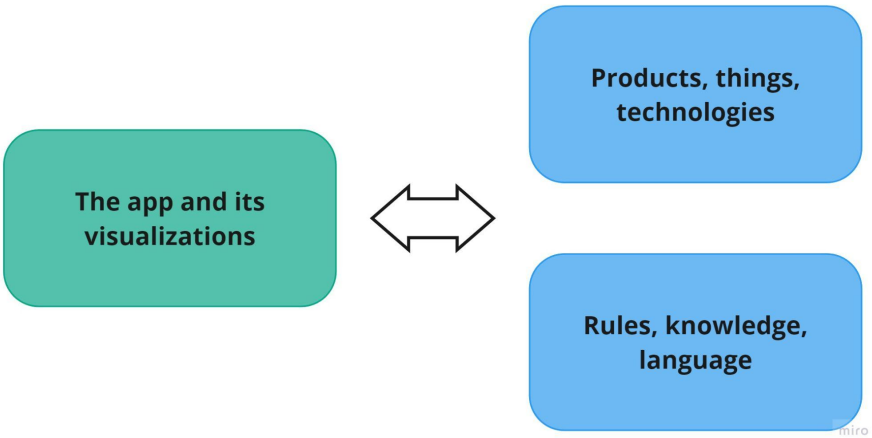
The first element, *'practical understanding, embodied habits, know-how'*, is about people knowing what to do in specific situations (Gram-Hanssen, 2009; Gram-Hanssen, 2010a). The thematic network with the Global Theme *'Energy consumption practices'* can be seen in relation with the first element, since there are Organizing Themes like *'Flexibility in practices'*, *'Experience'*, and *'Monitoring energy consumption'*. All of these Organizing Themes contain issues from the qualitative data about how the informant understand and perform their practices regarding energy activities and monitoring their energy consumption.



The second element, *'engagements, meanings',* is about how they are engaged in the practice, and if they are goal-oriented. Often normative views in the society influence this element (Gram-Hanssen, 2009; Gram-Hanssen, 2010a). The thematic network with the Global Theme *'Reasons for monitoring energy consumption'* can be seen in relation with the second element, since there are Organizing Themes like *'Convenience', 'Sustainability', 'Economy'* and *'Comfort'*. All of these Organizing Themes contain issues from the qualitative data about why the informants are engaged in monitoring their energy consumption.



The third element, *'products, things' technologies',* is about how things and technologies typically are a part of people performing and structuring practices. Furthermore, the fourth element, *'rules, knowledge, language',* is about how people should do things. This is based on both implicit and explicit rules about how to perform the practice, but the practitioner's knowledge also plays a role in, how they perform the practice (Gram-Hanssen, 2009; Gram-Hanssen, 2010a). The thematic network with the Global Theme *'The app and its visualizations'* can be seen in relation with both the third and the fourth element. In this Global Theme there are Organizing Themes like *'Use of apps', 'Wishes for the app', 'Proposal for app', 'Questioning the app', 'Deficient understanding', 'Technological interest',* and *'Visualizations'*. All of these Organizing Themes contain issues from the qualitative data about how the informants understand and use energy app to monitor their energy consumption. It is also about either the informants interest in different technologies or how they understand and interpret energy feedback visualizations.



6.2.5 Step 5: Summarize the thematic networks and Step 6: Interpret Patterns

Step 5 in the coding process is where the thematic networks are presented like fulfilling summaries. Here, the central themes and patterns are described. Step 6 is using the summaries and combining these with theoretical concepts to explore the qualitative data (Attride-Stirling, 2001). These two steps will not be discussed further here, since the result is the thematic analysis itself. That being the case, the thematic analysis is now ready to take form and will be presented in the next section.

7.0 Analysis

In the following section, the thematic analysis will be presented. The three thematic networks that are identified from the qualitative empirical data will be the foundation for the analysis. Before introducing the findings of the data, an introduction of each informant will be provided to give the reader an idea about the informant's background and motivation for being a part of this study.

7.1 Introducing the informants

Bo is a man in his 60s. He lives alone in a rented apartment and is a pensioner. In general, Bo is very engaged in the things he is interested in. For example, he is the chairman of the department in the housing association where he lives. Before Bo retired, he worked as a carpenter in a workshop, where he helped young people with social and economic problems.

Karsten is a man in his 40s. He lives in a big owned house of 280 square meters with his wife and their three children. His profession as an engineer in the energy sector gives him a natural interest in energy consumption in general. This is also the main reason why he has installed PreHEAT in his house.

Michelle and Lars are a couple in their 60s. They live in a rented terraced house and are both early pensioners. Due to the fact that they are early pensioners, they both spend most of their days at home.

Malene and Kenneth are a couple in their 20s. They live in a rented apartment and are both students. Malene studies biology at Aalborg University and Kenneth studies interaction design at Aalborg University. Kenneth is due to his educational background especially interested in the interaction between technologies and people, and has by himself studied how technologies in peoples' homes can affect their behavior.

Lillian and Morten are a couple in their 50s. They live in a rented terrace house. Lillian is an early pensioner and Morten works as a consultant in a union. They live together with their daughter Rachel who is in her 20s. In addition, they have a son in his 20s who lives in Copenhagen but is home visiting the family several times a year for a week or so at a time.

Niels is a man in his 30s. He lives alone in a rented apartment and works as a carpenter. Niels is the chairman for the resident's board in the housing association he lives in, and due to this, he is engaged in some of the action that is implemented in their apartments.

Bente is a woman in her 50s. She lives with her husband in an owned house. She is an early pensioner and is home most of the week. Bente and her husband are a part of the SUSTENANCE-project in Voerladegaard. They have both an electric car and solar cells.

Klaus is a man in his 50s. He lives with his wife in an owned house. He works as a landscape architect. Klaus and his wife are a part of the SUSTENANCE-project in Voerladegaard. They have both an electric car and solar cells.

Kalle is a man in his 40s. He lives with his wife and three children in an owned house. He works as a chief within gas trading in the energy sector.

Majken and Nicklas are a couple who lives in an owned house. Majken is in her 70s, while Nicklas is in his 80s. They are both pensioners. Majken and Nicklas are a part of the SUSTENANCE-project in Voerladegaard. They have solar cells.

Rasmus is a man in his 50s. He lives with his wife in an owned house. He works as a road engineer, and due to his profession as an engineer, he has an interest in technology. Rasmus and his wife are a part of the SUSTENANCE-project in Voerladegaard. They have solar cells.

7.2 Reasons for monitoring energy consumption

The first thematic network to analyze is the network with the Global Theme *'Reasons for monitoring energy consumption'*. The findings regarding this thematic network will be in the basis of unfolding the four Organizing Themes *'Sustainability', 'Economy', 'Comfort'* and *'Convenience'*.

7.2.1 Sustainability

The main reason for the majority of the informants, when talking about why they are interested in monitoring their energy consumption, is the sustainability and climate actions they are referring to at first. All the informants participating in the SUSTENANCE-project have solar cells, since it was one of the criterias for being a part of the project. Furthermore, several of the informants have an electric car as well. Bo is the chairman of the department he lives in and was one of the people who had to argue in front of all the residents in the department about having PreHEAT implemented. His opinion is:

> *"My view on it is that it is about sustainability. It is about CO2 footprint. Is it possible to make something, where the CO2 footprint is reduced, and we still save money? Well, I do not think it is necessary to say what is the most important thing. It is clear, that the sustainable perspective is essential. There is no question about that"* (Bo, 60s, renter)[8].

For Bo, it is the sustainable perspective that is the main reason for implementing PreHEAT, and he shared this opinion with most of the informants. When Bente is asked why she got PreHEAT implemented in her home, she quickly responds:

> *"It is mostly for the sake of the environment. That is for sure"* (Bente, 50s, owner)[9].

[8] Translated from Danish: *"Fordi mit kig på, det handler om bæredygtighed, det handler om CO2-aftryk, det handler om. kan man lave noget, der er bæredygtigt. Kan man lave noget, som man kan sige, hvor CO2-aftrykket bliver mindre, og man samtidig kan spare penge? Ja. Jamen jeg behøver sikkert sige, hvad er vigtigst der? Nej. Altså det er jo helt klart, at det bæredygtige, den er vigtig. Ja. Altså det er der ikke snak om."*

[9] Translated from Danish: *"Det er mest for miljøets skyld. Det er det."*

Even though the majority thinks the sustainable perspective was influential for them to implement PreHEAT as well as their engagement in monitoring their energy consumption, some informants are not agreeing with this. For example, Niels does not have any interest in climate actions. Karsten, on the other hand, is not arguing whether he is interested in sustainability or not, but has another take on it:

> *"Well, since we have district heating, you can say that I do not have much of an opportunity to say whether it (the energy) should be green or not green. After all, it is our district heating supplier that decides that"* (Karsten, 40s, owner)[10].

It is, without doubt, the sustainability element that is the informants' main argument when talking about why they have PreHEAT, and why they think the technology is interesting. But after talking more about their reasons for monitoring their energy consumption, a pattern emerges. Already in Bo's quotation, the economic aspects are mentioned, and this seems to be typical for most informants. Even though they want to be interested in the environmental impact of their energy consumption, a tendency for the economic aspects to be more important is seen.

7.2.2 Economy

Several of the informants are referring to the energy crisis the world has been through the last year, where the energy prices have risen. Therefore, the majority of the informants think that the price is an influential part of this when talking about their energy consumption. There are two ways the informants argue that the economy has an impact on the implementation of PreHEAT and their interest in monitoring their energy consumption. The first way of thinking on the economy, is to save money on the energy delivered. Michelle is arguing:

> *"So, it just should not be crazy expensive, right? So, that is no secret. We would like to have it as cheap as possible. I mean, who would not want something like that? Because, honestly, it is just a necessity, isn't it?"* (Michelle, 60s, renter)[11].

Michelle sees the energy she and her husband use as something that is just a necessity. She does not think that the energy itself gives her any kind of value. She is aware that she is using energy to make some practices in her everyday life, and achieving a nice indoor temperature,

[10] Translated from Danish: *"Jamen i og med at vi har fjernvarme, så kan du så sige, at jeg har jo ikke den store mulighed for at sige, om det er skal være grøn eller ikke skal være grøn eller noget. Det er jo vores fjernvarme forsyning der bestemmer det."*
[11] Translated from Danish: *"Altså, det skal bare ikke være møgdyr, jo. Altså, det er da ingen hemmelighed. Vi vil da gerne have det så billigt som muligt. Altså, hvem vil ikke det med sådan noget? Fordi, helt ærligt, det er jo bare en nødvendighed, ikke også?"*

which is why she is calling it a necessity which she would like as cheap as possible. Another way of thinking about the economy is, that some informants are monitoring their energy consumption with the aim of reducing their energy consumption, and in this way saving money on the energy bill. Neogrid advertise, that when implementing PreHEAT, it is possible to reduce the energy consumption. Lars is talking about reducing energy consumption:

> *"We have always thought about that. Sometimes when people say that 'now we have to save on that too', we think that we have actually done nothing but saving. We save on both electricity and have tried to teach our own children to turn off some lights and turn down the temperature"* (Lars, 60s, renter)[12].

Lars has always thought about reducing the energy consumption in the household, with an economic incitement in mind. He and his wife have always tried to educate their children in how to reduce their energy consumption, so that the energy bill would not be massive. For others, for example Bente, it is very explicit, that she is not thinking about economy when she is reducing her energy consumption. As written in the section above, she is thinking about reducing her consumption, but it is mainly for the sake of the environment. She is underlining her point by saying:

> *"Economically, it is not a problem for us. So, it is mostly about the energy consumption and being able to be conscious about is"* (Bente, 50s, owner)[13].

For Bente, the reason to monitor her energy consumption is not economic. Kalle is of the same belief. He is not interested in PreHEAT to save money, but to reduce his energy consumption:

> *"So, my incentive for it has not been in an economic aspect. No. But I think it is really cool that we can use technologies to make things smarter and use our resources in general in a better and smarter way. That is the driving force. It is something like this that I think is super cool, and it is not about the fact that I can save 2, 5 or 20 kroner, or something like that."* (Kalle, 40s, owner)[14].

[12] Translated from Danish: *"Det har vi altid tænkt på. Nogle gange når folk siger, at 'nu skal vi også spare på det',så tænker vi, at vi har faktisk ikke gjort andet end at spare. Vi sparer både på strøm og forsøgte at lære vores egne børn at slukke nogle lys og skrue ned for varmen."*

[13] Translated from Danish: *"Økonomisk er det ikke noget problem for os kan man sige, Så det handler mest om forbruget og det at kunne være bevidst omkring det."*

[14] Translated from Danish: *"Altså, mit incitament for det har ikke været af økonomisk karakter. Nej. Men jeg synes jo også, at det er mega fedt, at vi kan bruge teknologier til at gøre tingene smartere og udnytte vores ressourcer generelt på en bedre og smartere måde. Det er det, der er drivkraft. Men det er jo sådan noget, jeg synes, der er mega fedt, og det handler ikke om, at jeg så kan spare 2 kroner, eller en 5'er, eller en 20'er, eller sådan noget."*

Kalle is of the belief that it is a small amount of money he will be able to save, and he is therefore not interested in even thinking about the economic benefits of reducing energy consumption. But if the economic benefits should be shown in a PreHEAT app both Kalle and Rasmus argue that it is important, that the users can rely on that it is their individual actual price that is shown. Rasmus thinks it is significant that the energy prices shown should be relevant for him:

> *"Yes, the energy price is important. So, now we receive from Norlys and have a variable agreement. So it would be smart if the prices from our company were shown. I'd like it to be relevant. I need to be able to trust that it is the price I can relate to that is shown."* (Rasmus, 50s, owner)[15].

According to both Rasmus and Kalle, it is essential for them to be able to trust the energy prices shown. If it is just some average prices for the whole association, they are not interested in seeing them at all. Even though the economy somehow influences every informant in some kind of way, there is another element that might have a higher value for some of them. This is seen in Malene's statement, when asking her if she and her husband are thinking about reducing their energy consumption to save money:

> *"When thinking about the temperature in our apartment, then we actually think a lot about it being comfortable, especially in the bedroom when we need to sleep. But with hot water, we think a lot on the economy."* (Malene, 20s, renter)[16].

There is a tendency that the majority thinks it is important to reduce their energy consumption, and in this way hopefully save some money. But when talking about how much they are willing to reduce their energy consumption, and in which ways, there is a tendency that the element of comfort comes up.

7.2.3 Comfort

There is pretty much consensus about having the temperature in the home at around 21–23 degrees Celsius. PreHEAT's main function is to secure that the baseline for the flow temperature is as low as possible. When setting the flow temperature lower than usually, this

[15] Translated from Danish: *"Ja, elprisen er vigtig. Altså, nu får vi fra Norlys og har en variabel aftale. Så var det jo smart, hvis det var priserne fra vores selskab der blev vist. Jeg vil i hvert fald helst, at det er relevant. Jeg skal kunne stole på, at det er den pris, jeg kan forholde mig til, som bliver vist."*
[16] Translated from Danish: *"Hvis man tænker på varmen i lejligheden Altså så tænker vi faktisk meget over at det er komfortabelt Særligt I soveværelset når man skal sove . Men med varmt vand, der tænker vi meget økonomi."*

will have the consequence, that the residents in the households will have a limit on how high the temperature in the home can be. Typically, the agreement between Neogrid and the users is, that the users should be able to have a maximum of 21 degrees Celsius in their homes. When talking with the informants about being able to have a maximum of 21 degrees Celsius in their households, the majority started to talk about comfort in their homes. It quickly became clear, that the definition of comfort is individual, which is seen in the couple Malene and Kenneth's definitions on comfort:

> *"Kenneth: I think it is about not having to walk around in socks or shoes indoor. And that you do not need to wear a sweater, but only a t-shirt. So, having a comfortable temperature. Like you can wear home clothes and not wear office clothes at home."* (Kenneth, 20s, renter)[17].

> *"Malene: Yes, so maybe I do not mind that much about to put on a sweater. No. But then I also have to be able to keep warm, just when wearing a sweater".* (Malene: 20s, renter)[18].

Even though Malene and Kenneth lives in the same household, they do not agree on what a comfortable feeling of heat is in the home. This dilemma is seen in every interview, where two informants are interviewed at the same time. In these situations, there is a tendency that it is the person that is freezing the most, that gets to set the temperature standards in the household. A clear example of this is seen in the case of both Lars and Michelle as well as Morten and Lillian. In both households, it is especially the women who like to have a high temperature in the floor heating in the bathroom. Lillian explains:

> *"Uh, well, the bathroom, at least I like it warm there. It does not have to be hot in the room, because it usually gets warm when you take a shower. But the floor, the fact that you do not get out onto such an icy floor, I think that is lovely".* (Lillian, 50s, renter)[19].

It is the same arguments Michelle has for having a warmer temperature in the bathroom, than the other rooms in the house. When the households have a higher temperature in the floor heating in the bathrooms, this will force the flow temperature to rise, which will ultimately

[17] Translated from Danish: *"Jeg tror, det handler om, at man ikke behøver at gå rundt i sokker eller i sutsko. Og ikke behøver at have en trøje på, man kan tage t-shirt på Altså have den her behagelige temperatur Ja Det er ligesom, at man kan gå i hjemmegående tøj og ikke gå i udgående office tøj."*

[18] Translated from Danish: *"Ja, altså jeg har måske ikke så meget mod det der med at skulle tage en trøje på Nej Men så skal jeg også kunne holde varmen bare med at have en trøje på."*

[19] Translated from Danish: *"Øh, altså, badeværelset, der kan jeg i hvert fald godt lide at der er varmt. Det behøver ikke at være varmt i rummet, for det bliver det jo som regel, når man tager et bad. Men gulvet, det der med, at man ikke kommer ud på sådan et iskoldt gulv, det synes jeg er dejligt."*

result in a higher energy consumption. Lars and Michelle are discussing this economic dilemma:

> *"Lars: I probably have no luck closing the floor heating in the bathroom."* (Lars, 60s, renter)[20].
>
> *"Michelle: No, you are out of luck. No. Haha."* (Michelle, 60s, renter)[21].
>
> *"Lars: But, now we will see how expensive it will be, and then it may be the consequence, that the floor heating will be closed."* (Lars, 60s, renter)[22].
>
> *"Michelle: Yes, yes maybe, yes."* (Michelle, 60s, renter)[23].

Even though Michelle and Lillian both are aware of the higher energy bill because of their wish to have a higher temperature in the floor heating in the bathroom, they are prioritizing the temperature and thereby the comfort.

In other households, there is no dilemma about what the right temperature and thereby comfort is. Here, they are keeping a temperature between 21 and 23 degrees Celsius and if they feel the temperature a bit cold, then they will just put on some socks or a sweater. Bente's opinion about having 21 degrees Celsius in the household is:

> *"Then it is not too high. It is that temperature we try to have. We stick to what does not feel uncomfortable, but if it gets cold, then we just put on a sweater."* (Bente, 50s, owner)[24].

This kind of flexibility about the informants comfort is seen with several of the informants.

The definition of comfort and which temperature there should be in a home is clearly something the informants have an opinion about, and often they are comparing their own standards for comfort with other people's comfort wishes. Lillian is telling about visiting others' homes, where they have a higher temperature than themselves:

[20] Translated from Danish: *"Det har jeg nok ikke held med at lukke gulvarmen i badeværelset."*
[21] Translated from Danish: *"Nej, det har du ikke held med at gøre. Nej. Haha."*
[22] Translated from Danish: *"Nu kan vi jo se, hvor dyrt det bliver, og så kan det være, at vi bliver nødt til at blive lukket på gulvarmen."*
[23] Translated from Danish: *"Ja, ja, det kan det jo være, ja."*
[24] Translated from Danish: *"Altså så er man ikke for højt Og det er sådan en af det vi prøver at sætte os på Vi holder os til det som ikke føles ubehageligt Men hvis det er sådan at det bliver koldt, så tager man bare en trøje på.."*

> *"I also think that when you visit someone who always just runs around in short-sleeved t-shirts, and it is 23 degrees Celsius, I do not need that at all. I do not think that is comfortable."* (Lillian, 50s, renter)[25].

The opinion about other people having a too high temperature is seen with various of the informants. Another perspective is, that some informants also are reflecting about their own temperature at home, when having guests visiting them. Again, it is especially Lillian who is talking about how different people need different kinds of temperatures:

> *"We have some guests, or some of our friends, who require warmth. Someone who has arthritis and someone who has something else that requires a high temperature in our home."* (Lillian, 50s, renter)[26].

For Lillian, it is important, that when they are having guests over, the guests are feeling comfortable with the temperature in their home. In these situations, they might raise the temperature quite a bit, so that their guests are feeling well, even though it will have a consequence of a higher energy bill. At home with Nicklas and Majken, there is another perspective on their indoor temperature and their guests' opinion about that. Nicklas is explaining:

> *"Well, we do not have it particularly warm. Around 21 degrees Celsius. We have kept the temperature on that level, and that is something we can live with. We have some friends who say that it is freezing in our home. But that is not correct. It is at least 21 degrees Celsius, and we know that for sure, because we have a thermometer to check it"*. (Nicklas, 80s, owner)[27].

Nicklas supports that if their home is around 21 degrees Celsius, then it is comfortable. He does not understand why some people think it is cold when they come to visit them. They are not willing to turn up the temperature just because they are having guests. This has resulted in, that they have bought some slippers for their guests to take on, if they are freezing their feet.

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[25] Translasted from Danish: *"Jeg synes også, at når man besøger nogen, der altid bare render rundt i kortærmet t-shirts, og der er 23 grader, det har jeg på ingen måde behov for. Det synes jeg ikke, at jeg er behageligt. "*

[26] Translated from Danish: "*Vi har nogle gæster, eller nogle af vores venner, som har brug for varme. En, der har gigt, og en, der har noget andet, hvor der skal være god varme på. "*

[27] Translated from Danish: *"Altså vi har det jo ikke specielt varmt Omkring 21 grader Og det har vi også holdt det på nu her, og det kan vi sådan set godt leve med Vi har nogle venner som siger vi har det jo hunde koldt, men det passer jo ikke Vi har jo 21 grader, fordi vi har termometer op Så det er 21 grader Mindst "*

7.2.4 Convenience

The last reason why the informants are interested in monitoring their energy consumption, and have PreHEAT implemented in their homes, is due to convenience. Several of the informants mention, that they appreciate that the PreHEAT system can make the heating of their homes more simple and efficient, without themselves being involved. Bo talks about, that a lot of the people living in the same department as himself are not informed about what PreHEAT is, even though they have it implemented. He is telling:

> *"There are probably quite a few people who actually have no idea what this PreHEAT is. And basically, if they get some good information, that is fine. But I am also sure, that there are a lot of residents who are just happy if they turn up their radiators and then heat comes out."* (Bo, 60s, renter)[28].

There is a tendency, that when talking about heating up homes, it is essential for the informants that it should be as easy as possible, and not something they necessarily have to be involved in. Thereby, this automatization that Neogrid offers of when to turn up and down for the temperature, is something several of the informants are interested in. Karsten, who is interested in technologies in general, and have a passion for sustainable solutions, is arguing:

> *"So, in general, I think it is fantastic that there is some automation in relation to heat. That you can use some data to assess whether is should be switched on or off. This is something I really would like to have. Because, there is no reason for us to turn up the heat, if we know that the temperature will rise, i.e. in relation to the weather forecast. So that part of it, there is a lot of optimization there."* (Karsten, 40s, owner)[29].

Karsten is interested in optimizing the heat in his household, so that he will be involved as little as possible in this. Having PreHEAT implemented gives him convenience, since he does not have to think about how he should adjust his temperature to have the 21 degrees Celsius that he and his family desire to have. This wish for convenience is something seen in several of the interviews.

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[28] Translated from Danish: *"Der bor nok ret mange, der egentlig aner, hvad det er for noget, det her (red: preheat). Og i bund og grund, hvis de får en god information, så er det fint. Men jeg er også sikker på, at der er rigtig mange beboere, der bare er glade, hvis de skruer op, og så kommer der varme."*

[29] Translasted from Danish: *"Altså generelt synes jeg at det er rigtig fint at der er noget automatik i forhold til, altså at man med data kan vurdere om der skal tændes eller slukkes. Men det er jo noget af det jeg rigtig gerne vil have. Fordi der er jo ingen grund til, at vi tænder for varmen,, hvis vi ved, at nu stiger temperaturen, altså i forhold til vejrudsigten. Så den del af det, der ligger en masse optimering der. "*

7.2.5 Partial conclusion

The reason for the informants' interest in monitoring their energy consumption and having PreHEAT implemented in their households differ. It is not possible to give a generalized answer about people's willingness to think about their consumption, since various elements are influencing their opinion. These different elements can be identified as the four Organizing Themes in the thematic network *'Sustainability', 'Economy', 'Comfort'* and *'Convenience'*. The engagements related to reducing a household's energy consumption does not simply concern economic savings. The environmental impact of using energy for heating up homes and using hot water is influential for various of the informants as well. The question of sustainability as a reason for reducing energy consumption was raised by several of the informants during the interview. With the majority, it was not the sustainable aspect that had the most influence in their everyday use of energy and the performing of practices in which the usage of energy is required. But it was a meaningful element for most of them, and when reflecting about the environmental issues, they could find situations where they would have decided another way of performing a practice, if it would be better for the environment. The issue of keeping a nicely and comfortable home is also an element that has a huge part of all the interviewees' engagements in monitoring their energy consumption. Even though they are interested in reducing their energy consumption, save money and take better care of the environment, it is important that the temperature in their homes is not too low. Most of the interviewed are willing to take on a pair of socks or a sweater if the temperature sometimes feels a bit chilly indoor. But in general, the comfort has a critical role in holding the practice of indoor climate together. Lastly, convenience is an aspect of the practice of monitoring energy consumption. Most of the informants are not interested in being extremely involved in their heat consumption and find it convenient to have an automated system like PreHEAT to adjust the temperature.

7.3 Energy consumption practices

The second thematic network to analyze is the network with the Global Theme *'Energy consumption practices'*. The findings regarding this thematic network will be in the basis of unfolding the three Organizing Themes *'Monitoring energy consumption', 'Experience'* and *'Flexibility in practices'*.

7.3.1 Monitoring energy consumption

When examining the practice of energy consumption and people's interest in monitoring their energy consumption feedback through a web app, it is essential to investigate how and if people are monitoring their energy consumption presently. In the empirical data, there is a tendency which show, that the informants can be divided into two groups. One group that is only monitoring their energy consumption when the energy bill is sent out to them. The other group is regularly monitoring their energy consumption, either manual or through some kind of technological device.

Nicklas and Majken is participating in the SUSTENANCE-project in Voerladegaard, and have therefore recently got a heat pump installed in their house. Before installing the heat pump, they had a gas stove. When asking them how they monitor their energy consumption, Nicklas respond:

> *"We are probably not too good at that. No. So, until we got the heat pump, we have had gas. Yes, and you get gas charges a couple of times a year, or something like that. And that is the way we have followed it. I have not gone down and read the meters endlessly."* (Nicklas, 80s, owner)[30].

Nicklas and Majken did not monitor their energy consumption when they had a gas stove implemented in their home. Now that they have a heat pump and access to the PreHEAT web app, they do not know if they will use it. Bente is having the same thoughts about monitoring energy consumption as Nicklas and Majken had. She is also a part of the SUSTENANCE-project, and therefore she also recently had a heat pump installed. She is telling about how she is monitoring her energy consumption:

> *"So, yes, it is a lot when the bill comes. And I would say that we are not as good at keeping an eye on it on an ongoing basis. Since we now have got a heat pump, we have of course kept a little more eye on it. Or, actually, a lot more eye on it."* (Bente, 50s, owner)[31].

[30] Translated from Danish: *"Det er vi jo nok ikke for god til. Nej. Altså, indtil vi fik varmepumpen, der har vi jo haft gas. Ja. Og der får man jo gasopkrævninger et par gange om året, eller sådan noget, og det er sådan på den måde, vi har fulgt med i det. Jeg har jo ikke gået ned og aflæst på målerne i tider og utider."*

[31] Translated from Danish: *"Så, ja det er meget når regningen kommer. Og jeg vil sige at vi er ikke så gode til at holde øje med det som løbende. Siden vi nu har fået varmepumpe så har vi selvfølgelig holdt lidt mere øje med det. Eller meget mere øje med det."*

The same tendency is seen with Bente, who did not monitor her energy consumption at all before having a heat pump. Now that she is a part of the SUSTENANCE-project, and she got a heat pump installed, she is more interested in energy consumption. What is common with Nicklas, Majken and Bente is, that they had gas stoves in their households before. Maybe this kind of heat supply is more difficult to monitor, or maybe they just did not think about their heat consumption. However, it is not just someone with a gas stove that is not monitoring the energy consumption. As written earlier, Kalle is more interested in using the world's resources better and smarter, than saving money. This might be why he is truly relying on the PreHEAT system to optimize his household's energy consumption. At least, he is not monitoring his consumption except when a bill is sent out to him.

The other group of informants is the ones that are monitoring their energy consumption regularly. Lars and Klaus are the only ones who are manually monitoring the consumption. They both go to the installment of either the heat pump or the district heating exchanger and read the numbers here. Lars is explaining how he is doing it:

> *"But, I read it every Sunday, so that I have it. I just do not write down the temperature. No. I only write down the consumption. (ed: manually on paper).* (Lars, 60s, renter)[32].

Lars has a notepad where he every Sunday writes down the prior week's consumption. In this way, he is able to see if something has changed in their consumption. Klaus is also checking the consumption on the heat exchanger, but then he is writing down the consumption in a more digital fashion:

> *"So, I actually use, what is it called, the heat exchanger itself. It has its own little box down there with a screen on it. And I go down there and read the consumption. And then I actually enter it in an energy app once in a while."* (Klaus, 50s, owner)[33].

Even though Klaus is manually reading his consumption, he is using an energy app to keep track of the development in his consumption. But, since he is monitoring it manually, it is only about once a month he is checking the consumption. The rest of the interviewees are monitoring their energy consumption, either through an app where it is possible for them to see the consumption, or on the website of their heat supplier. The ones who are monitoring

[32] Translated from Danish: *"Men altså, jeg læser jo af hver søndag, så jeg har den. Jeg skriver bare ikke temperaturen ned. Nej. Jeg skriver kun forbruget ned. (Red: manuelt på papir)"*
[33] Translated from Danish: *"Så jeg bruger faktisk, hvad hedder det, altså, selve på varmeveksleren, den har jo sin egen lille kasse dernede med en skærm på. Og der kan man gå ned og aflæse forbruget, og så taster jeg faktisk en gang imellem det ind i sådan en energi app"*

their energy consumption digitally is on average checking the consumption at least one to two times a week.

7.3.2 Experience

When all the interviewees talk about how they manage the practice of energy consumption, it is clear, that they are often relying on experiences they have had in the past. As we have established earlier in the analysis, it is essential for the informants to have a nice comfort in their homes. This feeling of comfort is something they know due to experiences of a home which were too hot or too cold. Bo is explaining how himself and a lot of the other residents in the housing association he lives in have a certain understanding of how their radiators should be set:

> *"There are many who have, what is it called, the idea that you have to set the thermostat on 3. And they have done that forever, setting it on 3. So why should it suddenly be set on 5? So, you can see, I think it would be cool to have a temperature on the thermostat. Instead of that 1,2,3 and 4, because then you have to have a thermometer inside to see how cold or hot it is."* (Bo, 60s, renter)[34].

Bo and his neighbors have been used to thermostats on their radiators, where the degree of heat input is shown in numbers from one to five. Here, he argues, people often has their radiator set on three since they have experienced the most comfortable temperature with this setting. When Neogrid is lowering the flow temperature, it sometimes has the effect, that people need to set their radiators differently to gain the same temperature in their homes. Karsten is also relying on his experiences and senses when practicing the management of heat:

> *"Well, so far it has been that way, that we have heat sensors, that is underfloor heating in the whole house. And then we have actually managed it by the fact that it is probably just 22 degrees Celsius almost all year round. There may be a few times during the year when we have it turned down, like if it is very hot outside."* (Karsten, 40s, owner)[35].

[34] Translated from Danish: *"Der er mange, der har... Der har, hvad hedder det, den der tanke, at man har kørt på tre på termostaten. Og det har man gjort i alle år. Og hvorfor skal den så nu pludselig køre på fem? Så kan du se, der synes jeg det ville være fedt med temperatur på termostaten. I stedet for det der 1, 2, 3, 4, for så skal du have en termometer indenfor for at se, hvor meget det er. "*

[35] Translated from Danish: *"Jamen hidtil har det jo været på den måde, at vi har varmesensorer - altså gulvvarme i hele huset. Og så har vi egentlig styret det ved, at det jo nok næsten bare året rundt står på mere eller mindre 22 grader. Der kan godt være nogle gange i løbet af året hvor man sådan lige har haft det skruet ned, sådan i forhold til hvis der er meget varmt udenfor."*

Karsten and his family are not reflecting on whether they could accept it being one or two degrees colder in their home, because they have always had 22 degrees Celsius. They know, that with this temperature all five people in the family are comfortable, and therefore they do not change this.

7.3.3 Flexibility in practices

For Neogrid to be able to keep their promise about their costumers to reduce the energy consumption, it is necessary that the users comply with some premises that the PreHEAT system assumes or requires for its users. The most influential part is that the flow temperature will be lowered, and therefore the users will not have the opportunity to turn up the heat as theywant. This will have the consequence that users of PreHEAT as a maximum will have about 21 degrees Celsius in their homes. Furthermore, the PreHEAT system has incorporated a function to avoid peak periods. By this, it is meant that, if possible, the heat will be provided to the households in the periods where it is cheapest. If these two functions in the PreHEAT system should have the best possible output, and thereby reduce the users' energy consumption, it is important that the users are willing to be slightly flexible on certain things in their everyday life.

When talking to the informants about the willingness for this flexibility, there are different kinds of opinions. Morten argues that he will have a high degree of willingness to flexibility, if it results in reducing their energy consumption:

> *"It is because if you say, it is only like half a degree Celsius, and that means quite a lot in relation to the emission of CO2. Then I think you can easily see the cleverness in it. Then you just put on socks. If you have 21 or 22 degrees Celsius normally, and then you go down to 20 or 21 degrees Celsius, you can save something on the heat. That is for sure. And there I think it is a small loss of comfort at home, where you might just have to wear a sweater instead."* (Morten, 50s, renter)[36].

Morten thinks that it will be okay to have it slightly cooler in their home if this means they can save money and be better for the environment. Several of the interviewees agree with this statement. Especially the students, Malene and Kenneth, are thinking a lot about the

[36] Translated from Danish: *"Det er jo fordi, at hvis man kan se det der, at det er bare en halv grad, og det betyder jo rimelig meget i forhold til udledningen af co2. Så synes jeg, at man kan sagtens se det smarte i det. Så tager man sgu lige strømper på. Hvis man har 21 eller 22 grader normalt, og så går man ned på 20-21 grader, der kan man godt spare noget på varmen. Det er helt sikkert. Og der synes jeg, at det er et lille komforttab, derhjemme, hvor man måske lige skal have en trøje på i stedet for."*

temperature in their home. For them, it is, as stated earlier in the analysis, both for economic and sustainable reasons. Another group of informants who are very flexible on the practices of energy consumption, is the people who are at home most of the day. There is a tendency, that the interviewees who stay at home most of the day, in general, think more about when to perform activities that consume energy. Rasmus explains:

> *"I am in the situation that my wife has become an early pensioner. So she has the opportunity to optimize. There is no reason to start laundering in the expensive times of the day. So, at least it is something we want to think more about. In other words, to get optimized as much as we can."* (Rasmus, 50s, owner)[37].

Before Rasmus' wife became an early pensioner, they were both in the labor market. This had the result that they did not think it was easy to be flexible about when to perform energy activities such as laundering or showering. Kalle and his wife are both working, and therefore their everyday life and routines are structured around their working hours. Kalle argues:

> *"You do not want to get up an hour earlier and take a shower, just to save two kroner. No. It is important that the work is able to measure up to the effort, you could say."* (Kalle, 40s, owner)[38].

Kalle and his family are not flexible regarding their comfort and energy activities. They are the household, interviewed for this study, that are most stagnated in their way of energy consumption practices.

During the interviews, themes that the informants were not familiar with sometimes appeared. Especially when talking about being flexible on the performance of energy consumption practices, Michelle was surprised a couple of times. Michelle has a room in their home, which they call 'Michelle's room'. Here, she is crafting and listening to music. It is only when she is using the room she turns on the radiators in there; otherwise they are turned off. When Michelle mentioned this, I, the interviewer, told her, that the most efficient way to heat up a home is by having every radiator turned on all the time[39]. Michelle was not aware of this:

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[37] Translated from Danish: *"Jeg er i den situation, at min kone er blevet en førtidspensionist, så hun har jo netop mulighed for at optimere. Der er ingen grund til, at man skal sætte en vask over på en dyr tid. Så det er i hvert fald noget, vi vil lege endnu mere med. Altså at få det optimeret så meget, vi kan."*

[38] Translated from Danish: *"Du gider jo ikke at stå op og tage et bad en time før for at spare to kroner. Nej. Det er jo også det der med, at arbejdet skal kunne stå på mål med indsatsen, kan man sige."*

[39] More information about the most efficient way to heat up a home with PreHEAT, read Neogrid's information brochure: Neogrid Technologies. (2021). In Tenants in housing associations (Ed.), *Information brochure to the tenants*

> *"Okay. Yes, you can always learn something. This is actually something we have had many discussions about at home. Yes. We have always had that about heat. So, it is also when you do not, what can you say, we are not completely ignorant. No no. But when you are not very much into the details, you can quickly have one or the other opinion. But then, on the other hand, I would say that I could get used to that. So it is not like that. After all, it is not like I really want to be able to turn the radiator on and off all the time. No no."* (Michelle, 60s, renter)[40].

When being informed about a better energy consumption practice than the one she used to perform, Michelle is ready to adapt this new form of practice. It is clear that Michelle never thought that turning the radiator on and off every time she enters 'her room' could be a way of using more energy. This willingness of changing energy consumption practices is in general something that is seen in all the interviews.

7.3.4 Partial conclusion

There are different opinions about whether it is interesting to monitor the informants' energy consumption or not. A group of the informants thinks it is a slight waste of time and maybe also too advanced to monitor through some digital device. This minority of the informants are not monitoring their energy consumption regularly, but only when the energy bill is sent out to them. On the other hand, the majority of the informants are frequently monitoring their energy consumption, either manually or with the help of technologies. Only a couple of the informants are doing it in the old fashion way, and are writing down their consumption on a piece of paper; the others are monitoring the energy consumption either on an app or a website.

Every informant is performing the practice of energy consumption in their homes. They are also all performing the practice of indoor climate regulation, which includes a comfortable temperature. It is often the informant's experiences or embodied habits that implicitly are the reason behind the informant's behavior regarding these energy activities. They have some prior understanding of how the radiators should be set and how many degrees Celsius there should be in the home. Some interviewees recalled experiences of practices from the past to

[40] Translated from Danish: Okay. *" Ja, man kan da altid lære noget. Det er faktisk noget vi har haft mange diskussioner om herhjemme det her. Ja. Det har vi altid haft, om det der varme der. Altså det er jo også, når man ikke, hvad skal man sige, vi er jo ikke helt uvidende. Det er ikke det, jeg mener. Nej, nej. Men når man ikke sådan er nede i detaljen, så kan man jo hurtigt have den ene og den anden mening. Men så vil jeg så til gengæld sige, at det kunne jeg også godt vende mig til. Altså det er jo ikke sådan. Det er jo ikke sådan, at jeg partout ville holde på. Nej. Jamen jeg ville skrue op eller skrue ned. Nej, nej."*

explain why they perform practices the way they do it now. For example, Karsten has had the experience of their house getting too hot in the summer, and therefore they turn down the temperature now when the summer months are coming. It seems like every informant has learned to do and appreciate specific aspects regarding their indoor climate so that it unconsciously has become a part of each of their bodily habits. An example of this is the informants who have a high degree of willingness towards being flexible about wearing a pair of socks or a sweater.

Finally, it is clear that some of the informants' energy practices and habits regarding this are influenced by the amount of information they have on the area. For example, Michelle was surprised about the fact, that she have had the wrong habit when turning the radiator on and off when she used a certain room. From now on, this information will most likely be an embedded part of her practices.

7.4 The app and its visualizations

The third thematic network to analyze, is the network with the Global Theme *'The app and its visualizations'*. The findings regarding this thematic network will be in the basis of unfolding the seven Organizing Themes *'Use of the app', 'Questioning the app', 'Wishes for the app', 'Proposals for the app', 'Visualizations', 'Technological interest'* and *'Deficient understanding'*. This thematic network has more Organizing Themes than the other networks, and might seem dense with information. But two of the identified Organizing Themes, *'Wishes for the app'* and *'Proposals for the app'*, will be analyzed together, since they have some similarities. Furthermore, two additional Organizing Themes are identified: *'Technological interest'* and *'Deficient understanding'*. These are two opposite issues, and are therefore chosen to be analyzed together with some comparative reflections.

7.4.1 Use of apps

Foremost, it is essential for the analysis of the Neogrid web app to emphasize, that the informants who are a part of the SUSTENANCE-project do not have access to any kind of app yet. Some of the informants who are not a part of the SUSTENANCE-project do have access to what Neogrid call their online dashboard. Morten is one of the informants, who have access to the online dashboard. Even though he does have access to his energy consumption feedback from Neogrid, he is not monitoring it. He explains:

> *"It was more of a program I could install on the computer. Which was very confusing. I must say that it was probably a little too technical. When I just had it explained, maybe it made good enough sense. But when I went into it a month later, I thought that I do not understand this."* (Morten, 50s, renter)[41].

To Morten, the online dashboard that Neogrid provides to their users is too complicated. He does not understand it at all, and therefore he does not use it. Kalle, who have had access to the online dashboard for more than two years, is not using it either:

> *"But I have to be honest and say that I have not used it that much."* (Kalle, 40s, owner)[42].

In his opinion, it is too much work to check the online dashboard, since it requires doing it on a computer. Both Morten and Kalle are arguing, that if Neogrid develops an app, which is easy to access and not as technical as the dashboard, they will without a doubt use it to monitor their energy consumption.

Some informants, who do not have access to the online dashboard, are using other energy apps to monitor their energy consumption. Especially the app 'Watts' are mentioned several times in the interviews.

In general there is a consensus in the fact that there is a huge interest in an app from Neogrid, where the informants would be able to check their energy consumption and how the PreHEAT system is influencing their consumption. Klaus is explaining, in which contexts of his everyday life a PreHEAT app could be valuable to him:

> *"I actually think it is great that you always can check the energy consumption. When I think of checking my heating consumption, it is not when I am down in the basement. It is not there that I think that I have to check it, even though I am next to it. It is when I am sitting in the sofa, or I think it is hot or cold. It is cool, that you are able to check it on your phone."* (Klaus, 50s, owner) [43].

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[41] Translated from Danish*: "Det var mere et program, jeg kunne installere på computeren. Som er meget forvirrende. Jeg må da sige, at den var nok lidt for teknisk anlagt. Da jeg lige fik den forklaret, gav det da måske god nok mening. Men da jeg så gik ind på den en måneds tid efter, så tænkte jeg, at det kan jeg ikke så meget være med til det her."*

[42] Translated from Danish: *"Men jeg skal være ærlig og sige, det er ikke så meget jeg har brugt den."*

[43] Translated from Danish: *"Jeg synes faktisk, at det er fedt, at man kan altid lige kan komme til at tjekke forbruget. Der hvor man kommer i tanke om at tjekke sin varme eller andet, det er jo ikke, når man står nede i kælderen. Det er ikke der, jeg lige kommer i tanke om, at nu skal jeg lige tjekke, fordi jeg er ved siden af den. Det er jo når jeg sidder oppe i sofaen, eller jeg synes, det er varmt eller koldt. Der er det fedt, at man bare kan tage det på telefonen og se det hele."*

Klaus shares this opinion with the majority of the informants. In their everyday life, it is essential for them, that they are able to check their energy consumption when and where they desire it. It is important to them, that they do not have to open a computer, but are able to monitor their energy consumption on their phones.

7.4.2 Questioning the app

Even though there are general positive thoughts about a PreHEAT app where the informants can monitor their energy consumption feedback, some informants have some suspicions, that they wish to examine furthert before using it. The question on the validity of the data in the app is an aspect especially amongst the men. Rasmus is arguing:

> *"Yes, the electricity price is crucial. We have Norlys, and have a variable agreement. So it was smart if it was our company's prices. At least, I like it to be relevant. I have to be able to trust that this is the price I have to deal with."* (Rasmus, 50s, owner)[44].

The element of the prices that will be shown in the app being relevant to the individual households, has a priority in several of the interviews. Kalle is not only questioning if the prices shown in the app are relevant to him and his household, he is also questioning how the data is calculated. Kalle has an interest in numbers in general, and his opinions about everything regarding his energy consumption data is, that he is interested in knowing how it is calculated. To him, it is important that every data in the app is transparent, so that he can validate them by himself by running through the numbers.

The questions about how the data are calculated and if the data are relevant for the individual household is just a minor element in the informants general thoughts about using an app to monitor their energy consumption.

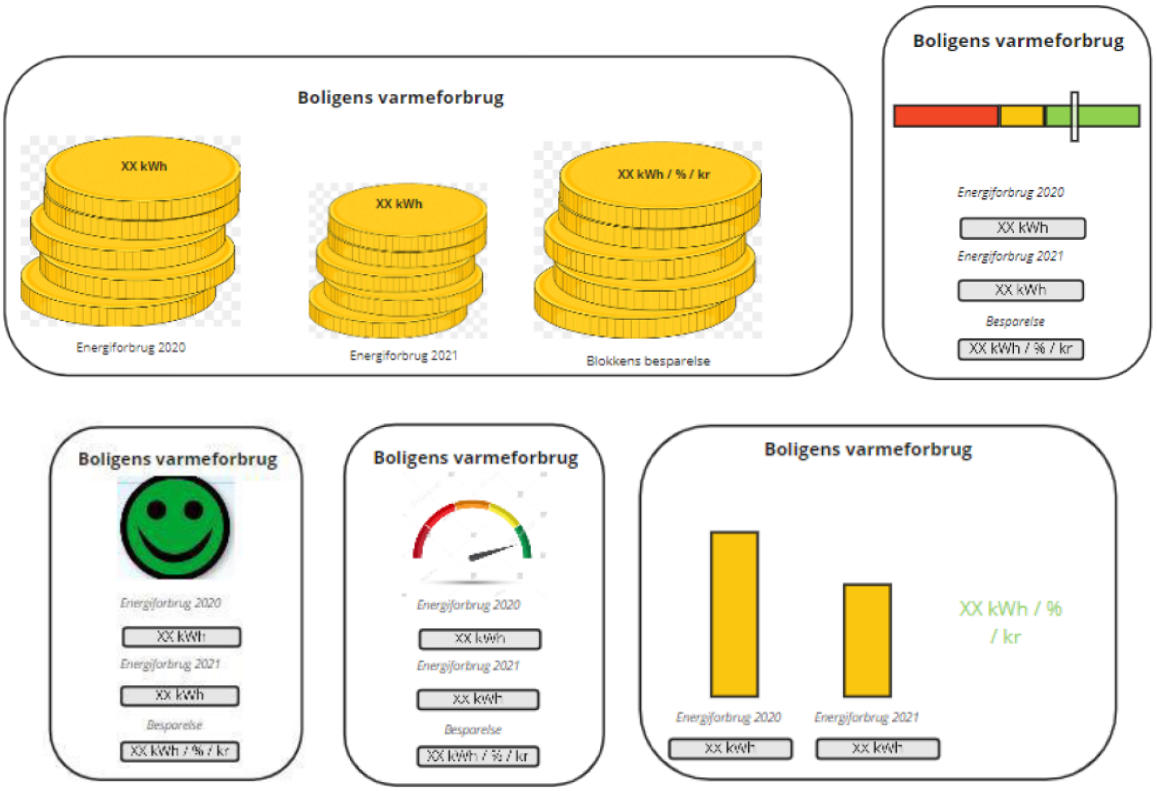
7.4.3 Visualizations

In the interviews I, the interviewer, had two different kinds of visualizations with me, that I wanted to discuss with the informants. Firstly, the informants were introduced to some paper-based mock-ups. These low-fidelity mock-ups illustrate a diverse set of ways to visualize energy consumption. Secondly, the informants were introduced to a high-fidelity

[44] Translated from Danish: *"Ja, og elprisen, det er jo den. Men for vi så er den variabel efter, altså nu er vi jo nordlys. Så var det jo smart, hvis det var vores selskab. Jeg vil i hvert fald helst, at det er relevant. Jeg skal kunne stole på, at det er den pris, jeg skal forholde mig til ved os."*

prototype of how Neogrid's PreHEAT web app will look like. In the interviews, these were presented as screenshots. To give the reader a better understanding of the visualizations, discussed in the analysis, they will each be illustrated visually.

The low-fidelity prototypes of different ways of visualizing a household's energy consumption include five different variations: 1) a stack of money, 2) a bar with color scale from red to green, 3) a smiley system, 4) a speedometer and lastly 5) a bar chart. The five different visualizations are shown below:



There is a clear consensus among the informants, that both the stack of money and the bar chart are not interesting, and not visualizations they ever hope to see in a PreHEAT app. Karsten is very explicit about his opinion about the money stack:

> *"Um, I do not like coins like that. I think it seems, excuse me, it seems a bit ridiculous."* (Karsten, 40s, owner)[45].

According to Karsten, it is too abstract and silly to show his energy consumption visualized as coins. He is interested in knowing a bit more detail about how his consumption is. The informants have the same issue with the bar chart. The majority of the informants do not

[45] Translated from Danish: *"Øh, jeg kan ikke lide sådan en gang mønter. Det virker, undskyld mig, det virker lidt plat. "*

think it gives an easy overview of their energy consumption; but rather an abstract overview which requires quite some interpretation.

Another visualization is the smiley system. This is the variation of the five visualizations, to which there is the most differing opinions about. Some are positive and some are very negative. Majken likes smileys because she thinks it is a simple way to get an overview:

> *"But it is fine with those smileys. It gives a quick overview. Is it okay, or is there something we need to take a closer look at. Yes, I like it."* (Majken, 70s, owner)[46].

To Majken the smiley is a well-known way of understanding if something is right or wrong. To her, is it essential to have an easy way to check if everything about the household's energy consumption is as it should be. Here, she thinks that the smiley system is well-fitted. Even though every informant is able to interpret the smiley, and thereby evaluate their energy consumption, some of them also have a neutral or decidedly negative attitude towards the smiley system. Bente is for example quite neutral about seeing a smiley in the app. She says that she does not care about it being there or not, and she will probably never use it. She would rather look at the numbers or texts in the app, even though they are in company with a smiley. Kalle, who is already established as a man with a high degree in the technological aspects of the PreHEAT app, is definitely not liking the smiley system. He explains:

> *"This smiley, it does not tell me anything about where… I can be right on the edge. It does not really tell anything about that. And just a green smiley, well that does not say much. So absolutely, right there, no thank you to the smiley, because it does not really tell me much."* (Kalle, 40s, owner)[47].

Kalle does not like that the smiley system gives him no information about where on the continuum he is. For instance, if the smiley is green, there is a possibility that he might be very close to having a yellow smiley, without knowing it. The majority actually mention this disadvantage of the smiley; that they will never know precisely what their energy consumption is. This leads the attention to the last two kinds of visualizations: the color scale and the speedometer. In most of the interviews, these two kinds of visualizations are

[46] Translated from Danish: *"Men det er fint med de der smiley Det giver sådan et hurtigt blik på Er det okay Eller er det noget vi lige skal kigge nærmere på Ja den kan jeg godt lide."*
[47] Translated from Danish: "*Den her smiley, der den fortæller mig ikke noget om, hvor, der kan jeg ligge lige på kanten, det fortæller den egentlig ikke noget om. Og bare en grøn smiley, jamen det siger ikke ret meget. Så absolut, lige ved den der, nej tak til smileyen, for den fortæller mig egentlig ikke ret meget"*

mentioned interchangeably, and the informants often do not distinguish between them. The common denominator when looking at both the color scale and speedometer, is that every informant likes them a lot. Some positive statements from the informants are for example:

> *"That one, I think, it is very easy. It is very quick to see. Yes, I think it is very quick to understand."* (Lillian, 50s, renter)[48].

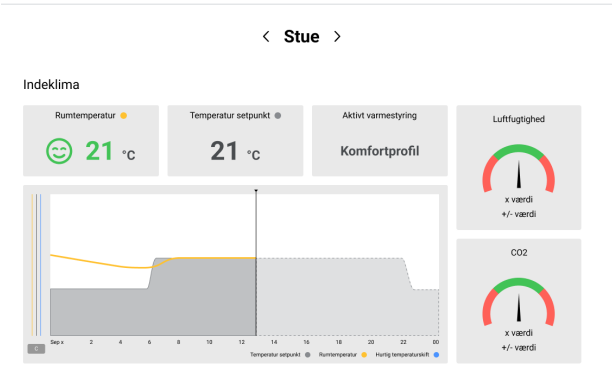
> *"So, I like the speedometer in relation to the fact that you would be able to have an idea of how close I am to the yellow area and things like that."* (Malene, 20s, renter)[49].

> *"And it is perhaps very good that it has a red to green interval there. So that you know that you are within the normal range."* (Rasmus, 50s, owner)[50].

> *"I think it is interesting that you get a few more nuances in these than for example the smiley."* (Bente, 50s, owner)[51].

All of the interviewees had the speedometer or the color scale as their favorite visualizations. To this, there are different explanations. First, they all liked that they are more nuanced than some of the other visualizations. They think it is simpler to interpret whether they are on a good track or should think about something regarding their energy consumption. Second, the majority of the informants are guided a lot by colors when they are interpreting the visualizations.

The informant's understanding of the visualizations in the high-fidelity prototypes of the PreHEAT app was also discussed. The informants were introduced to four screenshots of how the app probably will look like.



The majority of the informants are able to interpret the first screenshot, or at least part of it. Klaus is one of the informants who understands the

[48] Translated from Danish: *"Den der, tænker jeg, det er meget nemt. Det er meget lynhurtigt at se. Ja, det synes jeg, det er meget hurtigt at forstå."*
[49] Translated from Danish: *"Altså jeg kan godt lide den der speedometer i forhold til, at man ville kunne have en idé om, hvor tæt er jeg på den gule område og sådan noget"*
[50] Translated from Danish:*"Og det er måske meget godt, at de ligger med sådan en rød-grøn interval der, så man ligesom ved, at man er inden for normalrammen der."*
[51] Translated from Danish: *"Jeg synes der er interessant ved den, at man får nogle flere nuance med end ved smileyer."*

visualization, and his attitude towards it is very positive:

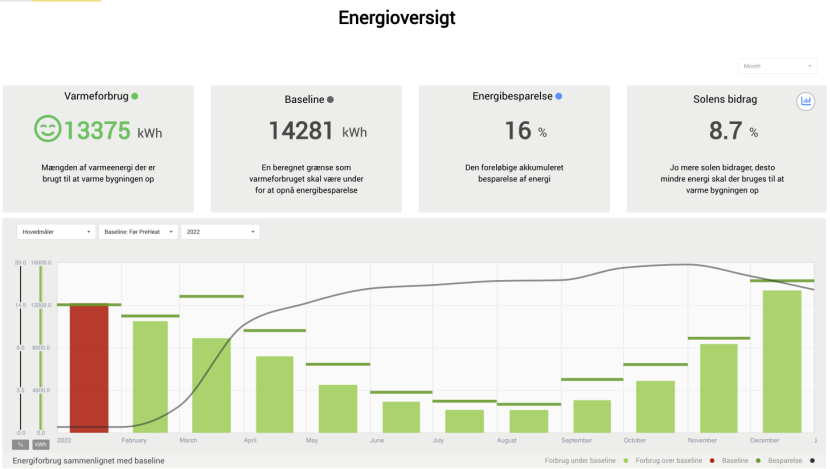
> *"Well, I think it looks easy and smart. It is easy to interpret. Yes. So it tells you both what the temperature is and shows you that it is the correct temperature. You can immediately see that it is as it should be."* (Klaus, 50s, owner)[52].

Klaus is of the opinion that the graph and the other visualizations here are great and should not be changed. Even though he easily understands the visualization, he likes the green smiley. He mentions that it was the first thing that he saw when looking at the screenshot, and it immediately gave him the information, that everything about the temperature in the living room was as it should be. Bente is also able to interpret the graph and the temperature settings at the top of the screen, but has a hard time interpreting the speedometers on the right side:

> *"Air humidity. I do not know what to use it for. But there is something with a green area, so I guess if it is within the green area, then it is fine. So, it is the same with CO2. And then I do not know what to do if it gets down into the red area. Then you probably have to change something. I guess."* (Bente, 50s, owner)[53].

Bente has trouble understanding the terms air humidity and CO2 and how they are influencing her indoor climate. She understands the visualization of the speedometer but does not know how to interpret it, and what to do if the speedometers suddenly turn into red areas. It is only the minority of the informants who do understand the importance of seeing both the air humidity and CO2 levels in their households. But there is an agreement, that it could be fine to have a little box, where Neogrid proposes different kinds of actions in case of the speedometers turn into red areas.

There are several nuanced attitudes towards the second screenshot from the Neogrid webapp. Some informants have absolutely no idea about how to interpret and understand the visualizations, while others think it is understandable.



[52] Translated from Danish: *"Jamen det synes jeg det ser nemt og smart og let aflæseligt ud i virkeligheden Ja Altså den fortæller jo både hvad temperaturen er Og den viser at det er rigtigt Det kan man umiddelbart se at det er som det skal være."*

[53] Translated from Danish: *"Lufifugtighed. Det ved jeg ikke lige hvad jeg skal bruge det til. Men der er så et eller andet med et grønt område, så gætter jeg på, at hvis det er inden for det grønne område, så er det fint. Altså er det samme med CO2. Øhm Og så ved jeg ikke hvad man skulle gøre hvis det kommer ned i det røde område, så skal man nok ændre på et eller andet. Gætter jeg på."*

Bente thinks that the visualization is valuable information:

> *"That comparison, I think that is nice. That you can say that we stay below some kind of baseline. We do all these things in our everyday life. So it makes a lot of sense to know that it is actually helping. Or if it does not help, that people then become aware that there might be something we can do differently."* (Bente, 50s, owner)[54].

Bente and her husband are trying to reduce their energy consumption, and therefore she would find it valuable to see how their energy consumption is now compared to how it was the year before. When Nicklas and Majken tried to interpret the same graph, they had a different experience than all the other informants. They simply did not understand what they were looking at, which is expressed in the following talk between the couple:

> *"Nicklas: Firstly, I look at the green smiley. It must be good. Yes, So the upper part here I think I can see through. But then we go down to the graph. So it is red and green and green and green. What does that mean?"* (Nicklas, 80s, owner)[55].

> *"Majken: So. Energy consumption compared to baseline. Yes. And the red must be something to do with the fact that there has been used too much compared to the baseline. Or what? So red, it just comes to my eye. That is not good. Where the green is good."* (Majken: 70s, owner)[56].

> *"Nicklas: So, it is not logical to me."* (Nicklas, 80s, owner)[57].

> *"Majken: No, I think you are right."* (Majken, 70s, owner)[58].

Both Majken and Nicklas do not understand the visualizations in this screenshot and are trying to understand them by looking at the colors. By looking at the colors, they try to come to a conclusion about whether the energy consumption feedback is positive or negative. When a visualization divides the informants this much, it is difficult to say whether it is the visualizations that should be changed, or if some people simply are not able to interpret

[54] Translated from Danish*: "Den der sammenligning med et eller anden form for gennemsnit. Det synes jeg er rart. At man kan sige, at vi holder os under en eller andet baseline. Vi laver alle de her krumspring. Så det giver rigtig god mening at vide, at det faktisk også er det der sker. Eller hvis det ikke sker, at man så bliver opmærksom på, at der måske er et eller andet, vi kan gøre anderledes"*

[55] Translated from Danish: *"Jeg kigger først på den grøn smiley. Så det må være godt. Ja Så det øverste her Det tror jeg godt jeg kan gennemskue Altså Det tror jeg godt jeg kan gennemskue. Men så går vi ned til grafen. Så er det jo rødt og grønt Og grønt og grønt Hvad betyder det?"*

[56] Translated from Danish: *"Altså. Energiforbrug sammenlignet med baseline. Ja. Og den røde Det må være noget med at der er brugt for meget i forhold til baseline. Eller hvad? Altså rødt det springer mig i øjnene. At det er ikke så godt. Hvor det grønne det er godt."*

[57] Translated from Danish: *"Altså det er ikke så logisk for mig"*

[58] Translated from Danish: *"Nej, det synes jeg du har ret i"*

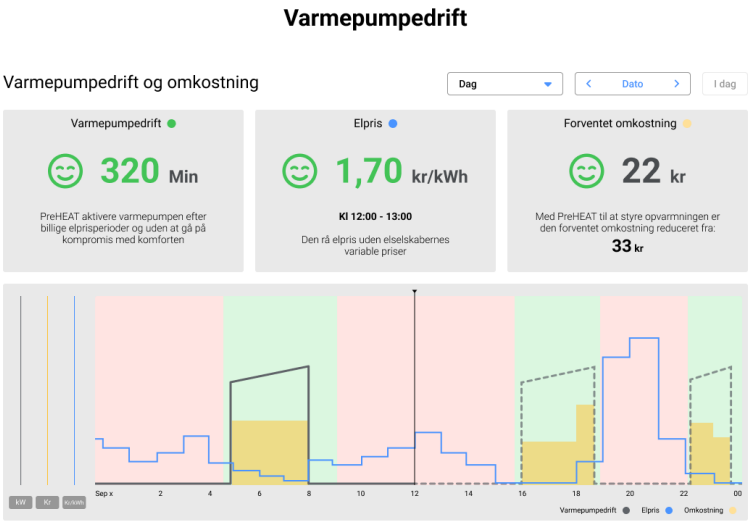
complex graphs. In this case, since it is only Nicklas and Majken who find it difficult, the conclusion might be that the visualizations are quite fine and understandable.

The third visualization about how much the sun is contributing to the heating of the house, is an element which constitutes one of the main functions in the PreHEAT system. Since the weather forecasts are such an influential part of how the PreHEAT system is working, most of the informants have the understanding and information about this. Therefore, the majority quickly were able to interpret what the visualization was about. Kalle's reaction to it was:

> *"That is a really good graph, that one. Yes. Yes, I think so. It is also cool that they convert the solar contribution into kilowatts."* (Kalle, 40s, owner)[59].

This kind of positivity towards the visualization and what it is showing, was seen in most of the interviews. Again, Nicklas and Majken did not understand the visualization.

The last screenshot, that was discussed in the interviews, was also the one that the most informants did not understand. Both the different numbers shown and the graph, challenged the majority of the interviewees. Since this visualization is about heat pump data, it is only shown and discussed with the informants that are participating in the SUSTENANCE-project.



[59] Translated from Danish: *"Det er en rigtig god graf, det der. Ja. Øhm... Ja, det synes jeg. Også det fedt, at man regner det om til sol i kilowatt."*

The first thing that confuses the informants, is the box that is telling about the heat pump operation. They are all able to interpret that it must be a good amount of time the heat pump has been running, since the smiley is green. What confuses the informants is the number itself. Rasmus explains:

> *"I do not know when it will turn red. I do not really have anything to relate it to. When I see it, I think, what can I use this number to? It is a little hard to understand."* (Rasmus, 50s, owner)[60].

Rasmus has nothing to put the numbers in relation to, and has no idea what the average time a heat pump should be running is. Therefore, he thinks it is information that confuses him. Bente does not know either how to interpret the minutes of the heat pump operation but argues:

> *"No, I do not know what that means. No. So far, at least. At one point or another, I probably have gotten a sense of what normal heat pump operation is."* (Bente, 50s, owner)[61].

Bente is aware of herself being a new heat pump owner, and thinks these numbers hopefully will be more understandable to her when she has more knowledge about heat pumps in general. All the participants in the SUSTENANCE-project got the heat pump installed for the purpose of the project, and therefore they have not owned it for long.

The graph that illustrates the heat pump operation is also challenging several of the informants. Nicklas is trying to interpret it:

> *"Well, across the screen there are a lot of steps. Which goes up and down and up and down. And then in the period from 5 o'clock to 8 o'clock, it suddenly rises very high. What does that mean, well, it does not tell me anything."* (Nicklas, 80s, owner)[62].

Even though Nicklas is trying to explain what he is seeing in the graph, he cannot interpret what it is illustrating in relation to the heat pump operation. Bente is also complaining about the complexity of the graph and gives up interpreting it, almost before she is getting started.

[60] Translated from Danish: *"Jeg ved jo ikke, hvornår den bliver rød. Jeg har ikke rigtig noget at forholde det til. Når jeg lige ser det, så tænker jeg, hvad kan jeg lige bruge tal til? Det er lidt svært at forstå."*

[61] Translated from Danish: *"Nej, jeg ved ikke hvad det betyder. Nej. Sådan er i hvert fald indtil videre kan man sige. På et eller andet tidspunkt så har jeg nok fået en fornemmelse af hvad er normalt varmepumpedrift."*

[62] Translated from Danish: *"Altså tværs af skærmen… Der kommer der jo en masse trappetrin. Som går op og ned op og ned op og ned. Og så i perioden fra klokken 5 Til klokken 8, der stiger det lige pludselig meget højt op. Hvad betyder det, ja det siger mig ikke noget. "*

She is both frustrated about the different graphs in the visualization, which to her does not make any sense. Furthermore, she is confused about the colors in the background. In her opinion, the colors should give her a quick understanding of whether or not the heat pump is operating as it should; but she does not think that is the case here. Therefore, she thinks that to give this visualization an easier design, she would like it to have just a white background color. Klaus is also confused by the colors, as he does not understand what they are supposed to give information about. The only informant that has anything positive to say about this screenshot is Rasmus, who thinks it is nice to have all the information together in one graph. Otherwise, the other informants think the graph and the numbers are too complicated.

7.4.3 Wishes and proposals for the app

After looking at the different kinds of prototypes of visualization of energy consumption feedback, and discussing the informant's understanding of the web app in general, every informant had some wishes or proposals for other things the web app might include. One thing which was mentioned again and again in the interviews, was getting some kind of alarm or message if something in the system is wrong. Kalle explains:

> *"Sometimes I have looked and wondered about what the flow temperature actually should be. Because it would be nice if the app could give me an alert or an email or something, if something is wrong. It could also be the cooling, is it too high or too low. And what can be done if possible?"* (Kalle, 40s, owner)[63].

Kalle is talking about getting an alarm about technical stuff like the flow temperature or if the cooling is wrong. Some of the other informants also mentioned getting an alarm for other stuff like, for example, if the temperature in a room was too high or too low. Bente is arguing that she is not that much into the technical stuff of PreHEAT, and therefore she is not quite sure what to expect the system to be able to do. Because of this, she is unsure what she would like to have alarms about. She is proposing, that in the beginning, it would be nice to get an alarm of everything possible. And then if she thinks the information is unnecessary or too uninteresting to her, she would like to turn off that kind of information. Rasmus is agreeing with this and explains:

[63] Translated from Danish: *"Jeg har da kigget på og undret mig nogle gange over det her med, hvad skal fremløbstemperaturen egentlig være? For det kunne være fedt, hvis den kunne give mig en alert eller en mail eller et eller andet, hvis der er noget galt.Det kunne også være ens, afkøling, er den for høj eller for lav, og hvad kan man eventuelt gøre?"*

> *"Well, you do not have to completely… It should not attack me with alerts all the time. It would be nice if there was an option to change your mind along the way if you think it is too much."* (Rasmus, 50s, owner)[64].

Rasmus is also of the opinion, that it would be positive to get some alarms if something is wrong or should be changed in the system. Something none of the informants are agreeing on is how these alarms should be sent out. Here the answers range from SMS, to email, to a push notification on the phone.

Another function that was discussed in several of the interviews is the opportunity to get some pieces of information about how to reduce energy consumption in the household. There are two different kinds of wishes regarding which kind of energy reduction information the app should contain. Some of the informants think it would be fine with some general information, while others are only interested in individualized tips about their specific energy consumption situation. Morten would like some general information about how to consume energy in the most efficient way:

> *"Small tips to save on the heat. So, if there are small tricks that you can give, then you can put them into the app. Maybe about when it is the holiday season, for example. Some good tips for how you manage the consumption if you are away 4,5 or 7 days. What should be turned off? Such tips could perhaps be good in an app."* (Morten, 50s, renter)[65].

Some general information and tips about how to set the radiator and so on when not at home, is information Morten thinks would be relevant and interesting to have incorporated in the PreHEAT web app. He is not the only informant that would be pleased with general information, but the majority would like the tips to be more individualized. Klaus is giving an example of what he means when he says he would like some individualized energy consumption tips:

[64] Translated from Danish: *"Altså man skal jo heller ikke fuldstændig... Det skal jo heller ikke vælte ind hele tiden med et eller andet. Der ville det jo være fint, hvis der var mulighed for, at man kan vælge om undervejs, hvis man tænker, at det bliver for meget."*
[65] Translated from Danish: *"Små tips til at spare på varmen. Sluk for Standby og alt det der. Så hvis der er sådan nogle tilsvarende små fifs, som man kan give, så kan man godt lægge nogle ind i en app. Og måske også det der, når man er på ferie, hvor man ved, når man holder efterårsferie eksempelvis. Nogle gode tips til, hvordan sætter du lige forbruget sådan, at hvis du skal væk for 4-5-7 dage? Hvad skal man så lige slukke? Sådan nogle tips kunne måske være gode i en app."*

> *"We can see that your consumption is much higher than it was last year at this time. Have you thought about this and that? At the same time, we can see that you actually have turned up the heat in some rooms, maybe you should do something about that."* (Klaus, 50s, owner)[66].

The majority of the informants would like individualized information about how their energy consumption is, and some tips about how they could reduce their consumption. For them, it is important that the information is directly about their consumption.

Another thing mentioned in two of the interviews is the wish for being able to compare one's household's energy consumption with that of others. Klaus is mentioning that he is a part of the SUSTENANCE-project, and he thinks it would be fun to compare his energy consumption data with the other participants in the project. At Voerladegaard, where the project is situated, the citizens know each other quite well, and therefore the participants often talk about their consumption with each other. Klaus is mentioning, that it would be interesting to have it as a feature in the web app so that it would be easier to check. Kalle, who is not a part of the SUSTENANCE-project, is also thinking that some kind of comparison element could be very appealing:

> *"I think it could be interesting that you could benchmark yourself against others. So, let us say I can type in, that I live in a house of 280 km2, and we are a family of two adults and three children. How does the benchmark compare to others?"* (Kalle, 40s, owner)[67].

Kalle thinks it could be fun to see a graph in the web app, where he could see how his and his family's energy consumption is compared to others. To him it is important that the users of PreHEAT could type in some kind of personal data, such as how big the house is, how many residents there are, etc., so that it would be possible for him to compare on a better basis. Kalle is further arguing, that this kind of comparison possibly would influence his energy reduction activities. If he in the app can see that his household is consuming way more energy than other households that look like him, he is sure, that they would try to change something.

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[66] Translated from Danish: *"Vi kan se at dit forbrug er meget højere end det var sidste år på den her tid. Har du tænkt på dit og dat. Vi kan samtidig se at I faktisk har skruet op på varmen i alle de der rum Altså skulle I gøre et eller andet."*

[67] Translated from Danish: *"Jeg synes, det kunne være interessant, at man kunne benchmarke sig op mod andre. Altså, lad os sige, at jeg kan taste ind. Jeg bor i et hus på 280 km2, og vi er en familie på to voksne og tre børn. Hvordan er benchmarket så i forhold til andre."*

7.4.5 Technological interest or deficient understanding?

Before the analysis reaches its end, there is an aspect of the informants that is essential to take into account. A huge technological interest is seen in some of the informants, whereas some informants have no interest at all in technological subjects. Of course, this has a significant impact on how they interpret and understand the app, its content and its visualizations. Especially some of the men, who have careers in the engineering world. They have knowledge of technological things and also an interest in it, which naturally gives them a better understanding of the app and its visualizations. On the other hand, several of the informants are either pensioners or early pensioners, and they do not have as high a technological knowledge or interest. A clear example of this is the couple Nicklas and Majken. Nicklas is in his 80s and Majken is in her 70s. For them, it was difficult just to set up an online interview on Microsoft Teams, which already before the interview gave me, the interviewer, the impression that they were not very technologically oriented. When trying to interpret the visualizations in the app, Nicklas and Majken had a deficient understanding of almost everything.

7.4.6 Partial conclusion

There are different kinds of technologies that are influencing the informants' practices regarding energy consumption and the monitoring of it. First and foremost, the heating system in general is the most essential element in order to perform the practice of energy consumption. The informants are either connected to the district heating or have a heat pump. No matter how the households are getting their heat into the homes, it is possible for them to monitor their energy consumption. The practice of monitoring the households' energy consumption varies from family to family. Some are manually checking the data, whilst others use digital solutions. By this, it can be concluded that the informants have different habits regarding monitoring energy consumption.

There are some rules, knowledge and language about energy consumption, that the informants have in different degrees. A specific kind of knowledge in this master's thesis is the feedback that Neogrid's PreHEAT app can give about the users' energy consumption. This is a knowledge every informant will receive, but they will use the knowledge in different kinds of ways. This depends on how their technological knowledge at a basic level is. In relation to technological knowledge, several of the interviewees argue that they have it from

either their educational or career background. Therefore, the knowledge has been embodied in their daily habits and has influenced them to have an interest in technology in general. The informants who are not very technologically oriented are, of course, practicing energy consumption, but might find it difficult to perform practices regarding monitoring their energy consumption. The lack of technological knowledge might result in a deficient understanding of energy consumption visualizations in the PreHEAT app. The visualization can, given that the users understand them, influence their energy consumption in the way that they become aware of how their consumption is.

8.0 Discussion

In this master's thesis, I asked 16 users of Neogrid's PreHEAT system *"How can energy consumption feedback be visualized in the most understandable way, and how are people's everyday practices influencing their relation to energy consumption?"* I resorted to Kirsten Gram-Hanssen's take on practice theory in relation to the qualitative empirical data. While analyzing the issues and patterns from the three thematic networks derived from the empirical data, a few things emerged that are worth considering, as they show how Gram-Hanssen's theoretical perspectives are actually enriched by this thesis.

As written in the analysis, several of the informants argue, that the environment and sustainability in general are important for them; also in relation to their energy consumption. Furthermore, some of the informants mentioned that they would like to have some tips and information in the PreHEAT app about how they could reduce their energy consumption. As Kirsten Gram-Hanssen argues, practices should be seen as social performances in the way that people coexist with other people. Also, *'engagements, meanings'*, which is one of the elements that holds a practice together, is grounded in the thought about practices often being influenced by normative views and moods in society (Gram-Hanssen, 2009; Gram-Hanssen, 2010a). Therefore, it can be discussed whether the informants' statements about the importance of sustainability regarding their energy consumption might be influenced by some normative thoughts that the majority in the society has. There is no doubt that every adult in the modern world is aware that it is important to think about the environment. The UN's SDGs are a well-known indicator of how significant these sustainable thoughts are (Hansson et al., 2021). People might typically see it as morally right to be sustainable or tell that they want to be sustainable, and therefore they might argue that one of the reasons for monitoring

their energy consumption is due to environmental issues. But the fact is somehow seen to be something else. Most of the informants say they are interested in sustainability, but on the other hand they also value their homes being comfortable. To the informants, when a home is comfortable, the temperature should be at least 21 degrees Celsius, and they should be able to turn up the heat if they feel cold. This highlights that the reasons and engagement for monitoring their energy consumption differs from knowledge and technical understanding. It is seen in the empirical data, that it is possible to be highly engaged in the environment without having the technical knowledge about how to reduce energy consumption. Thereby, it could be discussed if some of the informants are missing what Gram-Hanssen (2009; 2010a) would put under the element *'rules, knowledge, language'*; that they simply do not have the knowledge of how to reduce their energy consumption. Or, if the reality is, that they simply are more goal-oriented towards the practice of a comfortable home than being sustainable.

It is interesting to consider the informants' willingness to be flexible regarding their energy consumption. In most of the interviews, the informants stated that they are willing to be flexible on for example the temperature in their home. Morten and Lillian usually have about 22 degrees Celsius in their home. But Morten argues that if they could see a significant reduction in their energy consumption, they would be willing to have the temperature one or two degrees Celsius colder at home. On the other hand, both Morten and Lillian have the opinion, like the majority of the informants, that the practice of having a comfortable home is a priority. Therefore, it can be discussed whether the statements are hypothetical, and some which will not be carried out in reality. Here, Gram-Hanssen's (2009; 2010a) element *'engagements, meanings'* can be included to describe how people are goal-oriented, since, as it is seen in the data, the informant's goal is to have a comfortable home.

Another relevant matter to discuss regarding the informants' flexibility, is how half of the informants are either pensioners or early pensioners. Furthermore, it is only three households in the empirical data that have children living at home. When reading the results of the empirical data, it seems like the majority is willing to be very flexible when they perform practices that consume energy. For example, when they shower, cook or launder clothes. There might be a bias in the data, since most of the informants are staying at home during the day, and therefore have the possibility to be flexible regarding these everyday practices. It is seen that the families who have children living at home, or the informants who have a job, are not willing to be as flexible. On one hand I am sure that the majority of people would like to be able to perform energy-consuming practices when the energy prices are at their lowest.

But on the other hand, it is essential to remember, as Gram-Hanssen argues (2009), that practices are social, and when people are performing a practice, they coexist with others socially. Practices are both social between people who interact together, which in the informants' situations are the ones they live with. But practices are also social between people who perform the same kind of practice. When people in Western countries have a job, they usually work between 8 o'clock and 16 o'clock in the afternoon. Thereby, they have to do all the practices such as cooking, laundering and showering during the hours they are home. Furthermore, if there are children living at home, people typically have a strict time schedule for when dinner should be ready or when the children are going to take a shower; and often they have loads of laundry. These energy-consuming practices are practices shared by the majority of Western society, and to use Gram-Hanssen's (2009; 2010a) element *'engagements, meanings',* the goal is to have as easy an everyday as possible. The element *'practical understanding, embodied habits, know-how'* can be seen in relation to the fact that people typically know how to perform practices in the most efficient way. And the most efficient way to perform everyday practices might not always seem to be the most sustainable way.

The last thing relevant to discuss from the qualitative empirical data, is if the new technology, the PreHEAT web app, actually will be able to change the practices of energy consumption. Gram-Hanssen (2009) argues, that for the new technology to change practices, it is important to look at the different consumer phases. Firstly, the acquisition of the technology. Already in this first step there might be some difficulties regarding some of the informants not being very technically skilled. Some of the informants, and here I especially think about the older couple Nicklas and Majken, might find it difficult to figure out how to access the web app. The next step in the consumer phases, is the use of the technology. Since the majority of the informants do not have access to the web app yet, their statements in the interviews are somehow hypothetical. They are assuming how and when they will use the web app. On one hand, the majority of the informants seem positive and interested in having a PreHEAT app where it is possible for them to monitor their energy consumption. Some informants even explain that having a visual look at their consumption might change their household's energy-consuming practices. On the other hand, a couple of the informants already have access to the PreHEAT app, and their honest opinion about the app, is that it is too complex and complicated; so they do not use it. Several of the informants are also arguing that it might be fun to monitor their energy consumption feedback in the app in the beginning, but after a

while, they will probably not use it as much. In Gram-Hanssen's (2009; 2010a) perspective, technologies are an essential part of structuring and understanding practices regarding a household's energy consumption; but whether or not that is the case in every interviewees' situation in this study might be discussed. Gram-Hanssen's (2009; 2010a) element of holding a practice together named *'rules, knowledge, language'* requires people to have some kind of knowledge to perform a practice. An example to illustrate that some informants do not have enough technical knowledge to manage the app is Bente. Bente does understand most of the graphs visualized in the app, but terms like air humidity and CO2 are not something she understands in relation to her indoor climate. Therefore, she does not have the knowledge to know what to do if these elements turn into a red area in the app. Because of the lack of knowledge, Bente is not able to have a practice about this, and in this way, it is seen that technologies are not always essential in structuring the performance of a practice such as energy consumption. In Bente's situation, the technology gives her a feeling of inequality and frustration instead.

The discussion about whether the new technology (the PreHEAT web app) will change the informants' practices regarding energy consumption, relates to Shove and Pantzar's article *'Consumers, Producers and Practices'* from 2005. Here, they argue that when two well-known things are combined, they can develop a new practice (Shove & Pantzar, 2005). The two things in this study are the practice of energy consumption and an energy consumption feedback app. It can be discussed if the new technology, the PreHEAT app, actually will change some of the informants' practices. The informants for whom the web app will influence their behavior, will be the ones where an energy consumption app is well-known, and they have the skills and knowledge to interpret the visualized data within the app. Shove and Pantzar (2005) argue that both the producers of the technology and the practitioners are equally important for the performance of the practice being completed. It can thereby be discussed whether Neogrid should rethink some of their visualizations in the PreHEAT web app. Here Gram-Hanssen's (2009) theoretical concepts of *internalization* and *externalizing* can be used to exemplify why it might be a good idea for Neogrid to think about the design of the PreHEAT web app. Internalization is the cognitive adoption of a new technology, where some skills and know-how are required from the practitioner to use the technology properly. Already in the internalization phase, Nicklas and Majken might be in an especially troublesome situation. They are not able to use the PreHEAT web app properly, since they do not understand its content. When this is not possible for Nicklas and Majken,

they will never be able to come to the process of externalizing. By externalizing, Gram-Hanssen (2009) argues that practitioners show other people how, when and where they are using the new technology; the PreHEAT web app. The externalizing process is important for practices to develop, since other people might find the technology interesting, and thereby use it as well (Gram-Hanssen, 2009).

For the appropriation process and the following internalization and externalizing phases to be completed, it can be discussed if they should rethink the user interface design of the web app. Chiang, Nararajan and Walker (2012) talk about the distinction between numerical, analogue and ambient displays, and maybe these three different kinds of ways to visualize could be interesting for Neogrid to look at. As it is now, the PreHEAT web app is a combination of a numerical and analogue display, where the user's energy consumption feedback is shown in both numbers and graphs. It can be discussed if some of the users of PreHEAT, like Nicklas and Majken, would find the web app more understandable if the energy consumption feedback were shown in an ambient display. In this way, they would not be forced to try to understand numbers or graphs, but would simply be shown an overall indication of their energy consumption situation.

9.0 Conclusion

This master's thesis has dealt with the problem statement *"How can energy consumption feedback be visualized in the most understandable way, and how are people's everyday practices influencing their relation to energy consumption?"*. In answering this question, the study has focused on the Aalborg-based company Neogrid Technologies and their smart heat management system PreHEAT which utilizes a web app showing energy consumption feedback. The results are based on 11 qualitative interviews with different users of PreHEAT.

Previous research has shown that energy consumption feedback technologies are an effective approach to use when the aim is to reduce energy consumption. The empirical data revealed that it is not possible to say one specific kind of visualization of energy consumption is the right for everyone. The majority of the informants are positive about a mix of numeric and analogue displays, while a few do not have the technical knowledge to understand complex numbers and graphs, and therefore would possibly be better served with a simple ambient display showing an abstract overall indication of the situation. There is a consensus that a

speedometer or a color scale is the easiest way to understand a visualization about energy consumption. The degree of interest and the reasons for monitoring their energy consumption differs between the interviewees. The reasons can be either due to sustainability, economics, comfort or convenience. Every informant is performing the practice of energy consumption in their homes, including the practice of regulating the indoor climate. They have gained the know-how to perform and appreciate specific aspects regarding the indoor climate, and these practices has unconsciously become a part of their bodily habits. Both the environmental and economical perspectives of energy consumption are influential for the informants to monitor their consumption as well as motivating them to reduce it. However, the highest priority for the informants is keeping a thermally comfortable home, since the temperature not being too low in their homes has a critical role in holding the practice of indoor climate together.

10.0 Future work

After spending the semester examining some PreHEAT users' understanding of energy consumption visualizations and talking with them about their everyday practices regarding energy consumption, some reflections about future work has crossed my mind. When writing a project as a university student, there will be some pragmatic aspects, which in the end determine the output in some kind of way. One of these pragmatic aspects is obviously the time limit to write the master's thesis, which in this study's case was four months from February until May 2023. If I had some more time for the research, one of the things that could be interesting to investigate is the user's perception and understanding of the PreHEAT web app after they have used the app for a while. The current context of the informant's relation to the PreHEAT web app is, that the web app has not been launched yet. Therefore, when discussing the app, it is still a prototype. It could be interesting to talk with the same informants after they have had access to the PreHEAT web app for a couple of months. This kind of longitudinal study could give some insights in how the users actually use the web app. Furthermore, it would be possible that the informants understand the visualizations of their energy consumption feedback in another way, if they have used the web app for some time.

From the findings in the empirical data, I found that there are several reasons for the informants to monitor their energy consumption. Previous research shows that energy consumption feedback technologies contribute to reducing the energy consumption in

households (Foulds et al., 2017), but it could be relevant to investigate if this statement holds. It is concluded that keeping their homes comfortable has a high priority for the informants, which might seem to be in contrast with reducing their energy consumption. Again, if it was possible to make a longitudinal study, I could follow the informants for a longer time, and in this way compare their energy consumption before and after they start using the PreHEAT web app. In this way, the statement about energy consumption feedback technologies influencing a reduction in energy consumption could be examined.

In the findings of the empirical data, I found an interest from some of the interviewees to have an aspect of competition incorporated in the PreHEAT web app. Previous research shows that if looking at households as communities instead of individuals, it will lead to more engagement from energy consumers and this often results in energy reductions (Huang et al., 2017). It could be insightful to collaborate with Neogrid about incorporating some kind of community-based approach into the PreHEAT web app, to see if the users of PreHEAT would find the energy consumption feedback more interesting and thereby as a better guideline for reducing their energy consumption.

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